CONCISE ORTHOPAEDIC NOTES

Revision aid for FRCS , EBOT , SICOT and Board Examinations

Passport for theory, clinical and oral sections

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FOREWARD

To successfully fulfil the requirements of and pass a Fellowship exit examination is the aspiration of every doctor in a speciality medical or surgical field. Yet all of us with experience in the teaching of specialised medicine or surgery realise that it is not just appropriate knowledge and its application to patients that is the requirement, but also strategy to meet the expectations of the examiners within the permitted time.

'Concise Orthopaedics Notes', authored by specialists, all who are members of the FRCS Mentor Group, is oriented towards providing the candidate, both knowledge and know-how when appearing for this examination in the field of Trauma and Orthopaedics. The ethos of the Group which is to ensure success of every candidate is evident throughout. The authors emphasise the often neglected aspect of patient-approach and respect of patient-dignity during the examination. Equal importance is given to the manner of answering the examiners' questions, believing "there is a fine line between confidence and arrogance".

Though titled 'Concise Orthopaedics Notes', the book is extensively comprehensive in its knowledge content. In easy-to-read font and bullet-point style, it succeeds in serving as a ready revision aid for those preparing for the United Kingdom and International exit examinations. It has the added advantage of being contemporary with up-to date guidelines incorporated.

The book is a welcome addition to the bank of information in Trauma and Orthopaedics and I feel extremely privileged to be asked to write the Foreword. I have no doubt that the book will find valued acceptance by surgeons in our field.

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PREFACE

These concise revision notes are aimed at candidates preparing for UK and international **FRCS** (Trauma & Orthopaedics) exit examination as well as the European Board **(EBOT)** and **SICOT** diplomas.

The book has been written in an easy to read style, with a focus on being an exam candidate's companion for quick revision on the go. Candidates are usually caught between a busy job and the demands of these challenging exams. This book covers the depth and breadth of Trauma & Orthopaedics knowledge to help candidates sail through the Fellowship exit examinations.

We have aimed to provide a high quality one stop concise knowledge bank to cover the whole syllabus of Trauma & Orthopaedics in a well organised bullet point style.

This will provide a useful resource for both part 1 (MCQs, EMQs) as well as part 2 (Viva and Clinical) components of the exit examinations. It is an ideal companion to complement your preparation for the examination with the most useful information presented in the most succinct manner.

The authors are senior members of the FRCS Mentor Group who have between them ample up to date experience and knowledge with the Fellowship examination. They have attended most postgraduate orthopaedic courses in the UK and internationally ,and have reviewed all relevant exam book. They have excellent track records of helping many candidates to pass their exams.

This book is complemented by hundreds of diagrams, illustrations, radiographs and clinical images. There are QR codes interspersed within the chapters which when scanned using your smartphone camera, link up to either the corresponding open-access seminal paper or to a YouTube video pertaining to the topic discussed.

We look forward to the readers' feedback that will help us immensely to improve the contents in the next edition for the benefit of future orthopaedic aspirants. Please leave us your opinion on Amazon or write to the email below.

We also invite anyone who is interested to become an author of the next edition, or to discuss future collaboration or sponsorship opportunities to contact the editor on: thefrcsmentor@gmail.com

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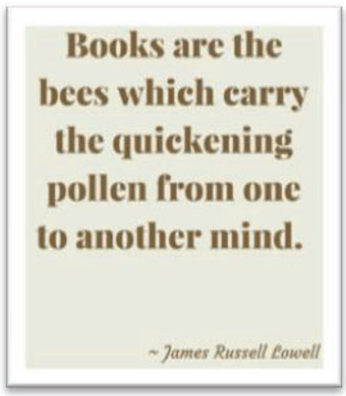
DEDICATION

This book would not have been possible without the dedicated team of talented and enthusiastic contributors who have participated to this project. To all of them, I am deeply grateful.

I would like to thank my wife (Reem), daughter (Talia) and son (Taym) for being a source of inspiration and encouragement, and for tolerating all those weekends and evenings I spent away from them while writing this book.

To the orthopaedic community, and to every clinician aspiring to excel in this profession, I dedicate this book.



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ABBREVIATIONS

A	Artery
AAA	Abdominal Aortic Aneurysm
ABx	Antibiotics
AD	Autosomal Dominant
ALL	Anterior Longitudinal Ligament
AR	Autosomal Recessive
AS	Ankylosing Spondylitis
Br	Branch
CSF	Cerebro Spinal Fluid
COT	Congenital Oblique Talus
CVT	Congenital Vertical Talus
CNS	Central Nervous System
DM	Diabetes Mellitus
Deg	Degrees
Ex	Examination
GT	Greater Trochanter
HA	HydroxyApatite
Hx	History
HTO	High Tibial Osteotomy
II	Image Intensifier
IN	Inter-Nervous plan
IR	Internal Rotation
Ix	Investigations
LFC	Lateral Femoral Condyle
Lig	Ligament
LM	Lateral Meniscus
Lt	Left
MM	Medial Meniscus
MT	MetaTarsal
Mx	Management
N	Nerve
NV	Neurovascular
NWB	Non-Weight Bearing
PG	ProteoGlycan
PNS	Peripheral Nervous System
Rt	Right
SB	Spina Bifida
Syn	Syndrome
Tx	Treatment
V	Vein
#	Fracture

General Guidance

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FRCS (Tr & Orth)

The FRCS (Tr &Orth) examination consists of two sections. Part 1 consists of MCQ and EMQ papers, both of which are timed and take place often in a driving test centre. You will need to choose your exam centre for section 1 and the date for your section 2 beforehand as part of your application. Both parts will need to be paid in full on application.

Please refer to the Trauma & Orthopaedics curriculum (updated August 2018) available on the GMC website for further guidance of the standard that you will be assessed on; please bear in mind that the syllabus is vast. Depending on your previous level of core knowledge and current circumstances (i.e. where you work, home situation etc) anywhere between 6–12 months of hard work and preparation is required to sit and pass this exam.

Section 1

Section 1 tests the theoretical knowledge of the candidate and is held at a test centre on a computer. You may have people around you undergoing different tests, such as driving theory tests.

Section 1 consists of two papers held on the same day (often morning and afternoon – the JCIE endeavours to provide a minimum of 30 minutes between each paper).

Paper 1: [2 hours] - Single Best Answer (SBA)

110 Multiple Choice Questions (Single Best Answer from a choice of 5 options)

Paper 2: [2 hours 30 minutes] Extending Matching Item (EMI)

135 Multiple Choice Questions (Extended Matching Item Format). 45 question stems with 3 sub questions, and a list of options to choose from with each option potentially being used once, more than once, or not at all.

You will be notified of your result (by email) within 4 weeks of sitting the exam. The score from each paper will be broken down to give you a cumulative result. The pass mark for this exam is variable and depends on how the whole cohort performs (often it varies anywhere between 60-70%).

Section 2

Section 2 consists of the clinical examination component and the oral component. They are held on different days either on subsequent days or with a “free” day in between. The standard of the pass mark is set at the level of a day one consultant in the generality of trauma and orthopaedics.

You will have as part of your examination two intermediate cases and two sets of 3 short cases (each intermediate and each set of short cases is divided into upper and lower limb, with spine potentially cropping up in either (or both). Each individual clinical case is marked and observed by 2 consultant examiners (a third person maybe present either as an observing examiner or invigilator for the examiners).

Day 1 - Clinicals

Intermediate cases

There will be two cases, each of 15-minutes duration, and each candidate will be marked in the following domains:

- History Taking / Data Gathering
  Summary of history and presentation / Structured approach / Logical thought process
- Clinical examination / Interpretation of findings / Plan of investigation
  Diagnosis (differential) / Clinical knowledge
- General management plan / Discussion of treatment options / Clinical reasoning
- Approach to patient / Bedside manner / Professionalism will be assessed throughout the exam

For the intermediate cases, as a general rule, the 1st 5 minutes is set aside for history taking, the 2nd 5 minutes for examination and the 3rd 5 minutes for discussion/management. Each Examiner will have his/her own mark sheet and will award a total of 6 times for each of the Clinical Intermediate Case examinations.

Short cases

Each short case is timed to 5 minutes, within which you are expected to (ideally) pick up on the diagnosis and move swiftly to management, specific to that patient. Five minutes is not long at all, and given the stress and anxiety associated with it, this time will pass quicker than anticipated. For this reason, it is important to not waste any valuable seconds/minutes and to have your pathology specific examinations down to a tee.

Within each 5 minute short case you will be marked in the following areas:

- Clinical Skills
- Clinical Knowledge

The purpose of the Clinical Short Case is for you to demonstrate that your observational, examination skills, and your knowledge, are sufficiently well-developed to make a relatively quick and accurate diagnosis for conditions that have typical clinical presentations. For complex problems, you may not necessarily come to a diagnosis, but you should be able to list an appropriate differential diagnosis.

The examination is rather like seeing a patient in the out-patient clinic and making a provisional diagnosis. Because of time limitations, you may not be able to perform a full examination and may only be able to ask a few (key) questions. However, it is important to still abide by good clinical practice and ensure that you remain polite and courteous to the patient, to introduce yourself and to use alcohol gel on your hands.

It is likely in a short case that the examiner will give clear instruction about what to examine or focus on, such as “Please examine this patient’s right hand” or “Please examine this patient’s forefoot”. There is no intention during this examination to trick the candidate and candidates are strongly encouraged to do precisely what is asked of them by the examiner. Candidates should, of course, show respect for the patient and attempt to avoid inflicting unnecessary pain during the examination.

Depending on how well or bad you are doing the examiner will intervene appropriately to either guide you back on track or to push you to move you on and score points. You may also be asked specifically to ask few *relevant* questions before proceeding with any examination – you won’t have time for a full history and so any questions asked must be relevant.

Day 2 - VIVAs

Four 30-minute orals in:

- **Adult Pathology**
- **Trauma**
- **Paediatric Orthopaedics and Hands (15 minutes for each)**
- **Applied basic sciences**

Candidates have up to a maximum of 7 years to complete the examination process as follows:

Section 1: Candidates have 2 years (from their 1st attempt) with a maximum of 4 attempts to gain eligibility to proceed to Section 2, with no re-entry

Section 2: Candidates have a maximum of 4 attempts with no re-entry

FRCS International

The overall exam structure is very similar to that held in the UK.
Section 1- Same format as the UK exam
Section 2- can differ

- One intermediate case (20 minutes)
- 4 x short cases (5 minute each, 20 minutes total) - Upper limb / Lower limb / Spine
- Oral component- same format as the UK exam

You have only four attempts for each section even if you switch from the national to the international exam. For example, if you have an unsuccessful attempt in section 2 in the UK exam you get only three attempts in the international FRCS

Fellowship of the European Board of Orthopaedics and Traumatology (FEBOT)

This exam is conducted by the European Federation of National Associations of Orthopaedics and Traumatology (EFORT) annually. It consists of 2 parts, held at separate times. You can give part 2 only after passing Part 1.

Part 1:
Online MCQ exam held at numerous centres all over Europe (similar to Pearson VUE centres). It consists of 100 MCQs of the single best answer type (SBA) which needs to be answered over 3 hours.

Part 2:
Consists of 5 viva stations, each with a pair of examiners. Each station lasts for 30 minutes. Each examiner quizzes you for 15 minutes generally over three topics. The clinical scenarios are usually presented to you on a laptop as a power-point presentation with X-rays/MRI/CT/Histology as needed. You may also need to draw diagrams at some stations.
The stations are as follows:

- Adult orthopaedic and trauma surgery – upper limb
- Adult orthopaedic and trauma surgery – lower limb
- Adult orthopaedic and trauma surgery – spine
- Children's orthopaedic and trauma surgery
- Basic sciences related to Orthopaedics, including biomechanics, statistics, audit methodology and outcome-based medicine

SICOT Diploma Examination

Candidates must be members of Société Internationale de Chirurgie Orthopédique et de Traumatologie (SICOT) or in the process of applying for membership at the time of registration.
The Diploma Examination consists of a written part and an oral part. The written part is comprised of 100 multiple-choice questions and lasts two hours. For the oral part, each candidate is examined by two examiners in four separate slots (30 minutes each) lasting two hours in total.
The syllabus covered in the exam is broadly divided into the following four domains:

- Basic Sciences – including Oncology & Infection
- Trauma
- Adult Pathology – Spine and Lower Limb
- Upper Limb and Paediatric Orthopaedics

THE WRITTEN EXAM

It is important to read the question thoroughly before attempting to look for the answer. The selection (and order) of words for any question has been methodically planned, and therefore this needs to be appreciated before attempting to select an answer.

There is no negative marking for the written exam, and this is why it is important to attempt to answer every question. With the electronic version of the exam, any difficult questions can be flagged and reviewed again later.
Often, you will find that you will be torn between 2 potential answers, and if you find yourself in this situation re-read the question and go with your gut instinct. After the exam, the questions and candidate responses are reviewed, and any such ambiguous questions will be discarded.

Be careful with educated guesses in the statistical analysis questions as they invariably have a habit of tempting you with the incorrect answer.

THE CLINICAL EXAM

Build up for the exam

You will know your exam, city/town well in advance. It is worthwhile doing some research about the hospitals around. Some hospitals may be a centre of treating a specific pathology or performing a particular type of surgery. It is worthwhile spending time reading about this to avoid any surprises on the day.

There are many courses available, which cater to giving that timed exam feeling and exposing you to patients/viva scenarios which can mirror the real thing. These can also be used in preparation for any of the other orthopaedic exams although the exam format may vary. These are expensive, so you may want to budget out which is suitable and appropriate for you. Just because a prestigious hospital conducts a course, it doesn't necessarily mean that it will be the most useful.

Book your hotel room, preferably at the same hotel where the viva is being conducted or nearby. The same hotel can sometimes be more expensive than a neighbouring hotel; however, it is important to remember that you have spent so much already on the exam, courses, textbooks etc that now is not the time to skimp out.

Try to see if you can get your room on a quiet floor. Try and avoid the temptation of reading the night before to avoid unnecessary stress. Last-minute reading is unlikely to make any difference to your performance.

The morning of the exam! It's finally here!

Wake up early and dress smart but conservatively, whilst remaining bare below the elbows.

You will be provided with all the equipment that you need for the exam, however to be on the safe side, it would not be a bad idea to carry with you a few items such as a pen, key, coin, and hand sanitizer. Try not to carry bulky items like measuring tape, torch, or blocks.

Have a good breakfast to build up the stamina that you need - you've got a long day ahead of you.

Start of the exam

You will line up with others in order of candidate number. You will be greeted by your examiner who will then take you to your room/cubicle where you will meet the 2nd examiner and possibly others who are either observing or assessing the examiners. Walk-in with confidence, smile and maintain a good body posture throughout. Shake hands from the outset and remain cool, calm and collected, instilling confidence in the patient and examiners.

Listen carefully to what the examiner says and answer only as requested, particularly in the short cases where time is limited. Take the hint in any particular question, for example if the examiner mentions 'weak', this maybe as a prompt to remind you to perform a neurological exam.

Gel your hands and as you're doing so, have a glance around the room. You will get a lot of information on what to expect by seeing if there are walking aids, splints, wooden blocks, prosthesis, custom shoes etc. You are now being assessed as a day 1 DGH consultant, and therefore it is time to move away from looking and sounding like a registrar.

Approach to the patient

Introduce yourself with a smile and ask for permission to examine before touching the patient.

> 'Hello, my name is Mr/Miss X, would it be okay if I examine you?
>
> 'I understand that you have been having a problem with X, can you please tell me more about that?'

You are observed and marked regarding your interaction and communication with the patient.
Always maintain eye contact and be polite to both the patients and the examiners!
If you have to ask the patient to be undressed, always maintain their modesty. You can say 'I would like to expose the limb/spine adequately but would also like to maintain the patients' dignity.

Choose carefully how you say things in order to instil confidence in both the patient and the examiner. There is a fine line between confidence and arrogance.

Treat the patient with respect and make sure you find out where it hurts and most importantly, don't hurt them! That will put them at ease and will also make your examiners happy. You are marked on your approach to the patient and your bedside manner.

Be systematic in how you take your history but focus on working out the diagnosis. Try to ask about the outcome score for example Oxford score for knee or hip case, you can do that in the exam only if you have practiced that or use it routinely in your daily clinical practice. You should also be able to summarize the outcome score in two or three sentences to avoid wasting your time.

Practicing in clinic with your consultant supervising you and covering all the important points within time is important to appear slick in the real exam. It is effortless to get carried away in the clinic, but you cannot afford to do so in the exam.
If your patient happens to be a child, always introduce yourself to both the parents and the child and ask permission from both before commencing your examination. It is imperative to approach the child playfully. That will gain the child's confidence quickly and saves valuable time.

Approach to Intermediate cases

Throughout the exam there are 2 intermediate cases, covering upper and lower limb, with spine potentially falling into one, both or neither one of these cases.

Often you will be shown a brief referral letter, usually from a GP, explaining the problem. The diagnosis may be made aware to you from the outset, in other circumstances you may need to formulate the diagnosis from your history and examination findings.

When faced with a complex patient with multiple problems, ask them what they feel is the main problem. It is important to be clear on this and to ask questions in depth about this. It is generally an issue with pain or function.

Pain

Pain is a key part of the orthopaedic history and therefore it is imperative that you take an accurate yet concise history relating to this. Key things to note with regards to pain can be remembered using the **SQITARS** mnemonic

- S – Site
- Q – Quality (sharp, dull)
- I – Intensity (score out of 10)
- T – Timing
- A – Aggravating factors
- R – Relieving factors
- S – Systemic/other features (weight loss, fever)

Finding out how this pain affects a patients' level of function/ability to work, is important and should not be forgotten. Ask about their work and hobbies so you can see how it affects these and you can thus judge what their expectations of treatment will be.

Ask the patient specifically what their expectations are and what they are hoping to gain from seeking medical attention. If the patient is not expecting/wanting surgery, it would be foolish to jump in and offer a hip replacement – this is likely not to go down well with the patient and the examiner(s).
Obtain a detailed medical and surgical history. Ask particularly for the history of diabetes, use of anticoagulants or steroids. Check for a history of smoking.

If the patient starts to digress, you should have a strategy to bring them back to the topic at hand without appearing rude or that you are bored of what they are saying. This can sometimes be difficult especially with talkative patients, but is something that just needs to be practiced. After completing your history, the examiner may ask you to summarise, if not now would be a good idea to suggest what examination you would like to proceed with.

You will then proceed to the clinical examination for which you have 5 minutes. You need to be able to interpret your findings and plan subsequent investigations. Any investigations that you suggest may then be provided to you so be prepared to analyse and come to a sensible conclusion from these.

You will then be asked to formulate a management plan with a discussion of the treatment options. You will need to justify and back up what you say. At this stage it is about demonstrating that you are a safe surgeon. It is important to involve other specialists if you feel the problem/issue requires this. Equally, it is important to be able to say that any plan that you consider is discussed with the patient in terms of the pros and cons.

Approach to Short cases

You will have two stations of 3 short cases each. There will be a pair of examiners for each station. Each short case will last 5 minutes, and will start with a bell. Five minutes is not long at all, and therefore it is important not to waste time during your short cases.

If you know what the condition is, say so sooner rather than later, but also back up why you think that. For example "This patient has features suggestive of rheumatoid hands because of the following". In doing this you are expressing to the examiner that you know what you are dealing with and all of a sudden the examiner does not need to question whether or not you can pick up on a spot diagnosis. Following on from this, you can then mention points specific to this condition. For example in a rheumatoid patient you want to assess their function, and ask about problems relating to their neck.

You are not allowed to take a history which can sometimes feel a bit unfair, mainly when some of the cases are complex. However, you still need to know if/where the patient is in pain, and what has been done about this already. Sometimes you may be allowed 1-3 questions depending on the pathology. You can ask something like:

- Where is the pain?
- How does it affect you?
- Did you have any trauma?
- What treatment have you had?

It's best to verbalise what you are examining as you go along to score points. Talk clearly and loud enough to be heard. Don't shout! Be clear and concise with the findings; don't be in doubt.
When it comes to examining the patient, remember:

Look: Keep your hands behind your back
Kneel to the part to be examined
Comment on any scars and what they may be due to, i.e.; ‘in keeping with’
Extensive abnormal scarring - think tumour/infection/trauma.
Check shoes in a lower limb or spine case - any modifications/ insoles/abnormal wear pattern or stretch.
Look for mobility aids, blocks

Feel: You can ask if the patient is particularly sore in any area to avoid hurting them.
For checking sensation, always let the patient know what is normal first. You can do this by touching their forehead to demonstrate as normal sensation.

Move: Check both active and passive range of motion of any joint.
In a foot or hand exam, quickly assess if there is a neurological versus tendon related problem by checking sensation, active and passive ROM and tenodesis test.
When checking for muscle power, it is better to place the joint in particular position and ask patient to push against you, which is easier for the patient to understand.

Try and focus your examination to the pathology or the question asked, for, e.g.: if it a case of hallux valgus, tailor your examination to this pathology. If you are asked to do a particular test such as the Thomas test, do the Thomas test and don’t start assessing for range of motion!

Make sure that you ensure your examiner sees what you’re examining. The exam is very similar to a driving test where you sometimes need to exaggerate certain manoeuvres to ensure it has been noted. Don’t be afraid to correct yourself if you have made an error. Not looking at the patients’ face during palpation is a common error, and will not be taken lightly by the examiner.

Try and practice to be flexible in your examination. You will be stopped frequently during your examination and sometimes rushed. This is not necessarily a bad thing, and often is because the examiner is trying to hurry you along to award you more points.

After a focused assessment, you need to be able to provide either an accurate diagnosis, particularly for spotters or a reasonable differential diagnosis. From this stage you will then be moved onto how you will manage this patient. It is important to have a logical approach to managing all patients, so that when you are faced with a rare condition that you have something to fall back on to. Don’t be afraid to say that you would not recommend surgery, as the patient is functioning well and has no pain. Hence, surgery could potentially make them worse.

The 3 short cases are run consecutively with no gaps in between, and so after 15 minutes you will feel as though you have been in a whirlwind. However, the key take home points are to not let one bad station affect your performance for your remaining stations and not to be fazed by a weird and wonderful diagnosis – because whatever the diagnosis; this can be safely addressed through a focused history and a systematic look, feel and move examination.

(Tipes & Tricks for prepration for FRCS exam)

THE VIVA (ORAL) EXAM

Introduction

This component is used to see if you have the knowledge base needed to work as a day one consultant in the generality of orthopaedics and trauma. More importantly, it tests whether you can use that knowledge base to solve clinical problems, identify solutions and test that your proposed solutions have worked. It also gives some opportunities to test professional behaviour; after all, this part of the examination is supposed to replicate a discussion between colleagues.

The key recommendation for any exam is to "practice, practice and practice" your viva technique until it becomes second nature to you.

The standards of any exam

All exams set out to provide an assessment of the knowledge and skills and the ability to use these to the standards of a consultant orthopaedic surgeon working anywhere in the world.

The standards are set to reassure your medical regulator, your employer and, most importantly, your patients that those being awarded the qualification today are of the same high standards as those who were awarded it in the years gone by. The examiners are looking for a safe surgeon with broad knowledge and sound basic principles that they would trust as a consultant colleague. It is with this standard in mind that the viva should be approached.

The viva examination is a test of not only knowledge but also of the candidate's ability to convey the required information to the examiners confidently and coherently that persuades the examiners that you are a safe orthopaedic surgeon.

Preparation for an excellent viva technique

Careful tactical planning is required beforehand. It is usually too late to alter your game plan on the day of the exam. Poorly thought out tactics and planning may lead to your downfall.

The basic knowledge required for the viva should be acquired in preparation for Part 1 of the exam. That does not mean however, that you can relax and assume that you can verbalise the right answer based on this knowledge, this is a technique which requires practice. The focus for preparation should therefore be on practising techniques and formulating logical answers to any possible question.

1. Knowledge base

In general, your knowledge needs to be broad and basic rather than narrow and detailed so that you can talk about anything on the curriculum. In short, 'Know something about everything'.
Draw up a list of essential topics in each section of the viva which you can focus on for your viva practice. It is easy to predict what topics will come up in the viva (but be prepared for the odd surprise!). For example, in the paediatric viva, you are likely to be asked about DDH, SUFE, Clubfoot, Septic arthritis of the hip, and/or cerebral palsy. For the trauma viva, you must know about hip, ankle and wrist fractures in detail, but basic principles of general fracture management will also be tested. In the basic sciences viva, surgical approaches are often asked as are the structure of cartilage, bone, meniscus, and tendons which are all must-knows. You will find all these topics and more covered within this guidebook.
There are a number of drawings and diagrams that you can be asked to reproduce. You may be asked to draw the brachial plexus or a stress-strain curve and label it. With practiced these are easy but also easy to make a mess if you are not rehearsed. Practice talking whilst you draw as this is not easy, and is something you should be practising in the run up to the exam.

2. Practice with colleagues

Working together as an exam group has been proven to yield positive results. Practicing your viva technique 2 or 3 times a week with a group of colleagues who are also taking the exam is an excellent way of building confidence and identifying gaps in your knowledge.

Try to simulate the exam scenario by sticking to one topic and making the questions harder with each response. Remember, it's an exam about common sense and making sensible decisions. If you come out with something outrageous and can't back it up, you will most likely fail.

3. Practice with an examiner

If there is an examiner in your region, who is happy to conduct a practice viva this is a golden opportunity which you cannot let slide. He/she knows the structure and standard of the exam, and this will give you an idea of the level you have to achieve.

4. Practice with your trainer/consultant

As invaluable as it is to have your fellow candidates test you, the fear of sounding stupid in front of your consultant instils anxiety which more realistically replicates the exam setting. It is important to take every opportunity you can to be grilled and put under the spotlight – you would rather make a fool out of yourself outside of the exam rather than on the exam days!

5. Practice, practice, practice!

As mentioned previously, this exam is about sensibly organizing your thoughts and verbalizing the same. All the knowledge that you have accumulated is irrelevant without this. The more you rehearse, the more at ease you (and therefore your examiners) will be.

Think through in real-time what words you would use in your answer to avoid ambiguity. Think what the examiner might say in response, and how you will respond. You may find that the form of words that comes to your mind in the first instance is clumsy – think about how you could present the same thing in a better way.

6. Courses

There are an increasing number of exam/viva preparation courses, and these are ideal for setting the scene for the real thing. A viva course is invaluable for final polishing of technique and acts as a confidence booster, allowing candidates to get into the exam mode, and gives them some idea of what to expect in the real scenario.

Try and get on a viva course that has a high faculty to candidate ratio. Remember that current examiners of specific exams are generally not allowed to take part in courses which cater to prepare individuals for that particular exam.

It is sensible to ask the advice of candidates who have recently cleared the exam and might be engaging with viva practice on such courses. Discuss with them what they found useful during their preparation and things they would recommend for the exam day.

7. Know your enemy

Finding out from previous candidates what topics/cases came up for them is useful to know as it gives you a feel for the level of expectation. However, this should not be taken as gospel and should most definitely be taken with a pinch of salt. A lot of the advice is person-specific and not always appropriate for each candidate. Additionally, don't underestimate the insight you can get from failed candidates. They are less likely to be biased as they may receive feedback and know exactly which part of the exam they failed and which one they passed.

On the day of exam

The viva part of the exam usually takes place a day or two after the clinical section, often in a hotel. The rooms are clearly expensive, but it is encouraged to book a room in the same hotel. This will avoid the stress of booking a taxi, looking into parking, and potentially arriving at your viva hot and sweaty before the exam has even started.

If you are on the second day of the viva, you will find the day in between stressful and challenging to spend productively as you mull over your performance in the clinical cases. Try not to think about your performance from the previous day and instead focus on the viva. You need to bear in mind that examiners don't know your past scores and it is unlikely you will meet the same examiner twice.

As you walk through and sit at the respective viva table, walk confidently, smile, shake hands and say thank you when asked to sit down. You have worked hard to get to this stage, and now is the time to show off your knowledge.

The oral tables

Your heart will be racing and your mouth dry, but the examiners will be aware of this. It is their job to find out how well you can perform, not to humiliate you. So, expect a polite introduction, a check of your candidate number and orientation to which viva you are about to sit.

There are two examiners per table, and you are at each table for 30 minutes. Sometimes a third person could be there who might be an assessor of the examiners, an observer or in training to be an examiner.
The viva is structured so that the examiners generally have pre-determined topics and questions in front of them. The questions have been written with a structure that begins with an opening statement or question that orientates the candidate to the topic. That usually doesn't carry any marks. It then moves on through questions that stimulate discussion that should show whether the candidate is competent in the topic, before opening up to advanced questions which encourage higher-order thinking that enables the candidate to achieve higher marks. The questioning is rapid-fire and generally starts as soon as you stop answering the last question. There will be no feedback, and the facial expression is neutral .Do not get hung up about this.

It is essential to draw whenever you can. Make sure your drawing is BIG, CLEAR and SIMPLE. Use the whole page, not just a corner. Describe what you are drawing and do not wait for the examiner to ask you details of what you are drawing. If you are shown an image on a laptop or a laminated sheet, have a good look at it, compose yourself and take a deep breath before answering. Please DO NOT TOUCH or point to them with your finger unless asked to do so. This can irritate the examiners, and is unlikely to go down well.

One of the examiners will ask questions from a range of topics for 15 minutes while the other scores. The examiners then swap after 15 minutes. Each examiner will quiz you on (at least) three topics within 15 minutes (5 minutes for each topic). A bell will ring every 15 minutes to remind the examiners to swap roles. Once the bell rings, please complete your sentence and move on swiftly to the other examiner.

The examiners are randomly allocated to tables. Hence, you may or may not have a hip specialist asking you about a hip dislocation case. Similarly, you could be asked about a disc prolapse case by a spinal or knee surgeon. So, keep an open mind. The exception to this rule is with regards to the Hand and Paediatrics table where specialist consultants in these two subspecialties will question you. Regardless which subspecialty is being tested, the examiners want to see that you can demonstrate that you are a safe surgeon, and that even when faced with a difficult scenario, you are able to fall back onto the first principles.
After 30 minutes, the final bell will be rung at which point you can thank the examiners and move on. Depending on your rotation, you will be given a break of varied duration before commencing your next viva table.

Question format

The examiners often use props to begin their viva questions. There may be laminated photos or laptops/iPads to demonstrate MRI scans, anatomical dissection, clinical photographs, X-rays and CT scans etc. All examiners have the same identical images to maintain standardisation of examination for every candidate. In specific exams, the examiner will have prepared short presentation slides with imaging embedded within them.

Questioning often starts with a settler question, to set the scene and try to calm your nerves. Questions will then progress to become more difficult, depending on how you perform. If you cannot answer the first question, this is unlikely to bode well, and the examiners may ask you a reserve question, tending to result in you scoring low on that topic. On the other hand, the examiners will continue to push you if you are doing well. The majority of the candidates will finish their viva being unsure of their performance, which is completely normal and is often a sign that the examiner was trying to push them towards scoring higher marks.

Listen to the question

Listen carefully to the wording of the question. Every word the examiner says is meaningful is used with intent, so it would be unwise to not pick up on these subtle hints.

If you are asked about the management of a patient, with any condition, start with history, examination, investigations and treatment. Avoid the temptation to cut corners and dive straight in with surgical management. The examiners are assessing that you are a safe surgeon who is treating the patient as a whole and not just the fracture/pathology.

If the question is 'what implant would you use' or 'what would you do?' don't talk about all the different options, state what YOU would do and back it up with reasoning and evidence. Often candidates are asked this question in the setting of arthroplasty, and therefore knowing key values from the NJR data score you some well needed brownie points.

When asked a question, take a deep breath and answer what you know. Don't try to make up an answer if you really don't know, stay safe and stick to basic principles. The examiners will see through your hesitation and uncertainty which can potentially make things worse. If you do not know, be honest and say so. This then gives them the opportunity to move you on and still allow you to score points.

There may be times when you may not understand a particular question. In this scenario, you are entirely justified to ask to the examiner to repeat it. Be careful with how you word this and say something along the lines of "I seem to have misunderstood, can you please repeat that?"

The examiners are genuinely on your side and are there to pass you. The majority of examiners understand that this is a stressful time and as such are friendly and nice. They just need to be confident that you have reached the standard of being competent enough to treat their loved ones.

Answering the question

Before answering the question, take few seconds to compose yourself. Think about the checklist of main points you want to discuss, including the buzz words you want to mention Start in a calm and structured manner, which demonstrates to the examiner your logical thought process. Try and avoid blurting out the first thing that comes to your mind and if there are certain key points to mention about that topic, say them early and show the examiner that you know what they are after. The viva is like a game of tennis where you need to respond appropriately to the shot played at you.

If there are certain "spot diagnoses" (for example rheumatoid hands or hallux valgus) then say the diagnosis early. The earlier you do this the less the examiner has to wonder if you can recognise key common orthopaedic presentations.

If you realise that you have said something that you should not have or incorrect, then just admit it say ’I would like to retract that’ and correct it. It would be detrimental to keep continuing down an incorrect path. Try and recognise any mistakes and back track early to allow yourself the opportunity to still score points.

If you are confident of a particular topic, keep talking about it and demonstrate your knowledge. If you are rambling, the examiner will tell you and bring you back on track. If you can direct the examiner onto a topic you know well, it gives you the opportunity to score highly and compensate for any stations which may not go as well.

Whenever an examiner asks you if you are sure about your answer, take it as a hint that you have answered incorrectly. So, unless you are very sure of yourself, come out early and think about revising your answer.

The examiners may cut you off mid-sentence. It can happen either when you are doing well or not so well. Don't let this put you off and just concentrate on the question in hand.

Always remember that the examiners are looking to pass a candidate that sounds like a safe, consultant colleague. This means that you need to give sensible answers and need not be a world expert. You should approach the answer as if it is your first week as a consultant, and less so like a registrar.

Quoting evidence

It is not necessary to know any papers to pass a viva or even the exam. But if you want to score high (and make up for questions which may not have gone so well) then it is worthwhile knowing some seminal papers to quote and to back up your answers (for example the Davis paper for trapeziectomy with or without LRTI is a classic).

Know which arthroplasty option you would want to use for your total hip, knee, shoulder and ankle replacement. These options should ideally be backed up with registry data, ODEP ratings and personal experience.

NICE, BOAST and MHRA guidelines are key cornerstones in the practice of Trauma and Orthopaedic surgery, and therefore stating their guidelines for certain clinical scenarios (for example open fractures) is key to scoring well. However, be careful about regurgitating guidelines in the exam without applying higher-order thinking and judgment .

Getting into difficulties

It is essential not to be discouraged or disheartened should an oral exam topic not go well. You must leave it behind you, remain focused and redeem the situation by focusing on answering the other oral exam topics well. Put things behind you when you go the next table. Remember that examiners don’t know your past performance, and more importantly that any one question or table can be compensated for.

It is of utmost importance that you never get into an argument with an examiner. It will get you nowhere. Swallow your pride and listen carefully to what has been said/asked. There may be hints of what you should be saying.
There are classic stories of candidates thinking they have failed a section, only to gain a good pass, but then failing the subsequent oral as they were too worried and distracted about their past performance.

Viva tactics

It quickly becomes apparent to the examiners how well a candidate has prepared for the structured oral examination. Usually, within the first two minutes or so, a score is formulated and tends to stay constant .

The viva will usually start easy and progress to higher levels depending on how the candidate performs. The questions are never asked to trick a candidate. So, keep it simple.

If you don't know an answer to a question, say so, and the examiners can move on to a different question. That is easier said than done, especially if the question is at the beginning of a topic and straightforward. There may not be a right answer to a question. However, there are certainly wrong answers!

If you wish to clarify a question, then do so. However, don't keep refining every single question with the examiners, as this will annoy them immensely.

If you are challenged about an answer, take the hint. You may be wrong even if you think you are right. That said, some examiners suggest standing your ground if you are convinced you are correct. Be prepared to back up your answer. If you have read it somewhere but can't remember, simply say 'my understanding from reading the literature is that … '
Treat examiners like respected colleagues. Examiners like a candidate who can take control of the viva and make life easy for them. Treat the exam as an intelligent discussion with a consultant colleague.

If you are asked about an operation you haven't done, say 'I have not done this procedure, but the principles are'. The examiners will respect your honesty and professionalism and appreciate that you are a safe surgeon who knows his/her limitations and understands the surgical principles.

When shown a photograph or radiograph which you do not know, say what you see and don't stay silent. For example, if presented with a photo of deformed lower limbs in a child, don't panic. Pause and start describing any rotational or angular deformities or shortening/lengthening that you can see.

Have a system to bail out of difficult situations. For example, when not sure about causes or classification, go through the surgical sieve - idiopathic, congenital or acquired (vascular, infective, traumatic, autoimmune, inflammatory, metabolic, neurological, neoplastic, degenerative, environmental).
Have a system for answering common questions. For example, when asked about surgical approach:

In an appropriately marked, consented and WHO check listed patient
Position and tourniquet, C-arm
Prepare and drape for adequate exposure
Landmarks
Incision details
Inter-nervous plane
Anatomical hazards

Any trauma scenario should start with 'I would assess and resuscitate/manage following ATLS principles/guidelines'. However, be careful when you are specifically told that this is an isolated injury. Answering that you will approach the patient as per ATLS principles will only irritate the examiners. Listen carefully to the question!

Advice for specific viva stations

Basic Sciences

Many candidates are apprehensive about this particular station. But it's probably the easiest one to score on. It is likely you will know more detail than the examiners themselves and is an excellent opportunity to teach the examiner what you know. Try to spend the 5 minutes giving the examiners a tutorial about the subject. If the questions seem difficult, it is likely that you are scoring well.
You will commonly be asked about anatomy or surgical approaches. Remember that the examiners are surgeons themselves, not biomedical engineers. The knowledge demanded from this station is usually broad and superficial. Draw whenever you can! And if you do draw, remember to draw BIG, CLEAR and SIMPLE to understand diagrams! Talking whilst you draw is a difficult skill and one that needs to be mastered for this exam.

Trauma

This can be one of the most difficult stations, and so it is important that you stay on your toes during this viva. Your approach to the trauma patient needs to be holistic and must always be life over limb. In addition to mentioning the ATLS guidelines, it is important that you know them in case the examiner asks you to go through them.

The management of polytrauma patients and common trauma scenarios (for example wrist and ankle fractures) requires a logical approach. Equally, for the trauma scenarios, this is probably the best opportunity to throw in relevant evidence to try and bump up your scores.

Classifications are generally not asked but are useful to know as they may still be expected if you are scoring high. However, if you mention a classification, be prepared to discuss it at length.

If unsure about the particular management of certain bony and/or soft tissue injuries then stick to broad principles and state the important things to consider, which are patient factors, injury factory and surgical factors.

Adult Pathology

You need to have a broad knowledge of different orthopaedic conditions. Anything can be asked here (including spines). You need to able to demonstrate that your approach to the patient is safe and holistic and that the treatment you suggest is appropriate for that patient.

Paediatrics and Hands

The examiners at these stations are usually specialist hand and paediatric orthopaedic surgeons. With this in mind, the topics covered are generally basic and very much day to day, and it is expected that you have come across them during your training. You need to demonstrate a broad understanding of the topics discussed.

MARKING SYSTEM

Section one

The papers are reviewed after each sitting by the examiners and any ambiguous or inappropriate questions are removed and not scored. The cumulative result of both papers is combined to then give you an overall score. The pass mark varies from sitting to sitting, but normally hovers between 60-70%.

Section two

A marking system is used from 4 - 8 in the 2nd part of the exam .This equates to the following:

- 4 - poor fail
- 5 - fail
- 6 - pass
- 7 - good pass
- 8 - exceptional pass

Examiners assess nine trainee characteristics during the standardised oral examination

- Personal qualities
- Communication skills
- Professionalism
- Surgical experience
- Organizational and logical, stepwise sequencing of thought process, ability to focus on the answers quickly
- Clinical reasoning, ability to justify and decision making
- Ability to handle stress
- Ability to deal with grey areas in practice and complex issues
- Ability to back up the answer with evidence from the literature

You will be scored for each question by two examiners. Both independently assess the performance in each of the six questions and do not confer before awarding their marks. They might also write notes to allow for feedback later if the results are challenged. These notes can also be made to document areas discussed, identify any clarification the co-examiner might want from the examiner before marking or even to indicate why an ‘8’ was awarded. So don’t assume any note made by the examiner on the sheet is detrimental for your score. Please avoid the temptation to look at the marking sheet as this will distract and confuse you.

The message is not to try and guess what mark you have achieved by the way you have answered a topic. Just treat every question as a new start and try not to be influenced by whatever you perceived in the previous question or table.

Scoring opportunities

There are 96 scoring opportunities in section 2 - 48 in the clinical part and 48 in the viva. The maximum mark attainable is 768 with a pass mark of 576. This means you need an average of 6 marks at each scoring opportunity to pass. Even if you are short by ONE mark, you fail! There is no truth in the argument that a particular examiner or one specific topic has caused your failure since this would be diluted by the multiple scoring opportunities available.

The marking descriptors

It is helpful to know what points you will be assessed for during the exam as it will guide your preparation for it. You can get a detailed description on the Joint Committee on Intercollegiate Examinations (JCIE) website under Panel of Examiners section. Make sure you go through it at least once to give you an idea about what is involved.

THE CONDUCT OF EXAMINERS

Examiners are not selected for their sadistic tendencies or cold hearts. They are consultants who have been in practice for at least five years and in that time have demonstrated an interest in and continued getting involved in training and education. They have put themselves forward with the support of their medical director and usually have ongoing roles in regional and national training committees, teaching roles and the supervision of trainees. They must also demonstrate that they have remained active in research and that they can take the time to fulfil the role (which includes unpaid weekends away from home).

Examiners are advised not to respond to inappropriate behaviour by candidates. Each examiner is encouraged to be polite and put candidates at ease. They are not allowed to examine a candidate that they know on a personal basis or if the candidate has worked for them in the recent past. They are not like the faculty you meet on courses. They are there to give the candidate the best possible chance of passing. Examiners are reminded that excessive stress is unpleasant and damages a potentially good candidate's performance. They are trained to keep a neutral expression and are not allowed to give a candidate feedback such as "well done or "excellent".

Every second an examiner talks provide less time for a candidate to show if he/she is competent. Therefore, examiners are encouraged to allow candidates the maximum time to talk as much as possible. With that said, beating around the bush will not be awarded!

In every diet of the examination, there will be a small team of 'examiner assessors'. These assessors report back to the Board on all aspects of the examination, from facilities and case-mix to catering arrangements and environment. These assessors are also trained (usually after finishing the maximum 10-year term as an examiner) to assess and feedback on examiner performance.

The assessors ensure the standard of examining remains high, but this is supplemented by detailed analysis of the marking behaviour of examiners afterwards, again being fed back to the examiners after the event. Each examiner gets to see how they marked candidates compared to their peers. Hawk and dove tendencies can be observed and reflected upon. Rest assured that stories of any particular examiners who routinely fail all candidates simply cannot be real – such an examiner would be flagged as an outlier and would not be allowed to continue in such a manner.

APPEARANCE

You should wear something conventional, smart and comfortable that you have worn before. Dressing formally focuses the mind for the task ahead.

You will not be marked down for your choice of shirt or blouse. However, if you are scruffy and unkempt for such an important event, the examiners may assume that you present yourself similarly in a clinical environment .This does not inspire patient trust and confidence.

Examiners are also aware that the stress of the examination may make candidates do strange things. The examiners will make every effort to put you at ease, but will also understand the beads of sweat trickling from your brow.

HOW TO AVOID WINDING THE EXAMINERS

Try and imagine yourself as the examiner. How and what would you expect/like to see from a candidate who could well be your consultant colleague in the future. When you think of it that way, it is easy to imagine that you want a colleague is remains calm under pressure, is able to communicate clearly, and is able to get their point(s) across without wasting time.

Disagreements and arguing with the examiner, is highly unlikely to go down well. So if things do escalate, be the bigger person and have methods to avoid such conflict. Using words like "obviously" or "basically" is likely to annoy the examiner simply because what is obvious and basic to you may not be to someone else.

Try and avoid mentioning things which you know little about. If the examiner were then to flag this up with you, this can be quite embarrassing.

Lastly, remember that the examiners want you to pass, and therefore show them that you have the knowledge, skill and composure of a day 1 DGH Trauma and Orthopaedic Consultant.

HIGHER ORDER THINKING

Higher-order thinking is a phrase often thrown around when discussing ways to answer questions in the viva. This is real-life clinical decision making, which is based on the problem at hand, the evidence for management and, most importantly, patient factors.

The assessment of recall and comprehension of knowledge is essential. However, recall and understanding are tested in Part 1 (MCQ/EMQ) of the exam, which is a different ball game. In contrast, higher-order thinking describes the decision making whilst taking all important factors into consideration.

RESULTS

Results for Part 2 of the exam are unusually released within the 2 weeks.

If you have passed, rejoice and celebrate with your loved ones! You have worked very hard for this, and you deserve it. Make sure you inform your consultants and trainers, especially those who took the time to help you prepare.

If you have been unsuccessful, you will be provided with a final performance report with feedback on your performance.

SUMMARY

The viva section of the orthopaedic examination is used to see if you have the knowledge-base needed to work as a day one consultant in the generality of orthopaedics and trauma. More importantly, however, it tests whether you can use that knowledge-base to identify problems, consider solutions and work as part of a team to optimise patient care.

Finally, this exam, for most of you, is the last exam you will ever sit. For that reason give it your best. On the day of the exam, stay calm, remain focused and, dare I say it, enjoy the experience. Good luck

Orthopaedic Basic Sciences

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CONTENTS

BIOMECHANICS

Science of structure and function of biological tissues

Statics: Study of forces acting on rigid bodies, either at rest or at constant velocity

Dynamics: Study of forces acting on rigid bodies in motion

Kinetics: Study of forces acting on rigid bodies to produce movements

Kinematics: The branch of mechanics concerned with the motion of objects without reference to the forces which cause the motion.

Kinesiology: The study of human movement

Newton's Laws of Motion

First law: An object either remains at rest or continues to move at a constant velocity, unless acted upon by a force

Second law: The vector sum of the forces (F) on an object is equal to the mass (m) of that object multiplied by the acceleration (a) of the object: F = ma.

Third law: When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body
(every action has an equal and opposite reaction)

Force: has both magnitude and direction, making it a vector quantity

- Types of forces:
  - Tensile 2 forces pull away from each other along same line
  - Compressive 2 forces push against each other along same line
  - Shear parallel (tangential) to surface but not along same direction
    Moment Force acting at distance from body (pivot)
    Causes twist (turning) rather than pull or push
  - Torque Rotational force (turning moment) perpendicular to long axis of a body (large femoral head in THR produces larger torque, leading to more volumetric wear)
    E.g. Larger screw driver has longer lever arm – increased torque force
  - Hoop stress force exerted circumferentially perpendicular to long access of cylinder wall
- Energy: Ability to do work
  Potential Due to body position
  Kinetic Work required to stop body or to move body from rest to a velocity
- Vector: A quantity that has both magnitude and direction
  Typically represented by an arrow whose direction is the same as that of the quantity and whose length is proportional to its magnitude
- Moment: Effect of a force at a perpendicular distance from the axis, which results in a rotational movement and angular acceleration

Corrosion

Chemical dissolving of metal

- Crevice Fatigue cracks or scratches with low oxygen tension
  316L stainless steel most prone to crevice corrosion
- Galvanic Between dissimilar metals such as stainless steel and cobalt-chrome, Highest risk
  Don't mix materials
  Electrochemical
- Fretting Micro-motion of two materials (abrasion of asperities)
  Movement disrupts protective oxide layer
  E.g. under head of screw or Trunnionosis of male taper (ARMD)
- Pitting Localized crevice corrosion leading to formation of tiny holes on surface when
  Passivating layer is removed (joint fluid comes in contact with metal – reoxidation of
  Layer releases H+ that dissolves titanium and Co-Cr implants

Isotropic Possess same mechanical properties in all directions of load (metal, ceramic)

Anisotropic Have mechanical properties that vary with orientation of loading (bone, ligament)
Property of structure (bone) not material (cortical/cancellous bone)

Working length

It is the unsupported length of a construct

Length between most distal point of fixation in proximal fragment and most proximal point of fixation in distal fragment

Longer working length - stress distributed over longer area of implant - construct is less stiff

Shorter working length - stress concentrated over small area – increases stiffness of implant

Moment of inertia (area)

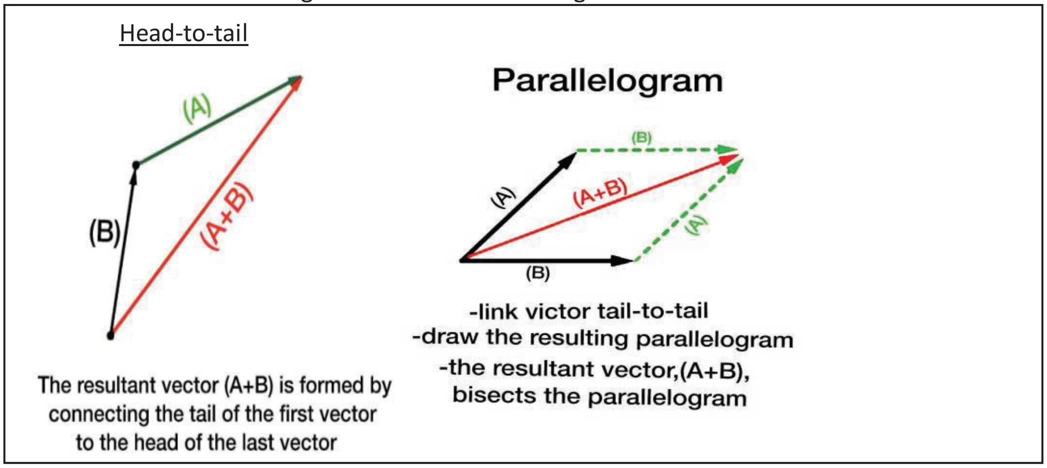
Ability of structure to resist deformation

Depends on mass and material & cross-sectional distribution of structure

Forces and lever arms

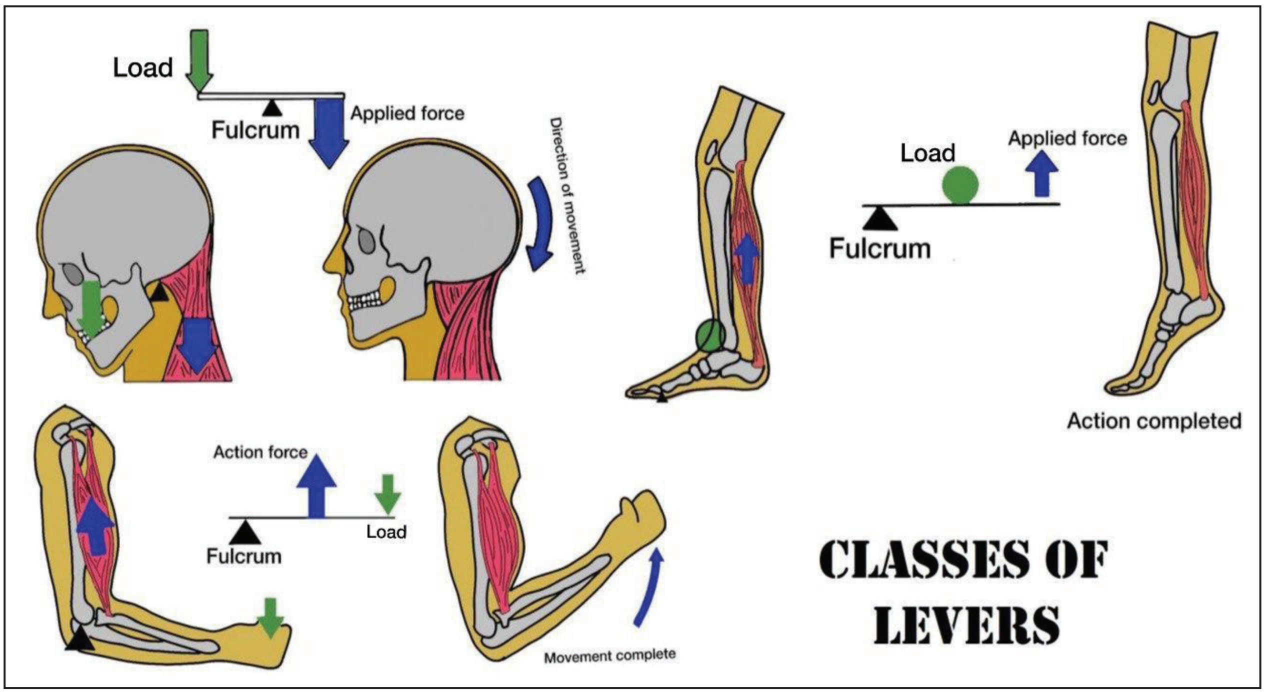
Methods to resolve forces about a body:

1) Trigonometry Calculating values
2) Vectors estimating the direction of resulting vector



Lever:
Rigid structure that turns around fixed point (e.g. bones)
Moment arm: Perpendicular distance from pivot point (fulcrum) to line of action of force
Classes of levers:

- 1st class Fulcrum between force and load
  Atlanto-occipital joint between erecter spinae and head
  Scissors
- 2nd class load between force and fulcrum
  Body weight on ankle between calf muscles and toes when standing on tip toes
  Nut cracker
- 3rd class force between fulcrum and load
  Elbow flexion muscles between elbow and hand



Tribology

Science of interacting surfaces in relative motion
Includes friction and lubrication and wear

Type of fluids Newtonian linear stress/strain relation, e.g. Saline
Non-Newtonian Synovial fluid

Friction

Resistance to motion of surfaces sliding over each other
Converts kinetics into heat
Reduced by lubrication
Proportional to load and coefficient of friction
Does not depend on surface area
Coefficient of friction - Articular cartilage < ceramic-on-ceramic < metal-on-metal < metal-on-poly

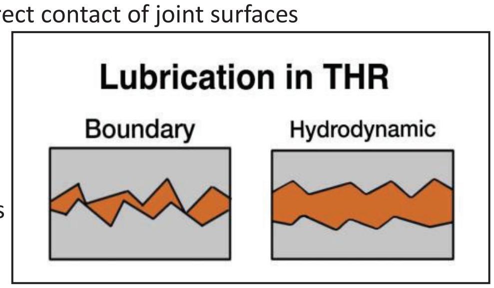
Lubrication

Process to reduce friction between opposing articulating surfaces by **interposition** of lubricant

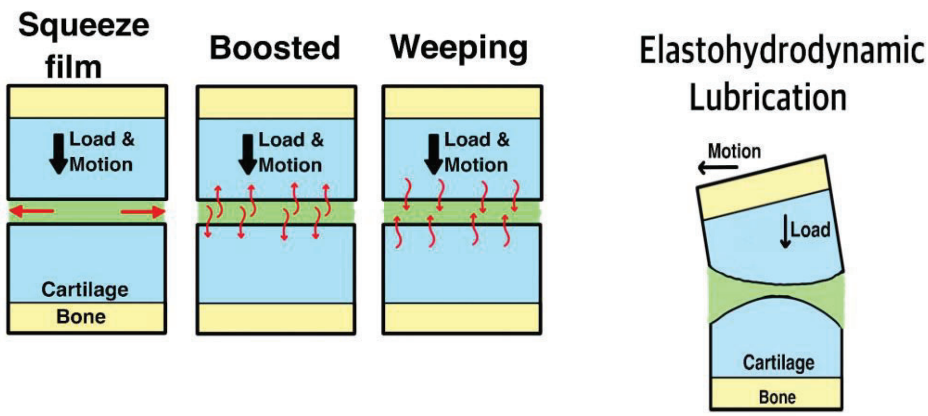
- **Lubrication in THR**

Boundary Contact between asperities due to high surface roughness of PE
Roughness/smoothness – depends on height of surface asperities (Ra)
Separated by lubricant, lubricin monolayer prevents direct contact of joint surfaces
Lambda ratio < 1

Hydrodynamic (fluid film)
Movements create thin fluid film
Fluid film separates joint surfaces
Hard on hard
Lambda ratio fluid film thickness/surface roughness
> 3 for fluid film lubrication
Usually require low loads at high speed

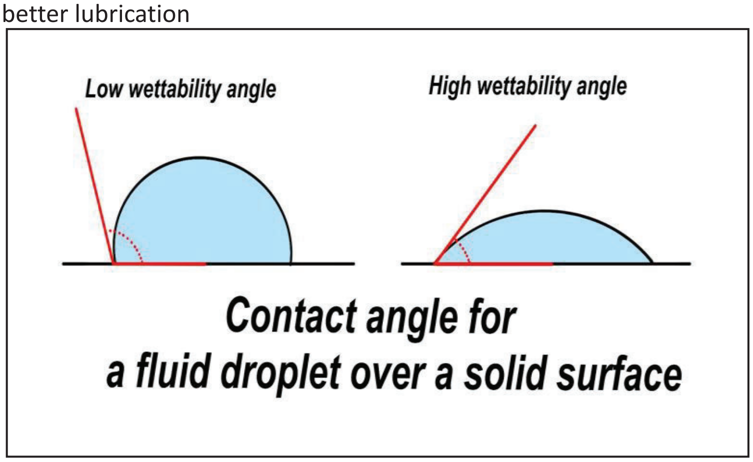


- **Lubrication in articular cartilage**
  - **Squeeze film** When standing still and parallel surfaces get closer
    Produces compressed film of synovial fluid
  - **Weeping** Fluid exudes from loaded articular cartilage
  - **Boosted** low molecular synovial components are pushed into articular cartilage leaving thicker Hyaluronic acid behind
  - **Elasto-hydrodynamic** Elastic deformation of articular bearing cartilage to increase surface area.
    During weight transfer or toe-off stage of gait
    Fluid pushed along



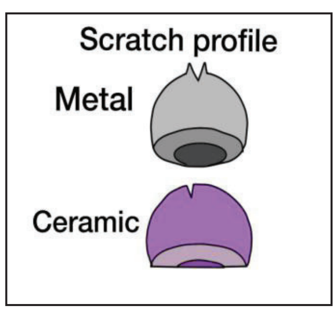
Wettability

Affinity of surface material to lubricant
Ceramic has greater wettability than metal
Measured using Theta contact angle
Small angle < 45^0 – hydrophilic – better lubrication
Large angle > 90^0 – hydrophobic



Hardness/notch sensitivity

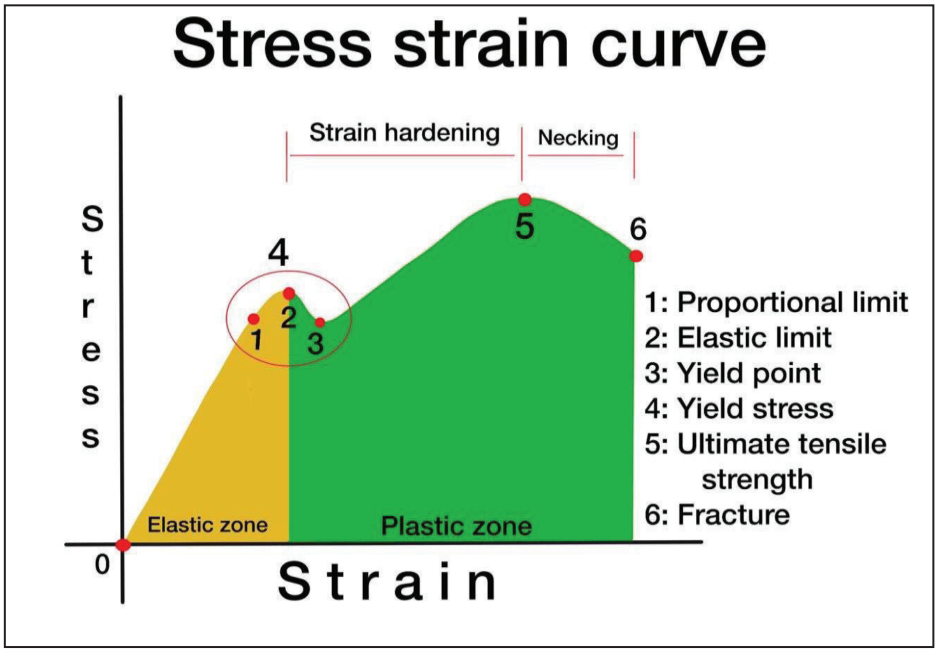
Surface property
Ability of material to resist scratching
Other surface properties are roughness & wettability



STRESS/ STRAIN CURVE

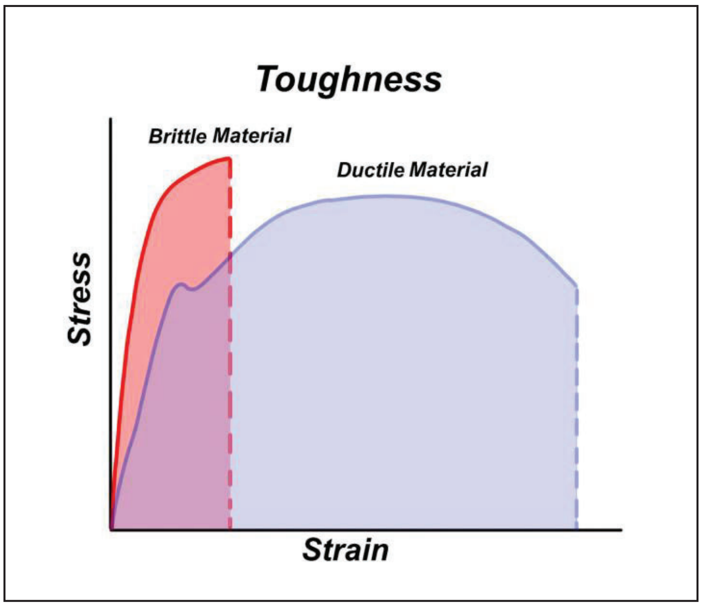
Deformation of material at distinct intervals of load
Unique for each material

- **Stress** Force per unit area (N/m^2) $1N/m^2 = 1$ Pascal
  Can be tensile or compressive
- **Strain** Change of length (deformation) of material when force is applied
  Change in length/original length, therefore ratio/percentage
  Fractures of cortical bone occur at 2% strain and cancellous bone fractures at 75% strain
- **Stiffness** Ability of material to resist deformation
  Stiffness is of a material, rigidity is of a structure
  The steeper the slope the stiffer the material
- **Elastic zone** Elastic deformation - Reversible
- **Elasticity** Ability to return to resting length/shape (zero strain) when stress removed
  Area under elastic slope called resilience
- **Hooke law** Stress is proportional to strain in elastic zone of stress-strain curve until proportionate limit
- **Yield point** Transition from elastic (reversible) to plastic (irreversible) zone
  Once material passes it, it no longer displays elastic behaviour
- **Plastic zone** Material will not regain original shape when stress removed
  Plastic deformation - irreversible (permanent)
  Strength of material
- **Ultimate tensile Strength (UTS)** Maximum stress (strength) before failure
  Broken instrument/stress fracture
- **Strain hardening** Occurs due to rearrangement of metal crystals, making them more intermingled to form stronger structure during plastic deformation
- **Necking** Between ultimate tensile strength and fracture/rupture
  Stress reduces as strain increases



Stress-strain curve differs under compression, tension or shear forces
Osteoporotic bone – yield point occurs at same strain as normal trabecular bone but the stress required to achieve yield point is much less (osteoporotic bone is less stiffer than normal bone, but is more brittle)
Osteomalacia – lower stiffness + higher ductility

- **Brittle material** little or no plastic deformation
  Ceramics & PMMA
- **Ductile material** large plastic deformation before failure
  Metal
- **Toughness** Amount of energy material can absorb before failure or fracture
- **Strain hardening** plastic deformation increases resistance to deformity

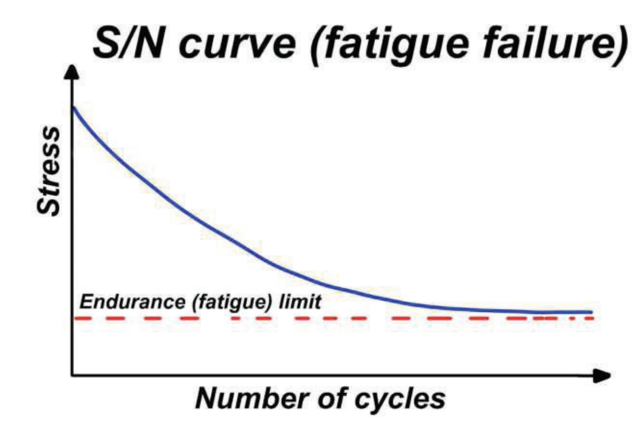


Stress/Strain (S/N) curve

Describes fatigue behaviour of material under cyclical loading
Y axis is Stress
X axis is Number of cyclical loadings, 10 million (1 million/year) used in Orthopaedics
Endurance limit: stress under which material will not fail regardless of how many loading cycles applied

Fatigue Failure Progressive failure due to application of cyclical stresses below the UTS.
Starts at stress-risers

Stress shielding from modulus mismatch
Seen with stiffer implants and extensively porous coated stems
Proximal coating allow proximal bone loading and less stress shielding



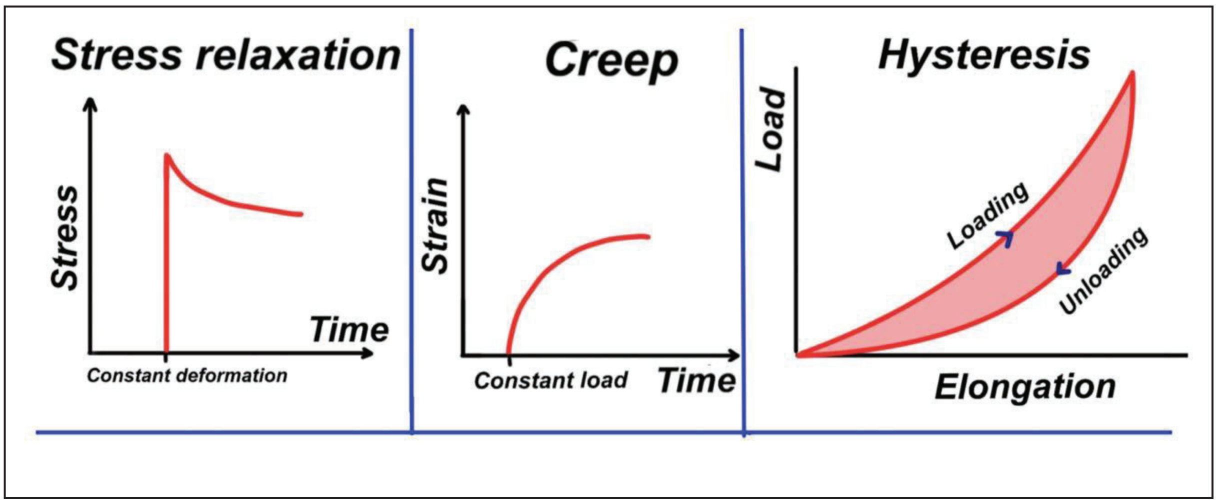

(Courtesy of H Hermina)

VISCOELASTIC MATERIALS

Viscous behaviour Rate- and time-dependent change in stress-strain relationship
Viscosity - Internal friction of material or resistance of liquid to flow
Elastic behaviour return to original shape after deforming force removed

Characteristics

Creep Increased deformation of material with time under constant load
Cement, intervertebral disc, Ponseti technique
Hysteresis Loss of energy under repeated loads
Unloading curve does not follow loading curve
Difference between two curves is energy dissipated due to internal friction
Stress relaxation Decreased stress over time with constant strain
Tendons & ligaments (Ponseti treatment)
Hoop stresses during insertion of femoral stem
Cycling of ACL graft
Rate Dependent Strain Behaviour stiffer and stronger at high strain rates than at low strain rates



Young modulus of elasticity Describes **stiffness of material**
Ability to resist deformation in elastic zone
Ceramic - Co-Cr alloy - Stainless steel - Titanium - Cortical bone - PMMA - Polyethylene - Cancellous bone - Tendon/ligament – Cartilage

WEAR & OSTEOLYSIS

Wear: Progressive loss of bearing substance from the material secondary to either mechanical or chemical (corrosive) action

Effective joint space defined as area around prosthetic joint where fluid can dissipate freely

Mechanisms of Wear

➢ **Chemical (corrosion)**		Unwanted loss of metal in an environment of solution
➢ **Mechanical**	Adhesive	Due to bonding between two bearing surfaces pressed together Material pulls away from weaker surface
	Abrasive	Asperities of harder material eroding softer one
	Fatigue	Failure under ultimate tensile strength due to repeated loading cycles Also called delamination Related to stress/strain curve and material stiffness

Quantification

Volumetric	volume of material	Directly related to square of radius of head (increased sliding distance) Dependant on type of articulation, lubrication and load
Linear	Height of material	Distance prosthesis has penetrated into liner

Modes of wear

1 Between normal bearing surfaces as intended by designer

2 Between bearing and non-bearing surfaces femoral head with acetabular shell following poly wear
Femoral component against tibial base plate

3 Normal bearing surfaces with interposed 3rd body

4 Two non-bearing surfaces back side of acetabulum poly liner and shell
Femoral neck against acetabular shell

Factors contributing to joint replacement wear

- **Patient factors**
  - Activity level, cultural demands
  - BMI
  - Co-morbidities
- **Implant factors**
  - Modular Vs mono-block
  - UHMWPE thickness
  - Fixation method
  - Implant constraint
  - Bearing material used
- **Surgical factors**
  - Soft tissue balance
  - Surgeon experience
  - 3rd body wear
  - Implant orientation

Wear rates	Titanium	poor resistance to wear
	UHMWPE	0.1-0.2 mm (100 – 200 MicroM)/year

HXLPE	Smaller wear particles & more resistant to wear 40 MicroM/year
Metal on metal	Small wear particles & more resistant to wear 5 MicroM/year Size of metal particles, 50 Nm
Ceramics	lowest wear rate, 2.5 MicroM/year

Consequences of Wear and Wear Particles

- Synovitis
- Aseptic Osteolysis and Loosening
- Systemic distribution
- Immune reaction
- Increased friction of the joint
- Misalignment of the joint and catastrophic failure

Aseptic Osteolysis and Loosening

Step 1: Particulate Debris Formation

Step 2: Macrophage Activated Osteoclast genesis and Osteolysis

- Particles result in macrophage activation and further macrophage recruitment
- Macrophage releases osteolytic factors (cytokines)including:
    - TNF- alpha
    - osteoclast activating factor
    - oxide radicals
    - hydrogen peroxide
    - acid phosphatase
    - interleukins (Il-1, IL-6)
    - prostaglandins
- Osteoclast activation and osteolysis
    - increase of TNF- alpha increases RANK
    - Increase of VEGF with UHMWPE particles enhance RANK and RANKL activation
    - RANKL mediated bone resorption - an increase in production of RANK and RANKL gene transcripts leads to osteolysis

Step 3: Prosthesis Micromotion

- Osteolysis surrounding the prosthesis leads to micromotion
    - micromotion leads to increase particle wear and further prosthesis loosening
    - N-telopeptide urine level is a marker for bone turnover and are elevated in osteolysis

Step 4: Debris Dissemination

- Increase in hydrostatic pressure leads to dissemination of debris into effective joint space
    - increased hydrostatic pressure is result of inflammatory response
    - dissemination of debris into effective joint space further propagates osteolysis

BONE COMPOSITION

Definition **Bone is** a composite, dynamic form of specialized hard connective tissue which is **anisotropic** and is **composed of** cells and extracellular matrix.

It is has **viscoelastic** properties

(**Composite** = made of materials that have different mechanical properties)

Functions of bone Locomotion

Protection	ribcage, skull
Haematopoietic	Produce WBC & RBC
Reservoir	Ca & Phosphate

Cells

Osteoblasts

Differentiate from **mesenchymal stem cells**

Osteoblasts express receptors to PTH, PTHrP, Vitamin D metabolites, gonadal and adrenal steroids, and certain cytokines and growth factors

Bone forming cells and also regulate osteoclast function

- **Produce:**
- Organic (non-mineralized) matrix Type I collagen - osteoid
- ALP
- Osteocalcin
- RANKL (Ligand) Member of tumour necrosis factor (TNF) cytokine family
  Produced in response to activation by PTH
  Can be stimulated by bone cancer cells
  Binds to and activates RANK cell surface receptors on immature osteoclasts
  Functions as key factor for osteoclast differentiation and activation
  Denosumab inhibits binding of RANKL to RANK
  Treat postmenopausal patients with osteoporosis
  Also used to treat GCT
- Osteoprotegrin (OPG) Block binding between RANKL and RANK receptor and consequently inhibit osteoclast formation and activation, acts as decoy to RANKL inhibiting activation of RANK on osteoclasts

Respond to chemical, mechanical and electrical stimulation

- **Stimulated by** PTH, Vit D, Oestrogen, BMP, PDGF, IGF, TGF-B
- **Inhibited by** TNF, Hydrogen Peroxide, Povidon Iodine, steroids, COX 2 inhibitors
- Osteoblasts have three fates:
  - Undergo apoptosis
  - Become osteocytes – stimulated by calcitonin and inhibited by PTH
  - Become Bone lining cells

Osteocytes

Derived from osteoblasts surrounded by matrix - Maintain bone mass

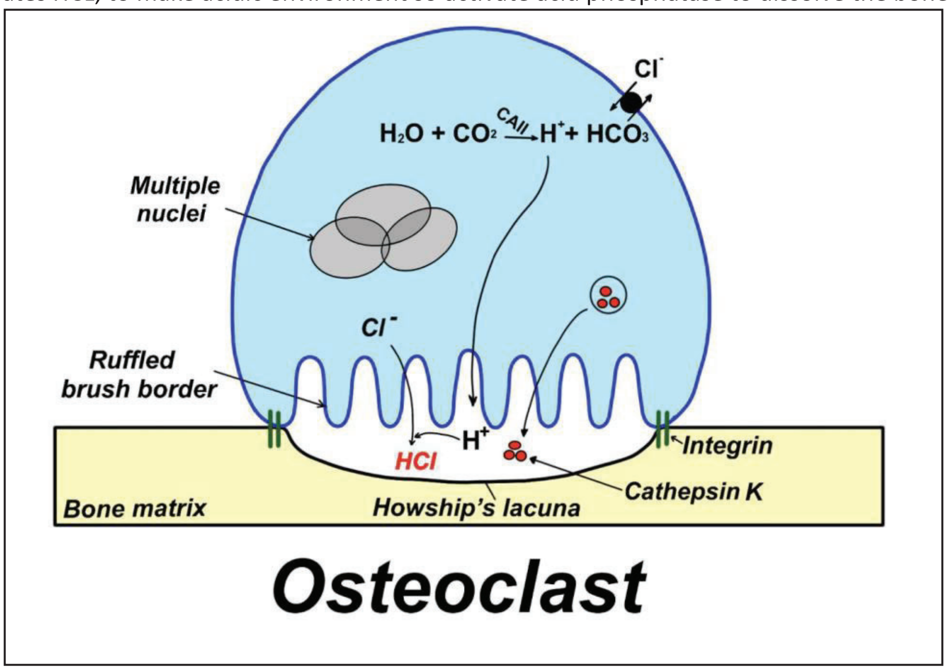
Stimulated by Calcitonin

Inhibited by PTH, bisphosphonates

Communicate by canaliculi

Osteoclasts

- Bone reabsorbing cells
- Lineage is from **monocytes/macrophages cells** (hematopoietic stem cell) – fuse together – multinucleated giant cells
- Have ruffled border to increase surface area for bone resorption
- They can be found in pits called **Howship's lacuna** which are cavities in the bone that is undergoing reabsorption or attach to the bone surface
- Attach to bone surfaces via special protiens called Integrins
- Produce Acid phosphatase
- Secrete **Carbonic anhydrase** - Enzyme that converts carbon dioxide and water into H+ and bicarbonate
- **Protons** created are then transported across ruffled border of osteoclast, leading to acidification and lower pH – increase solubility of HA - **demineralization of bone matrix**
- **Cathepsin K** - enzyme used at ruffled border that functions to resorb bone
- Organic matrix resorbed by proteolysis
- Creates HCL, to make acidic environment so activate acid phosphatase to dissolve the bone



- Stimulated by (osteolysis) RANKL, IL1, 6, PTH (indirectly as there are no PTH receptors on osteoclasts), Cancer cells
- Inhibited by Calcitonin (through direct receptors) – dissolution of ruffled border
  Bisphosphonates – causes apoptosis of osteoclasts
  Oestrogen
  IL 10
  Osteoprotegrin (OPG) - Bind to RANKL, inhibited by corticosteroids

Bone lining cells

Dormant, become osteoblasts when activated
Present on surface of bone

Matrix

- **Organic** 30 %
  - Type 1 Collagen (b***one***) - tensile strength of bone
  - Proteoglycans - compressive strength
  - Non-collagenous proteins: Osteocalcin (most abundant); Osteonectin - regulate calcium; Osteopontin
  - Growth factors & Cytokines :IL1, IL6, BMP
- **Inorganic** 70 %
  - Calcium reservoir – provides compressive strength
  - Calcium hydroxyapatite Ca10 (PO4)6(OH) 2
  - Calcium phosphate

Bone marrow

- Red: contains mesenchymal stem cells (pluripotent & self-regeneration)
  - Most commonly found in flat bones & epiphysis/metaphysis of long bone in children
  - Haematopoietic
- Yellow: most commonly found in diaphysis of long bones
  - Contains fat cells

Periosteum

Outside covering of the bone it has two layers

- Inner (cambium): vascular
  - Forms callus, enlarge diameter of bone at diaphysis
- Outer: Fibrous
  - Contiguous with joint capsule

Functions
- supplies blood to the outer third of bone
- Provides attachment to muscles, ligaments and tendons
- Prevents spillage of bone components into surrounding tissue

BONE METABOLISM

Calcium

99% of body calcium stored in skeleton as Calcium hydroxyapatite "$Ca_{10} (PO_4)_6(OH)_2$"
2.2 – 2.6 mmol

In plasma 55% free ionized, measured on gas analysis
45% bound to proteins, decreased with low Albumin

- Requirement 1500 mg/day for postmenopausal, pregnant and for healing
  Lactating mother 2000 mg/day
  Adults 750 mg/day
  Rickets 5000 mg/day
- Functions Bone compressive strength
  Muscle contracture
  Nerve conduction
  Coagulation

Hypercalcaemia

Symptoms Polyuria, polydipsia, confusion, muscle weakness, vomiting,
Constipation, Peptic ulcer, pancreatitis

Causes Bone cancer due to activation of RANK\RANKL (PTHrP mediated) -
Low PTH
Hyperparathyroidism - High PTH
Vitamin D mediated (toxicity), milk-alkali syndrome, and
Immobilization
High bone turn-over, e.g. Paget's
Genetic – familial hypocalciuric hypercalcaemia: mutated calcium sensing receptor

Treatment Hydration (enhances glomerular filtration and excretion of Ca),
Diuretics (inhibits Ca resorption in distal renal tubule),
IV Bisphosphonates (inhibits osteoclast function), Dialysis
Basal ganglia calcification on X-rays

Hypocalcaemia

Causes Vit D deficiency - both Ca and PO4 decreased
Renal failure, hypoparathyroidism, Pseudohypoparathyroidism,
Pancreatitis, hypoproteinaemia

Symptoms Paraesthesia, convulsions, mood swings
Trousseau's Sign – carpo-pedal spasm after BP cuff inflation
Chvostek's Sign - facial muscle contractions initiated by tapping on facial nerve
Basal ganglia calcification

Treatment calcium gluconate infusion with cardiac monitoring

Phosphate

Important in enzyme function
85% of body phosphorus stored in skeleton

PTH

From chief cells of parathyroid glands - Most common cause of hypocalcaemia is thyroidectomy
Teriparatide is the synthetic form

Effects:

- Blood — Increase serum Ca
  Decrease Phosphate levels in blood
- Bone — Stimulates osteoblasts to secrete IL-1, IL-6 and other cytokines to activate osteoclasts
  Pulsed – anabolic effect, continuous – catabolic effect
- GI Tract — Stimulates conversion of 25(OH) vitamin D3 to 1, 25(OH) 2 vitamin D3 (active hormone
  Increase absorption of Ca from small intestines
- Kidney — Increase absorption of Ca from kidney and increase phosphate excretion

Pseudohypoparathyrodism

- McCune-Albright hereditary osteodystrophy
- High level of PTH as the receptors are not responding to PTH
- Hyperplastic parathyroid glands
- Bone changes consistent with hyperparathyroidism
- Hypocalcaemia
- PTH receptor abnormality; kidneys are resistant to PTH opportunity
- No response to the exogenous hormone
- Brachydactyly, low intelligence, exostosis

Hyperparathyroidism

Bones (fractures), stones, groans (GI) and psychic moans

- **Primary** — Adenoma/hyperplasia and rarely carcinoma
- **Secondary** — Renal failure, Hypocalcaemia
- **Tertiary** — parathyroid acquire autonomy in secretion of PTH

	Serum Ca	Serum Phos	Serum PTH
Primary	↑	↓	↑
Secondary	normal or ↓	↑	↑
Tertiary	↑	↑	↑

Generalized osteopaenia
Acro-osteolysis - erosion of terminal phalanx
Treatment — parathyroidectomy if Ca > 2.85mmol/l or T score < -2.5

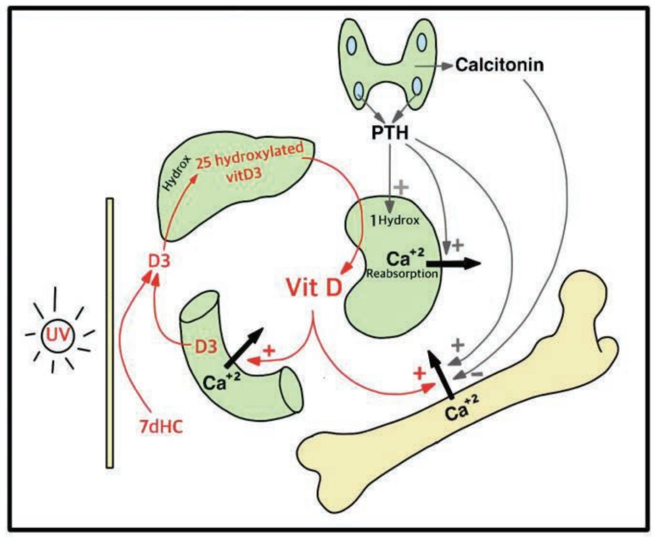
Vitamin D

Natural steroid
From diet and sun
Dehydrocholecalciferol is converted in skin by UV to Cholecalciferol (vitD3),then 25 hydroxylated in the liver and 1 hydroxylated in kidney to become 1, 25(OH) 2 Cholecalciferol(Vit D)
In elderly, renal hydroxylation is reduced

Effects:

- Blood — Increase serum Ca
  Increase phosphate
- Bone — Promotes mineralization of osteoid
  Maintains serum calcium levels by activating osteoclasts for bone resorption

- GI Tract
- Increases intestinal absorption of calcium and phosphate
- Kidney
- Decreases calcium and phosphate excretion



Calcitonin

Produced by Para-follicular C cells of thyroid

Effects:

- Blood Decrease serum Ca and phosphate
- Bone Oppose osteoclastic bone resorption by decreasing number and activity of osteoclasts
- GI Tract
- ? inhibitory effect on intestinal absorption of calcium and phosphate
- Kidney
- Increases calcium and phosphate excretion

Oestrogen

- Inhibits bone resorption and stimulate bone formation
- Increased risk of breast cancer and heart disease
- Decreases risk of endometrial cancer

Thyroxine

- Regulates skeletal growth at physis by stimulating chondrocyte growth, Type X collagen synthesis, ALP activity
- Increase bone resorption and can lead to osteoporosis

Growth hormone

- Increases serum calcium by increase absorption in intestine & Decrease urinary excretion
- Gigantism Over secretion of GH from pituitary adenoma
  Affect proliferative zone of growth plate
  Called acromegaly when physis closed

BONE BLOOD SUPPLY

Three sources of blood supply

- Nutrient artery system (diaphyseal)
  - Enter diaphyseal cortex through nutrient foramen
  - Enter medullary canal, and branches into ascending and descending arteries
  - High pressure
  - Derived from systemic circulation
  - Supply inner 2/3 of bone
- Metaphyseal-epiphyseal system
  - Arises from peri-articular vascular plexus (e.g. geniculate arteries)
- Periosteal system
  - Mostly capillaries supplying outer 1/3rd of mature diaphysis
  - Via muscle attachment
  - Low pressure
  - Dominant in children

Blood flow

- Centrifugal: Inside to outside; Mature bone; Disrupted with reaming
- Centripetal: Outside to inside; Fractured and immature bone

OSSIFICATION/BONE FORMATION

- **Endochondral**: Foetal long bone development, longitudinal growth of physis; Secondary (indirect) fracture healing; Cartilage is replaced by bone
- **Intramembranous**: Direct laying down of bone without cartilage model; Foetal bone development of flat bones & Distraction osteogenesis; Mesenchymal cells differentiate into osteoblasts

Perrin strain theory differentiation of progenitor cells depends on strain at the fracture site

<2%	direct bone formation
2 – 10%	Callus
10 – 100%	fibrous union
>100 %	non-union

Piezoelectric charge shift of fluids through Volkmann canal results in movements of charged particles leading to changes in electric potential

Bone remodels in response to electric charges

Tension side is +ve and stimulates osteoclasts

Compression side is –ve and stimulates osteoblasts

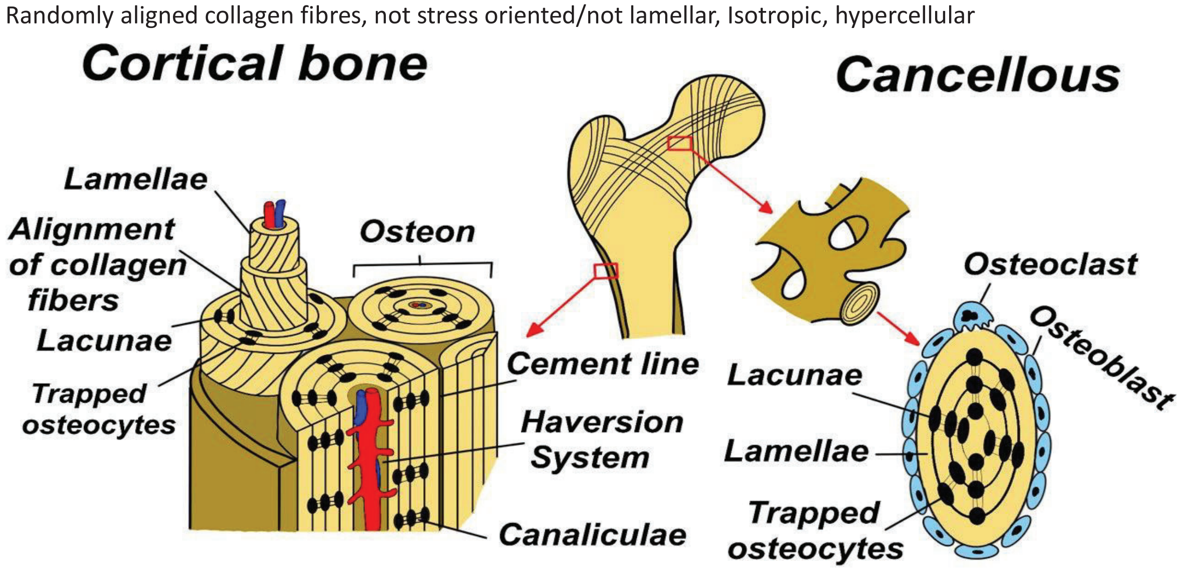
STRUCTURE OF BONE

Lamellar "mature"

- **Cortical:**
    - High young's modulus – 20Gpa
    - 80% of skeleton
    - Slow turnover
    - Osteoblasts deposit bone in concentric thin sheets – lamellar arrangement
    - Haversian system (Osteon)
        - Functional unit of bone
        - Concentric layer of osteocytes surrounded by concentric layers of lamella
        - Lamellae are from collagen produced by osteblasts
        - Haversian canal contains capillaries, venules, nerves and lymphatics
        - Volkmann's canals Run perpendicular to osteons and Haversian canals
          Connect blood vessels between Haversian canals
          Transmit blood vessels from periosteum into bone
        - Outer margin delineated by cement lines
          No osteocytes
          Not connected by collagen fibers – weak area for fracture propagation

Cancellous (trabecular)

- Lower young's modulus - 20 times less stiff than cortical bone (1Gpa)
- Less dense
- Higher turnover rate compared to cortical
- Parallel interconnecting sheets of trabeculae to afford maximum strength for minimum mass
- Haversian system not present
- **Woven "immature"**
  Embryo and fracture callus, or pathologic – tumor, OI, Paget's
  Randomly aligned collagen fibres, not stress oriented/not lamellar, Isotropic, hypercellular



BONE GRAFT

Material that assists and supports bone healing through its mechanical and or its biological properties

Indications structural stability Bone loss
Enhance fracture healing non-union

Classification according to qualities

- **Osteoconductive**
    - Provides a three-dimensional scaffold for new bone to grow on e.g. cancellous bone graft
- **Osteoinductive**
    - Contains biological factors that stimulate bone growth and increase differentiation of undifferentiated mesenchymal cells into bone forming cells such as:
      Bone Morphogenetic Protein (BMP)
      Transforming growth factor beta (TGF-B) e.g. Allomatrix
- **Osteogenic**
    - Contains live mesenchymal cells, osteoblasts, and osteocytes cells that produce bone

Classification according to source

Autograft

- Harvested from same individual
- Gold standard
- Taken with osteotome not saw to avoid thermal necrosis
  Bone graft harvesting system (Synthes) Reamer Irrigator Aspirator
- Taking eccentrically too much bone can produce a stress fracture
- Cortical, cancellous, or Cortico-cancellous e.g. Fresh autograft or bone marrow aspirate
- Vascularized autograft best for irradiated bone and large defects
  Free fibula strut graft (peroneal artery) useful for diaphyseal reconstruction
  Free iliac crest (deep circumflex iliac A) useful for metaphyseal reconstruction
  Distal radius for scaphoid fractures

<u>Advantages</u>

- Osteoconductive, osteoinductive & osteogenic
- Sterile
- Rapid incorporation via creeping substitution
- No risk of disease transmission
- Not immunogenic

<u>Disadvantages</u>

- Donor site morbidity (scar , haematoma , infection , pain)
- Limited volume

Allograft

- Harvested from the same species
- Fresh allograft - osteoconductive & osteoinductive because BMP are preserved

<u>Advantages</u>

- More Volume
- No donor site morbidity

<u>Disadvantages</u>

- Highest risk of disease transmission and immunogenicity

Allografts are mainly processed and stored using two different methods:

Fresh frozen BMP preserved, femoral heads
Less antigenic and still preserves biomechanical properties
Problems with storage, as they require cold temperature

Freeze dried osteoconductive, least immunogenicity, No BMP
Can be stored at room temperature
Screened for HIV, HBV, HCV, HTLV-1, syphilis
Produced by the removal of minerals from cortical bone
Osteoinductive - Contain collagen, BMP 2 & 7, (TGF-B), residual calcium
No mesenchymal cells
Poor mechanical properties

DBM Demineralized bone matrix
Highly processed allograft derivative (Upto 40% mineral content removed by acid wash)
Inferior structural integrity and poor mechanical properties
Osteoconductive and inductive (due to presence of remaining growth factors)

Bone substitute

Synthetic, inorganic or biologically organic combination which is used instead of autograft or allograft for treating bone defects

It could be ceramics (HA, TCP, Calcium sulphate) or growth factors (DBM, BMP 2, 7) or composite (Collagen with

Ideal bone substitute

- Biocompatible - not evoke any adverse inflammatory response
- Osteoconductive, osteoinductive and osteogenic
- Resorbable
- Easily moulded into bone defect within a short setting time
- Thermally nonconductive, sterilizable
- Radiolucent
- Readily available at reasonable cost

Fastest to slowest resorption - Ca sulphate - tricalcium phosphate (TCP) - Ca Hydroxyapatite

- Allomatrix DBM putty with calcium sulphate carrier
- ChronOS (Synthes) Resorbs faster than bone growth occurs but very high compressive strength
  Resorbed in 4-12 weeks
  Increased rate of serous drainage at surgical site
  Ineffective in the treatment of non-union
  Osteoconductive - Used to fill non weight bearing bone defects
  Powder/pellet/putty
  Mix with blood to form cohesive mixture that is easy to handle
- Cerement Calcium Sulphate & Ca Hydroxyapatite
  Provides filler and structural support

Xenograft

Graft taken from another species, not used as high risk of immungenicity

Graft Incorporation

Process of envelopment and interdigitation of the donor bone tissue with new bone deposited by the recipient (Urist)

Primary stage **Inflammation** surrounded by haematoma – platelets attract macrophages & fibroblasts (**chemotaxis**)
Osteoblasts **differentiation**

Secondary stage	**Creeping substitution** and **revascularization – osteoinduction – conduction - remodelling** Osteoclasts remove dead bone and ostoblasts lay down new osteoid on dead trabeculae Remodeling by osteoclasts
Cancellous Graft	Incorporates via **CREEPING SUBSITUTION** simultaneous process in which osteoclast reabsorbs graft and osteoblast lay down new bone
Cortical Graft	Incorporates via **CUTTING CONES** in which the graft is reabsorbed first before new bone is laid down, sow process

How to set up bone bank?

Complex process consists of

- Donor selection
- Donor Consenting from patient if alive or next of kin if dead
  Also to consent for Testing for Hep B, C & HIV and access to medical records
- Donor Screening exclude those at high risk of infection , malignancy , inflammatory conditions
- Graft Haversting
- Graft preparation / cleansing
  - Physical debridement
  - Pulse lavage or ultrasonification
  - Alcohol soaks to denature proteins and decrease bacterial load
  - Antibiotic soak to further decrease the bacterial load
  - Sterilization (Gamma radiation)
- Graft Storage - 20 for 1 year
  -70 for 5 years
- Graft Distribution

FRACTURE HEALING

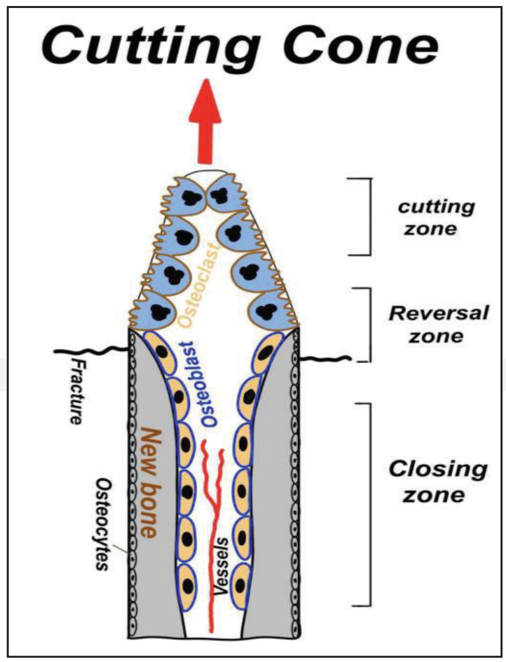
The diamond concept by **Giannoudis (2007) –** bone regeneration requires presence and utilization of growth factors (osteoinduction), scaffolding (osteoconduction), mesenchymal stem cells (osteogenesis), and mechanical environment (vascular status)

Newman, Elliot (BJJ 2016) – Unified theory of bone healing and non-union (BHN theory)
Based on biological + mechanical environment
Bone healing units respond to – Wolff's law, Perren's strain theory, and Frost's concept of mechanostat

Primary / direct

- With absolute stability at physiological load compression plating or lag screws
- Strain < 2% < 5 MicroM gap
  Any more will increase tension and disrupt fracture haling-need
  Compression to achieve lesser strain (Perren's strain theory)
- No callus
- **Cutting cone**

Cutting zone Osteoclasts cross fracture gap to resorb bone & leave path for blood vessels & osteoblasts
Reversal zone Vascular bundle forms Haversian system
Closing zone Osteoblasts migration to form mature mineralized Haversian bone



Secondary / indirect
With non-rigid fixation
Braces/plasters, IM nail, Ex fix, Bridge plate
Callus formation - Endochondral ossification between bone ends
Relative stability (Strain 2 – 10%)
Stages

- Haemostasis Haematoma formation – platelets – coagulation - fibrin clot
- Inflammation 0 -1 weeks
  Neutrophil – produces Cytokines
  Osteoblasts
  Fibroblasts – collagen
  Osteoclasts (resorp bone ends)
  Macrophage (remove debris)
- Repair Soft callus 2 - 4 weeks
  Type II & III collagen
  Hard callus (woven bone) 1 - 4 months
  Type I collagen
- Remodelling Takes months to years
  Disorganised woven bone mature into organised stress orientated lamellar bone

Biology of bone healing

	Depends on Wolff law, piezoelectric charges and endocrine factors
	Facilitated by cutting cones which remove woven bone and lay down Haversian canals
Wolff's law	bone remodels in response to mechanical stresses
	Julius Wolf, 19th Century German Anatomist / Surgeon
Stability	stable fracture will not lose position when managed by simple conservative method
	Ability to withstand stress of everyday activity

Growth factors (cytokines)

- BMP osteoinductive - lead to bone formation
  Activates mesenchymal cells to transform into osteoblasts
  Belongs to the TGF family
  - 2 Osteogenic
    Used in open tibia fracture and spine fusion
    Improves rotator cuff healing
    Adjunct to decompression in AVN
  - 3 antagonizes activity of BMP-2
    Not osteoinductive
  - 4&6 osteogenic
  - 7 osteogenic
    Used for long bone non-union
  - 9 osteogenic
  - 12 improve rotator cuff healing
- **TGF-B** Transforming growth factor Beta
  Produced by platelets
  Stimulates production of Type II collagen and proteoglycans
- **IGF** Insulin-like growth factor
  Produced by platelets
  Most abundant growth factor in bone
  Directs bone healing
  Stimulate osteoblasts & chondroblasts
- **PDGF** signals inflammatory cells to migrate to fracture site
- **IL-1** Produced by macrophage
  Part of inflammatory cascade in RA that lead to joint damage
  Antagonists of IL-1 used for treatment of RA (Anakinra)
  Activates osteoclasts and causes osteolysis
  Increased in OA and associated with disc damage
- **IL-6** Produced by macrophage
  Causes osteolysis
  Highest correlation with peri-prosthetic infection
  Activates osteoclasts in multiple myeloma
  Increased in OA
- **IL-10** Inhibits osteoclast formation
  Improves patella tendon healing
- **FGF** Fibroblast Growth Factor
- **TNF** Tumour Necrosis Factor
- **Corticosteroids** decrease GI absorption of Ca and decrease renal reabsorption
  Inhibit osteoblasts
  Can lead to secondary hyperparathyroidism

NON-UNION

FDA definition: fracture that is at least 9 months old and has not shown any progressive signs of healing for 3 consecutive months

More simply, any fracture that shows no possibility of healing without further intervention

Clinical union Absence of tenderness, abnormal motion & pain on loading

Radiological union bridging bone on 3 out of 4 cortices

Delayed union some progression but less than anticipated for the particular bone

Factors affecting fracture healing

- **Local**
  - Soft tissue trauma, Bone loss, infection
  - Type of bone (distal radius 6 weeks, tibia 3 months), displacement
  - Comminution (compromise of blood supply to intercalary segment)
  - Inadequate stabilization - Mechanical issues of fracture fixation method and application
- **Systemic**
  - DM (decreased cellularity of fracture callus)
  - Nutrition (Vit D, Protein)
  - Head injury (enhances healing)
  - Smoking inhibits growth of new blood vessels as bone is remodelled
    - Nicotine increase aggregation of platelets
    - CO displaces O2 from Hb resulting in lower oxygen tension in tissues
    - Urine dipstick Cotinine testing
  - **Medications** Bisphosphonates, Quinolones, Steroids, NSAIDS

(Courtesy of L Prakash)

Types of non-union

- Hypertrophic
  - Biology normal
  - No need for bone graft
  - Stability problem
- Atrophic
  - Inadequate blood supply
  - Sclerotic edges
- Infected – always rule out as a cause

Treatment

Tibia Dynamisation

Exchange nailing to bigger nail, fibula osteotomy not required

Reaming generates autograft

Exogen Low intensity pulsed ultrasound (LIPUS) accelerates fracture healing

Stimulates chondroblasts & osteoblasts, Enhances blood flow

Application for 20 minutes a day

Has NICE approval in UK for treatment of non-union (after 9 months) of long bones

Infected non-union Radical surgical debridement of infected/non-viable bone ends

Bony stabilization

Dead space management - **Masquelet technique**

Debridement followed by cement spacer to prevent fibrous ingrowth whilst allowing membrane to develop which can be filled later with bone graft

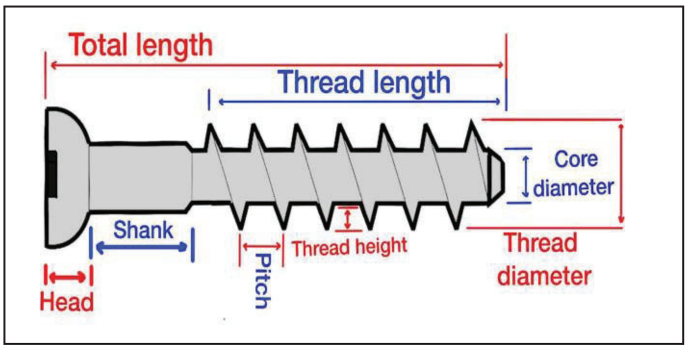
Soft tissue care by VAC

SCREW

Device to convert rotational forces into linear movement
Working length of screw = length of bone traversed by screw

Parts of a screw

- Head Attachment for screw driver that helps to arrest forward motion and allows compression through a dynamic compression plate
  Has conical part for countersinking or flat
  Hexagonal - avoids slippage and better torque spread across 6 points
  Star
  Cross



- Run out Transitional area between head and thread – weakest part of the screw
  Allow counter sink
- Shaft Dictates bending and rotational strength
- Thread Determine outer diameter
  Deeper thread – the greater resistance to pull-out
  Outer diameter dictates pull-out strength
  Thread depth = (outer - core diameter)/2
- Pitch Distance between threads, cortical screw has finer pitch than cancellous
- Tip Blunt or self-tapping
- Flute Remove bone debris in self tapping screws
  Sharp in self-drilling, requires no pilot hole

Diameter of core determines drill used

7.3mm (cannulated)	5.0
6.5mm (cancellous)	3.2
5.0mm (locking)	4.3
4.5mm cortical screw	3.2
4.0mm (cancellous)	2.5
4.0mm (locking)	3.2
3.5mm cortical screw	2.5
2.7mm cortical screw	2.0
2.0mm cortical screw	1.5
1.5mm cortical screw	1.1

Lead distance advanced in 1 revolution
Torsional rigidity is proportional to 4^{th} power core diameter
Bending rigidity proportional to 4^{th} power of radius of core

How to maximize pullout strength

- Larger outer/inner core diameter ratio (thread depth)
  - Increase outer diameter
  - Decrease inner diameter
- More threads
  - Smaller pitch
  - Longer screw
- Locking screw
- More threads

Types of screws

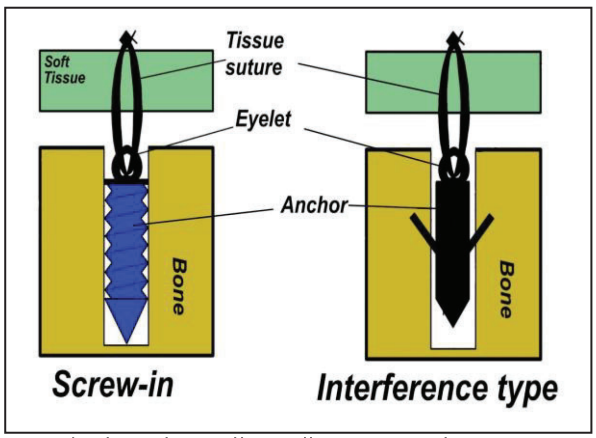
<u>- Cortical</u>

<u>- Cancellous</u> don't remove bone, but pushes it away
Spiral tip creates own thread

<u>- Bolt</u> For rotational stability
Wider inner diameter
Small thread, doesn't need pull out strength

<u>- Suture anchor</u> where inadequate soft tissue stock makes it impossible to perform a direct soft tissue-to-soft tissue repair
Types **Screw in**
Interference


(Courtesy of M Elgendy)



<u>- Reverse cutting</u> easier to remove

<u>- Locking</u> requires resistance to bending and relatively smaller pull-out strength
Bicortical more rigid axially and rotationally


(Courtesy of M Zekrey)

Herbert screw Differential pitch with coarse pitch distally (advancing more than proximal end of screw with each turn)
Cannulated Lower thread depth results in decreased pull out strength
Self-tapping
Self-drilling
Double-pitch
Headless


(Courtesy of N Walsh)

Mechanisms of screw function

Positional: Syndesmotic screw
Compression (lag)

Lagging techniques

- **By technique**

  Threaded into opposite cortex, and slides through over-drilled glide hole (outer diameter of screw) in near cortex

  For screw to produce interfragmentary compression thread must purchase the far cortex only
- **By design**

  Same can be achieved with partially threaded screw

  Positioned 90^0 to fracture

Countersink

To increase surface area to reduce stress (stress=force/area)
Only on cortical bone
Countersinking cancellous bone will leave soft bone which less able to resist stress – use washer
Ratio of length of fracture /diameter of bone should be at least 2:1
Lag screw is weak against shear and bending forces – add neutralization plate
Washer acts as 1-hole plate to improve compression, spreads load applied by head on underlying cortex preventing screw head from breaking through thin cortex

IM NAIL

Load sharing device
Can be load bearing if there is significant bone loss
Load sharing/bearing is a concept not a device

What affects bending and torsional rigidity (moment of inertia) of nails?

1. Material properties
   Titanium Vs Stainless steel
2. Structural properties
   Bending rigidity proportional to 4th power of nail diameter (cylindrical structure)
   Bending rigidity of hollow nail is proportional to 4th power of (outer radius – inner Radius)
3. Working length
   Length of bone between most proximal and most distal fixation points
   Reaming reduces working length of nail by jamming bigger diameter nail at isthmus – stiffer construct
   Fragmented fracture – increased working length – partial weight bearing
   Transverse fracture – short working length – FWB
   - Slotted nails
     Allow compression by isthmus and tighter fit
     Reduced nail mass will reduce ability to resist forces and rigidity reduced
     Slot disrupts hoop stresses and reduces rigidity and resistance to torque
   - Hollow nails
     More flexible to anatomical variations than solid nails
     Reduced rigidity due to reduced mass compensated by reaming to use larger nail
     Increase risk of bacterial infection persistence

End caps prevent bone ingrowth into nail
Extend nail height if it is over inserted

Generations of femoral nails

1st	Antegrade	
2nd	2 recon screws, proximal diameter 13 mm	
3rd	PFN /Gamma/IMHS	Sliding screws
	Wider proximally, 16 mm	
4th	Compression of fracture - InterTAN	

Interlocking screws provide axial and rotational and angular stability
Increased radiation exposure
Holes weaken nail

Coremus™ IM Nail Extractor System

EXTERNAL FIXATOR

- **Types**
  Uniplanar Anisotropic behaviour
  Biplanar used for unstable fractures
  Modular Hoffman, Surgeon from Geneva
  Hybrid
  Ring isotropic behaviour
  Static (Ilizarov), Dynamic (TSF)
  Bridging (spanning)
- **Indications**
  intra-articular fractures with metaphyseal comminution
  Open fractures
  Closed fractures with soft tissue damage
  Can be used for fractures with bone loss and osteomyelitis

Principles
Avoid placing pins inside zone of injury
Avoid bone necrosis, pilot drill hole cooling with saline irrigation, stop-start technique
Safe corridors to avoid NV injury, Circular frame require safe corridor on both sides of bone
Increase rigidity as below
Convert to ORIF before 2 weeks to reduce risk of infection

Factors that increase rigidity

1. Most important factor is **anatomical reduction**
2. 2nd most important factor is diameter of pins - be aware that if > 1/3 bone diameter can cause fracture
3. Decreased bone to rod distance to reduce near cortex stress - allow 2 inches for dressing change
4. Reduce working length of pins
5. Placement of central pins closer to fracture (near-near), but outside the zone of injury
6. Placement of peripheral pins farther from fracture (far-far)
7. Addition of pins and bars in same or another plane
8. HA coating of pins
9. Placing pins in multiple planes

Rigidity of ring & wire fixator

1. Increase diameter of wire, 1.8 for adult and 1.5 for child
2. Increase tension of wires, 130N for adult and 110N for child
3. 1 wire above ring and another below to prevent ring deformation
4. Increase crossing angle, Ideally 90^0
5. Increase number of wires and/or number of rings
6. Opposing olive wires, Prevent slippage of wires
7. Decrease diameter of ring
8. Use slotted bolts


(Courtesy of J Hanniball)

PLATES

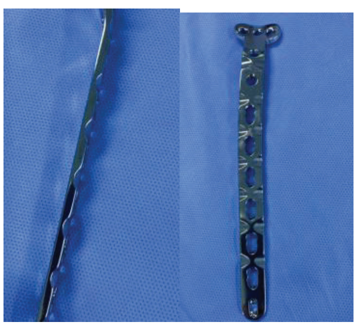
Definition: Stripe of biomaterial containing holes that accept screws, pegs which may be conventional or locking

Types

- **Tension band** Applied to tension side of bone to resist gaping
  Bone strong in compression so better to apply plate on tension side of bone

- **Compression** By prebending plate (concave side to bone) to prevent gapping on opposite side of fracture
  Placing screws eccentrically in combi-hole to slide down slope on axilla side of oblique fracture to slide with compression
  Oval Vs circular holes
  Better for simple fracture
  Standard plates rely on friction between plate & bone
  - Broad DCP has advantage of multiplanar screw holes to prevent stress fractures
  - LC-DCP preserves periosteal blood supply by promoting low contact with periosteal surface


(Courtesy of M Elgendy)


(Courtesy of M Elgendy)

- **Locking** Threaded screw hole that allows screw to lock into plate and perform as fixed-angle device
  Acts as internal external-fixator
  Useful for Osteoporotic bone
  To bridge comminuted fractures
  Can use unicortical locking screws in presence of other obstructing irremovable metalwork
  Better pull out strength of the whole construct
  Preserve periosteal blood supply (sits off bone)
  Expensive


(Courtesy of J Hanniball)

  Cold welding – difficult to remove screws
  Stability of construct determined by screw-plate interface rather than bone-plate interface
  Uses thicker screws – increased core diameter and lower pitch (as stiffness of construct depends on bending stiffness of screw and not on their pull-out strength)

Stability increases with

- bicortical locking screws
- Increased number of screws
- Screw divergence from screw hole < 5 deg (cross-threading reduces overall bending stiffness by 30 - 60%)
- Longer plate

- **Bridging** provides relative stability, relative length and alignment
  Preserves blood supply to fracture fragments as fracture site is undisturbed
  Long working length
  Better for comminuted fractures
  Secondary bone union – don't put screws across bridged part of fracture
- **Neutralisation** Plate to neutralise rotational, bending and shearing forces
  Lag screws provide absolute stability
- **Buttress/anti-glide**
  Resists shear forces during axial loading
  Plate must conform to bone contour
  Intra-articular – buttress
  Diaphysis – anti-glide

Working length distance between two screws closest to fracture
Unsupported section on both sides of fracture
Decrease working length to decrease strain across fracture

Use 6 – 8 cortices on each fracture side to neutralize torsional forces

Rigidity (bending stiffness) is proportional to cube value (3rd power) of thickness (rectangular structure)

TENSION BAND

Device that transform distraction tensile forces into compression forces by translating center of rotation of a fracture from compression side to tensile side

Pre-requisites Need to neutralize rotational forces with K wires/screws
Implant (plate or wire) strong enough to withstand tensile forces should be used on tensile surface
Need strong opposite cortex to bear compressive load
Intact buttress of opposite cortex - Fracture should not be comminuted (as it will lead to collapse)

Devices K-wires and cerclage wire
Plate

Sites olecranon, patella, medial malleolus, GT of humerus, 5th MT
Tension-band plating of femur (on lateral aspect)
Can be used for small fractures that can't be fixed with other techniques

In patella quadriceps muscle and patellar tendon exert tension on anterior aspect
Cerclage wire resists tensile forces ,and energy transferred to posterior articular aspect as compressive force

ARTICULAR CARTILAGE

Avascular, aneural, alymphatic and not immunogenic
Nourished by synovial fluid and underlying cancellous bone, mainly by diffusion
Thickness 5 – 7 mm in weight bearing joints
Has very low coefficient of friction 0.0002, 30 times smoother than modern bearing surfaces
Anisotropic
Viscoelastic - creep and stress relaxation when loaded
Physiologic loading and hydrostatic pressure changes are chondroprotective

Functions

1) Shock absorption
2) Decrease friction
3) Distributes load

- **Components** Cells 5% and extracellular Matrix 75%

Cells

Chondrocytes from mesenchymal stem cells designated towards cartilaginous lineage
Produce extracellular matrix (collagen and PG)
Loss and increased in size with OA & aging

Extracellular Matrix

- Water: 65-80% of weight
- Collagen fibers: Most abundant is **type II**
  Provides tensile strength
- Proteoglycans Provides compression strength
  Provide osmotic properties due to its negative charges (hold water) to resist compression
  Aggrecan: largest in size and most abundant by weight
  Possesses > 100 Chondroitin sulfate & keratin sulfate chains
  Interact with HA to form large proteoglycan aggregates via link proteins
  Elastin

In arthritis Subchondral oedema, sclerosis, eburnation, cysts
Increased water content due to damaged cartilage matrix (reduced cross-links).
Reduction in PG concentration and increased degeneration
Eburnation Pathological change where subchondral bone is converted to dense, smooth surface that resembles ivory

Structure

It has a layered structure that shows decreased water and collagen and increase in proteoglycans from superficial to deep

- **Superficial tangential** (10-20% thickness)
  - Thinnest layer
  - Highest water and collagen content
  - Almost entirely collagen fibres, lie horizontally parallel to joint surface to resist shear stress
  - Flat chondrocytes parallel with lamina splendens
  - Covered with lubricin
  - Resists shear
- **Intermediate "Transition zone"** (40-60% thickness)
  - Thickest layer
  - Collagen fibers obliquely oriented
  - More rounded chondrocytes
  - Represent transition of shear to compression loading
- **Deep basal "Radial zone"** (30% thickness)
  - Collagen fibres lie longitudinally perpendicular to joint surface to resist compression
  - Rounded spherical and more concentrated chondrocytes
  - Arranged in columns
- **Calcified cartilage** anchors the cartilage to the bone
- **Tidemark** Acellular boundary between un-calcified & calcified cartilage
  - Diffusion barrier
  - Anchor by HA crystals to the subchondral bone
  - Damage superficial to it has poor potential for healing
  - Damage that violates this layer heals with fibrocartilage from undifferentiated marrow mesenchymal stem cells – theory behind abrasion chondroplasty

As you get deeper, the concentration of water and collagen decreases and the concentration of proteoglycan increase

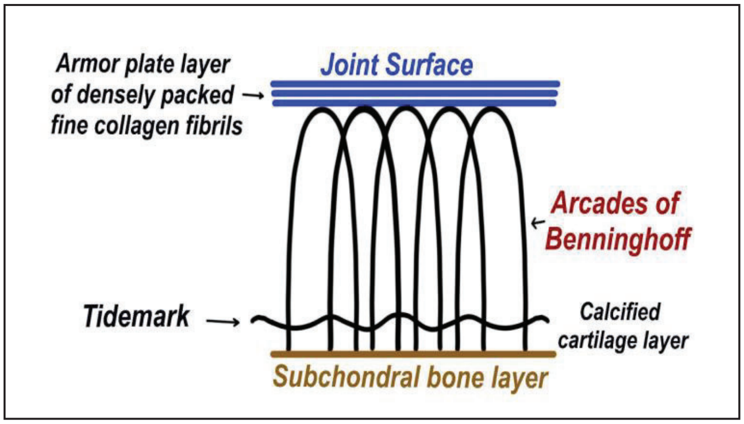
Differentiation based on environment

Higher friction and less elastic and doesn't absorb water

Repair occurs by type 1 collagen

Arcade of Benninghoff:

A three-dimensional structure shows arrangement of collagen fibres into arcades through the articular cartilage, giving rise to the appearance of the three zones in cross-sectional studies. The collagen fibres are anchored to tidemarks deeply, travel perpendicular through the radial basal zone then it curves obliquely in the transition zone.

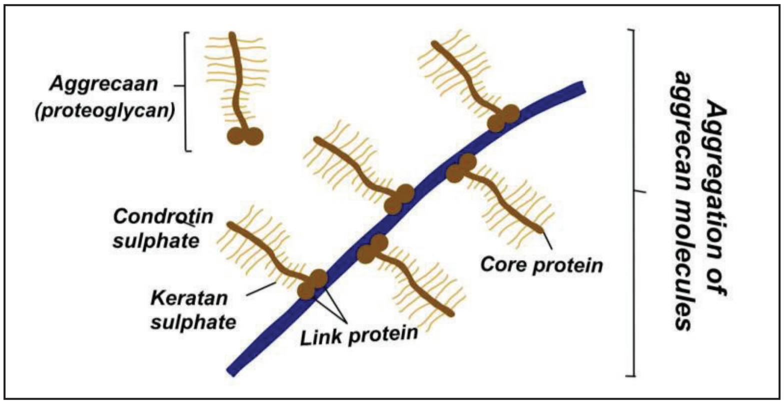


Proteoglycans

Hydrophilic molecules responsible for the water content of articular cartilage.

In arthritis, there is weakness of type II collagen meshwork and failure to resist the swelling pressure of the existing proteoglycans.

- composed of **Hyaluronic acid back bone**
  Link proteins
  Link protein connects to **protein core**
  Core protein contained Keratine Sulphate, Chondroitin
  Sulphate and other proteins (increased CS: KS ratio in OA)
  The last 3 are called **aggrecan**
  PG provides compressive strength by trapping water



Types of cartilage in body

Physeal	Growth plate
Fibrocartilage	Tendon/lig insertion into bone, volar plate
Elastic cartilage	Trachea, auricle, epiglottis
Hyaline	Articular
Fibro-elastic	Meniscus

SYNOVIUM

Function to produce Synovial fluid
Ultra-filtrate (dialysate) of plasma
Nutrition to articular cartilage
Lubricate articular cartilage

- **Contents**
  Contains all component of blood plasma except cellular elements and coagulation factors
  Hyaluronic acid
  Lubricin
- **Cells**

Type A	Synoviocyte	phagocyte, activated in RA
Type B	Synoviocyte	produce synovial fluid
Type C	Synoviocyte	precursor to A & B

- **Fluid**

Normal	WBC < 200/ml, < 25% neutrophils Equal glucose & protein to serum Straw colour, clear
Inflammation	WBC 2000-50 000/ml, < 50% neutrophils Glucose 25 mg/ml lower than serum Yellow-green, cloudy
Infection	WBC > 50 000/ml, > 80% neutrophils Glucose 25 mg/ml lower than serum Or a synovial / serum glucose ratio of < 0.5 Pus

COLLAGEN

Structural protein
Most common protein in body (30 % of total protein content)
Produced by fibroblasts and chondroblasts – procollagen (intra-cellular) – tropocollagen (extra-cellular)
The **triple helical structure** provides tensile strength - 3 polypeptide α chains (2 α1 and 1 α2)
While the **quartile staggered array** affords some compressive strength
Holes (zone existing between ends of fibrils) and pores (zone existing between sides of fibrils of collagen)
Vitamin C contribute – deficient in scurvy
Amino acids are Glycine, Proline & Lysine
Proline and Lysin are hydroxylated to hydroxyproline and hydroxylysine
One end of helix called N-terminal and other C-terminal - used as markers of collagen turnover

Types	I	90% of collagen in body Bone, tendon, ligaments, annulus, meniscus, cornea & skin Osteogenesis imperfecta, Ehlers Danlos
	II	Articular (Hyaline) cartilage & nucleus pulposus
	III	Skin & blood vessels Proliferative (repair) phase of tendon and ligament healing & soft callus Ehlers Danlos, Dupuytren's
	IV	Basement membrane, lens capsule Renal disease
	V, VI, IX	Articular cartilage
	X	Endochondral ossification Produced in zone of hypertrophy

TENDON & LIGAMENT

Main cell is **fibroblast (Tenocyte)**
Extracellular is mainly **Collagen type 1**

- Tendon — Transmit tensile load from muscle to bone and store energy
- Ligament — Augment static mechanical stability of joints
  Prevent excessive or abnormal movement
  Provide proprioceptive feedback

Both contain water, Prostaglandins, plasma proteins
In comparison to ligaments, **tendons have more collagen** and less elastin and Proteoglycans
More organised collagen
And are less viscoelastic
Collagen in both tendons and ligament decreases with age

Aponeurosis

Fibrous sheet or flat, expanded tendon, giving attachment to muscular fibers and serving as the means of proximal or distal attachment (origin or insertion) of a flat muscle
It sometimes also performs the functions of a fascia for other muscles

Types Paratenon covered — patellar & Achilles
Good vascular supply - heal better
Facilitates gliding

Sheath covered — Hand flexor tendons
Nutrition by diffusion in avascular areas
Vinculae which carry blood supply to only one tendon segment
Prone to adhesion

Layers: paratenon - epitenon - endotenon - fascicles

Morphology of insertion of tendons & ligaments into bone

- **Direct** — 4 zones **Z1** parallel collagen fibers
  Z2 parallel collagen fibers intermeshed with unmineralized fibrocartilage
  Z3 Fibrocartilage become mineralized
  Z4 mineralized fibrocartilage fuses with bone
  E.g. ACL
- **Indirect** — Via Sharpey perforating collagen fibres into periosteum
  E.g. Superficial MCL

Healing

- Hematoma
  Haemostasis – Platelets, Coagulation, fibrin clot
  1 to 15 mins
- Inflammation
  Neutrophils, Macrophages, Angiogenesis
  1- 7 days
- Repair
  Fibroblasts produce type III Collagen (disorganised and weak)
  7-21 days

- Remodelling
  - Type I replace type III Collagen
  - 18 months
  - Weakest at 7- 10 days
  - After 21 days most strength recovered

Early ROM post-repair stimulates collagen formation and promotes orientation + prevents adhesion formation

Kessler repair

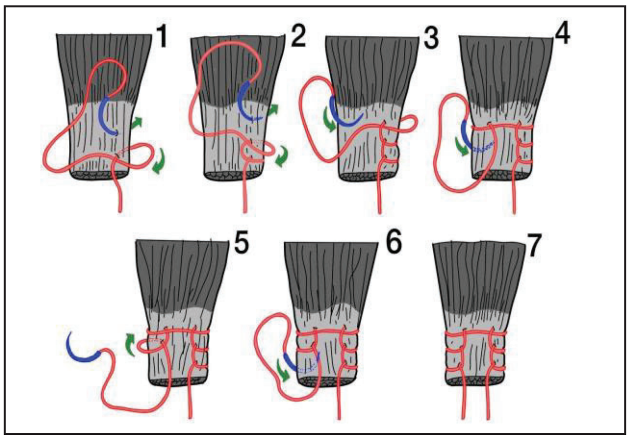
For flexor tendons of hand

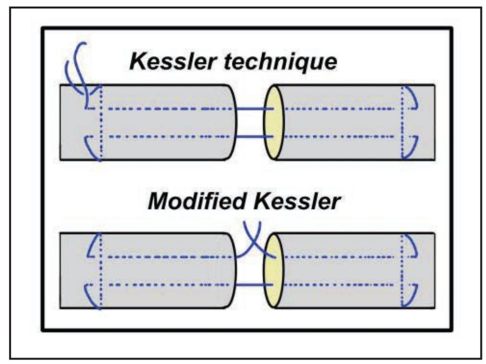
Non-cutting needle

4 strand repair with 4/0 nylon using modified kessler technique (gives 80% repair strength) and 6/0 for epitendious continous sutures (gives 20 % repair strength) prevents adhesions and make gliding smooth

The locking loop accomplished by placing the vertical components of the suture behind the transverse component of the suture relative to the cut tendon end provided greater tensile gap strength

Krackow repair





Dermal patches e.g. Graft jacket
Processed from donated human skin
Serve as framework to support cellular repopulation and vascularization

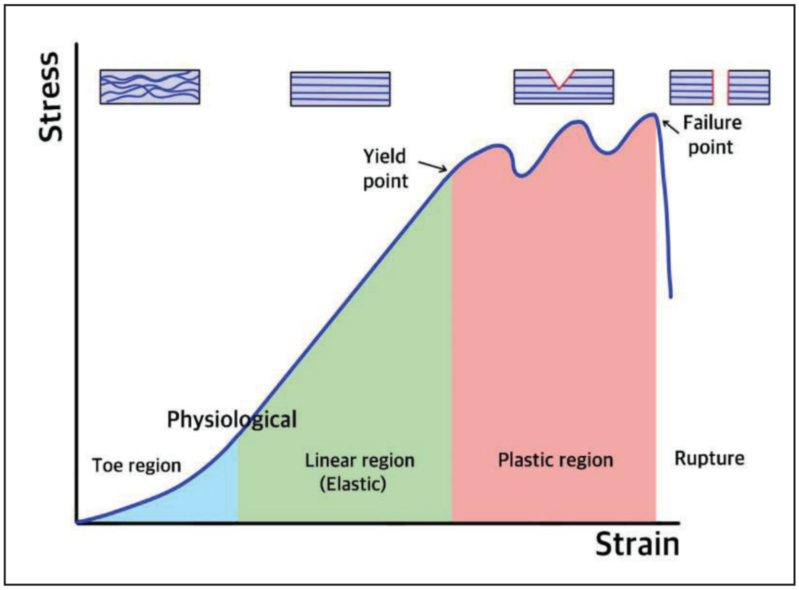
Tendinosis Absence of inflammatory cells - degenerative process
Vascular ingrowth
Hyper-cellularity - Fibroblast hypertrophy, disorganized collagen

Enthesitis inflammation of tendon-bone junction

Stress – strain curve of tendons and ligaments

Called **load – elongation curve**

- Toe region crimped fibrils become aligned parallel along direction of loading
- Linear region elastic Hooke's law
  Steeper than toes region
  Intermediate loads



- Plastic region
- Failure region high loads
  Sequential failure of fibrils gives rise to spikes

Tendons carry higher loads, recruit fibers quickly. Collagen less crimped, therefore have a smaller toe region
Ligaments recruit fibers gradually due to the CRIMP arrangement of collagen elongated toe region.

Ligaments

Function stabilize joints
Propriocepion

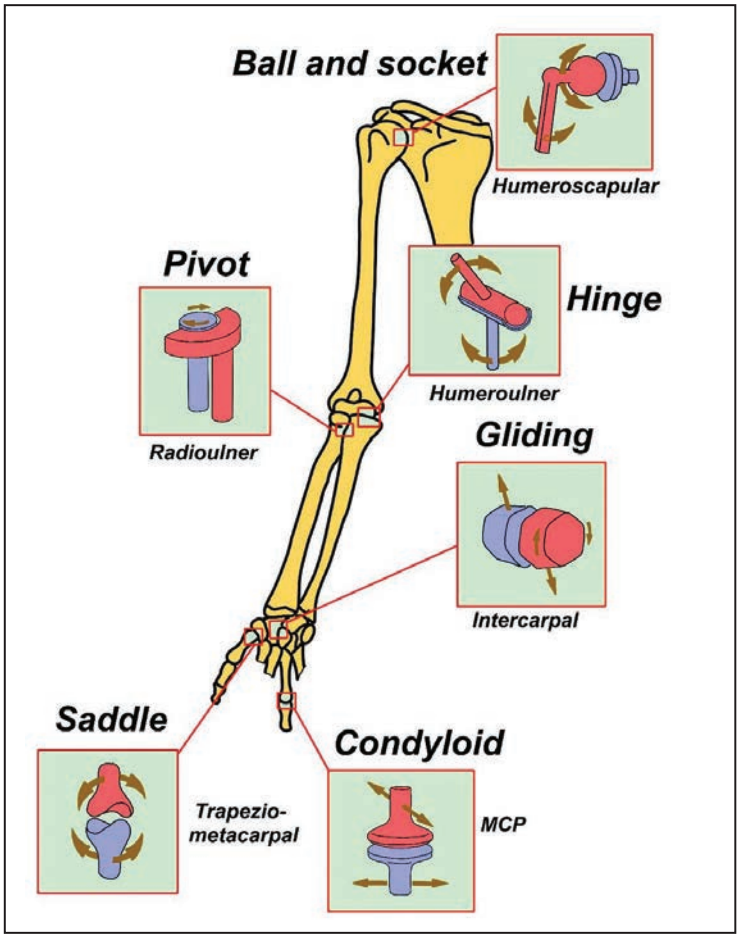
Main cell is fibroblast (20% cellular component)
Type I collagen (80% matrix component)
Contain **more Elastin, PG & water** compared to tendons and **less collagen**
Tensile strength reduced with age and steroids
Blood supply from insertion site

- **Classification of ligament injuries**

Grade 1	strain	Pain	no instability
Grade 2	Partial tear	Pain	some laxity with firm end point
	Bracing - Return to sports 6 weeks		
Grade 3	Complete tear	less pain	no end point
	Bracing, surgery in selected cases		

JOINTS

- **Connection**
  - Fibrous — bones connected by fibrous tissue
    Skull, DRUJ, Distal tibio-fibular
  - Cartilaginous — Bones connected by hyaline or fibro-cartilage
    Intervetebral
- **Geometry**



MUSCLES

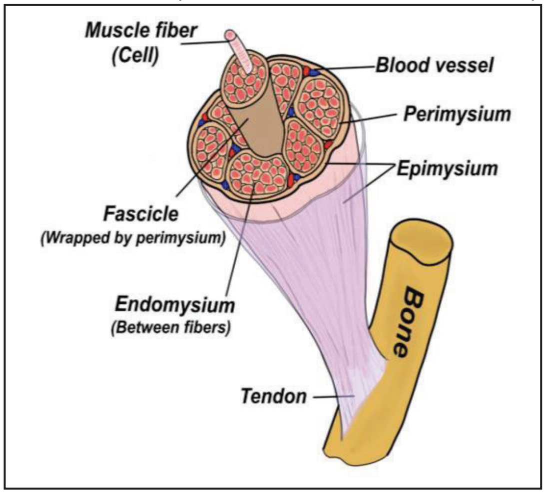
- **Function** Facilitate motion
  Storage - glycogen
  Protect organs
- **Motor unit** Motor neuron + muscle fibers it innervates
  Small unit gives precision control
  Large unit gives less control but greater force

Sarcolemma Muscle cell membrane

Microscopic Structure

Each muscle bundle is covered by **EPIMYSIUM** and contains fascicles which are covered by **PERIMYSIUM** which contains muscle fibers called myofibrils which are covered by **ENDOMYSIUM**.

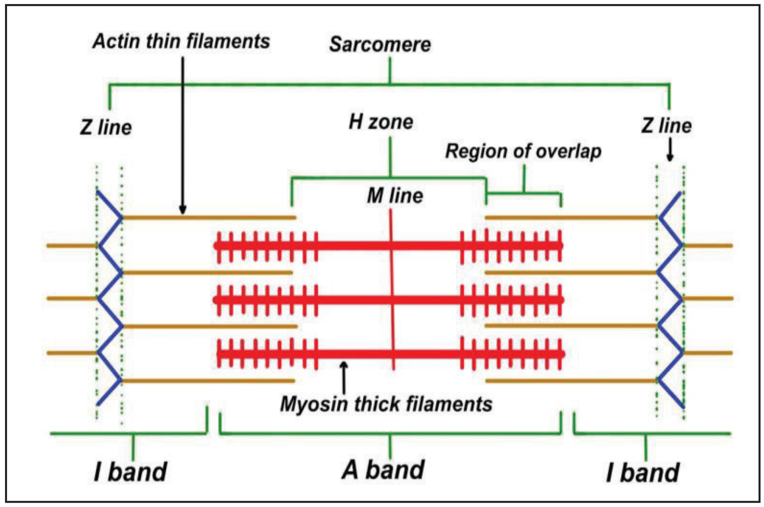
Myofibrils are composed of sarcomeres which in turn contains alternating protein filaments thick filaments are called myosin and thin filaments called actin. Actin has troponin to which Ca binds and tropomyosin which covers the binding sites for the myosin on actin.



Satellite cells within muscle that stays dormant until muscle injury occurs
Responsible for producing new muscle fibres and new satellite cells in response to injury

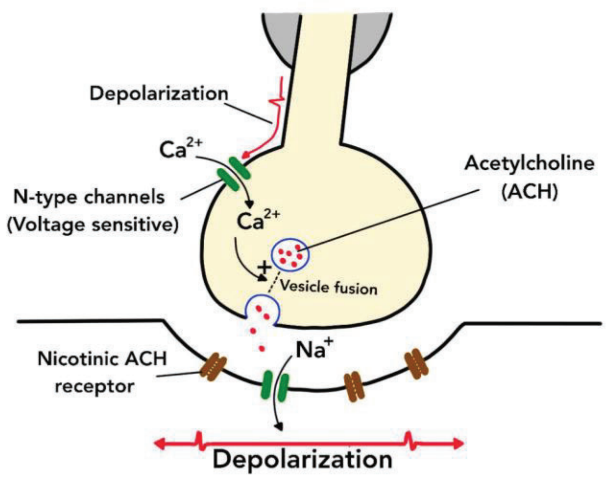
- **Sarcomere** Basic contractile unit
  Measure 2.5 MicroM when relaxed, shorter at myo-tendinous junction
  A Anisotropic band is the thicker Myosin filament anchored to M line
  H zone is myosin only, no overlap, gets shorter with muscle contraction
  I Isotropic band is gap between A bands, Actin filaments only
  Z protein line between sarcomers
  M Myosin line runs through centre of sarcomere, connects Myosin
  Muscle shortening occurs due to movement of actin filament over myosin filament

(Sarcomeres)



Mechanism of Contraction

- Triggered by action potential (AP) through nerve impulse
- Arrival of AP at motor neuron end-plate causes **diffusion of Ca** into the nerve which causes **release of acetylcholine** (ACh) from vesicles into synapse
- ACh attaches to the ACh receptors
- ACh **open Na ion channels** on postsynaptic muscle membrane to let Na in
- Resting muscle fibre has resting potential of −95 mV
- Influx of sodium ions reduces charge
- When end plate potential reaches **threshold voltage of −50 mV** - action potential created
  This causes the **release of Ca** from sarcoplasmic retinaculum through the T-Tubules into the muscle cytoplasm



The neuromuscular junction

- **Ca attaches to Troponin on the Actin filament** and **causes the tropomyosin to move** and exposes the myosin binding sites the myosin heads attach to actin and cause sliding motion using ATP as energy source

- Action potential sweeps down length of fibre as it does in an axon
- This whole process is called **contraction excitation coupling**
- Enzyme acetyl cholinesterase breaks down AC
- Resting potential restored by **outflow of potassium ions**

Myasthenia gravis due to Antibodies that block AC receptors at motor end plates
Botox blocks release of AC from end plate

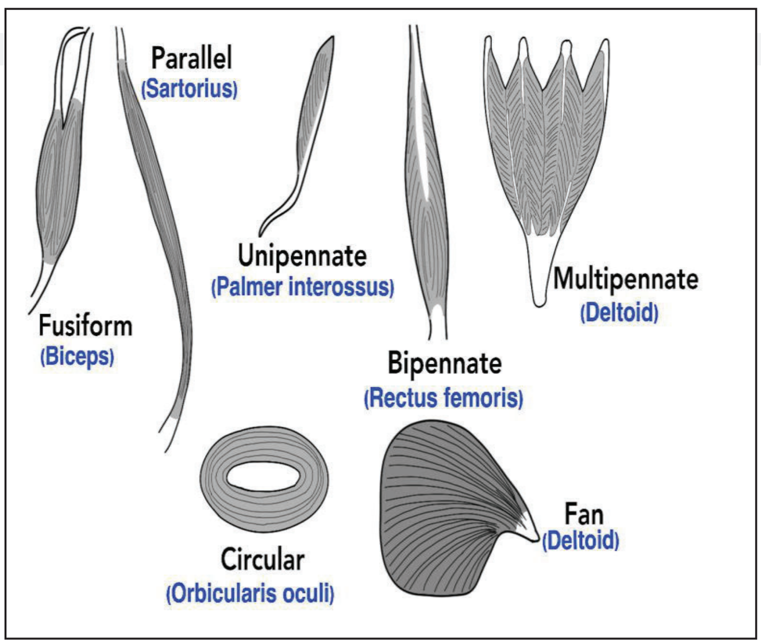
Types of muscle fibers

Affect duration and speed of contraction

- **Type I** Slow twitch (slow red ox)
  Aerobic (oxidative metabolism)
  Numerous mitochondria
  Low strength
  Fatigue resistant
  Endurance activities balance & posture
  Requires O2 - have more vascularity and myoglobin
- **Type II** Fast twitch
  Anaerobic (Glycolytic) - **IIA (oxidative-glycolytic)**, **IIB (mainly glycolytic)**
  High strength
  Sparse mitochondria in IIB
  Fatigable – IIB, intermediate fatigue resistance in IIA

Types of muscle

- **Macroscopic**
  - Parallel Sartorius
  - Fusiform Biceps
  - Fan (triangular) Pec major
  - Pinnate (fascicles attach obliquely to tendon)
    - Uni Palmar interossei
    - Bi Rectus femoris
    - Multi Deltoid
  - Circular
  - Triangular
  - Fusiform



Types of muscle contraction

Force of muscle is proportional to its cross section and fibre size
Overloading leads to muscle fibre hypertrophy
Speed (Amplitude) of contraction is related to length
Work capacity = (force) x (amplitude)

- **Isometric** **length of muscle is constant** while force/resistance is changing
  No joint movement
  Pushing immovable object
- **Isotonic** length changes while **force is constant**
  Moving muscles by moving joints
  Biceps curls using weights
  Muscle shortening – **concentric**
  Muscle lengthening – **eccentric** when external force is greater than force muscle can generate
- **Isokinetic** muscle contraction with **constant speed**
  Best method to maximize strength

Types of muscle exercise
  Closed chain distal end of extremity fixed – squat, pull up
  Open chain distal end of extremity free - leg extension, hamstring curl. Increase JRF

Passive stretch muscle passively lengthen
  Hamstrings while touching toes

Golgi tendon organ Proprioception in muscle
  Monitor tension developed in muscle, stretch receptor
  Prevents damage during excessive force generation
  Stimulation results in reflex relaxation of muscle
  Lies in myotendinous junction

Muscles metabolic systems

- **Anaerobic** Does not use O2
  - ATP Kreb's cycle to generate ATP from glucose and fatty acids
    Adenosine Triphosphate System
    Basis for Creatine Phosphate supplementation
    For intense muscle activity lasting < 20 sec
  - Lactic Hydrolysis of glucose
    Converts carbohydrates into energy
    For intense muscle activity lasting < 20 - 120 sec
- **Aerobic** Longer duration exercises.

Muscle injury

Soreness Due to edema and inflammation
  Raised CK levels

Strain At myo-tendinous junction
  Inflammation followed by fibrosis

Atrophy from disuse or nerve injury
  Fatty infiltration
  Loss of cross sectional area
  Occurs faster in muscles crossing single joint
  Most changes occur during initial days of disuse
  More prominent if immobilization occurs without tension

(Muscle structure and physiology)

Neutrophils are the first cells to appear following acute muscle injury

NERVE

Motor cell body in anterior horn of spinal cord grey matter and sensory cell bodies in dorsal root ganglion

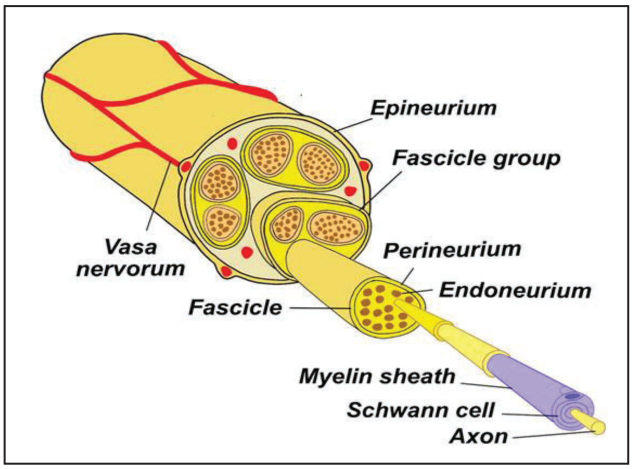
Neuron

Cell body Perikaryon

Dendrites Cytoplasmic extensions from cell body that receives input

<u>Axon</u>

- Conduct electrical signals via action potentials
- **Schwann cells** Myelinate peripheral nerves
  Myelin can regenerate
  Increase velocity of conduction of action potential
- **Glial cells** non-neuronal connective tissue cells that maintain homeostasis, form myelin, and provide protection
  - In CNS Oligodendrocytes
  - In PNS Schwann cells
- Epineurium Surrounds group of fascicles to form peripheral nerve
  Protects against compression
- Perineurium surrounds group of axons to form fascicle
  Protects against stretch
- Endoneurium surrounds individual axons
- Protects against stretch



Blood supply

- **Extrinsic vessels** Segmental vessels run in connective tissue surrounding nerve trunk and form vasa nervorum
- **Intrinsic vessels** Longitudinally oriented capillaries within endoneurium with tight junctions between endothelial lining cells to provide blood nerve barrier

Nerve physiology

Conduction velocity

Faster in

- Myelinated axons (Saltatory conduction is active in unmyelinated and passive in myelinated)
- Larger nerves
- Upper limbs than lower limbs
- Proximal than distal

Reduced in

- hypothermia
- Extremes of age
- demyelinating conditions (compressive pathologies)

Normal resting potential is -70 mv

Na/K ATPase pump pumps Na out & K in

For every 3 Na+ ions pumped out only 2 K+ ions pumped in (creates -ve charge inside relative to outside)

Resting potential Established from unequal distribution of ions on either side of neuron membrane

Action potential Depolarization of cell membrane of neurone resulting in transmission of impulse
Dependent on ATP and O2
Initiated by mechanical stimulus or chemically by neurotransmitter

Nerve Action Potential

Resting membrane potential is - 70 mV due to ionic concentration inside and outside of the cell

- The resting membrane potential is maintained by:
    - layer lipid membrane that is impermeable to water soluble ions
    - Selectively permeable ion channels
    - Active Na+/K+ exchange pump
    - Donnan equilibrium: due to large charged organic molecules that can not cross the lipid bilayer

Threshold stimulus: minimum stimulus intensity needed to produce an action potential

Sub-threshold stimulus: stimulus intensity that will not produce action potential propagation

Summation potential: repetitive subthreshold stimuli may be sufficient to initiate response

1. A stimulus strong enough to cross the **threshold voltage of -55 mv** starts an action potential propagation
2. **Voltage gated Na channels open** and Na rush in
3. When reaches the highest point that is + 30 mV "reversal of membrane polarity", Na channels shut and **voltage gated K channels open**, that leads to loss of positive charge and repolarisation starts.
4. K channels are slow to shut and therefore the nerve goes in to hyperpolarised state "more negative"
5. The Na-K ATPase pump then resotre it to the resting membrane potential of -70mv

- **Absolute refractory period**

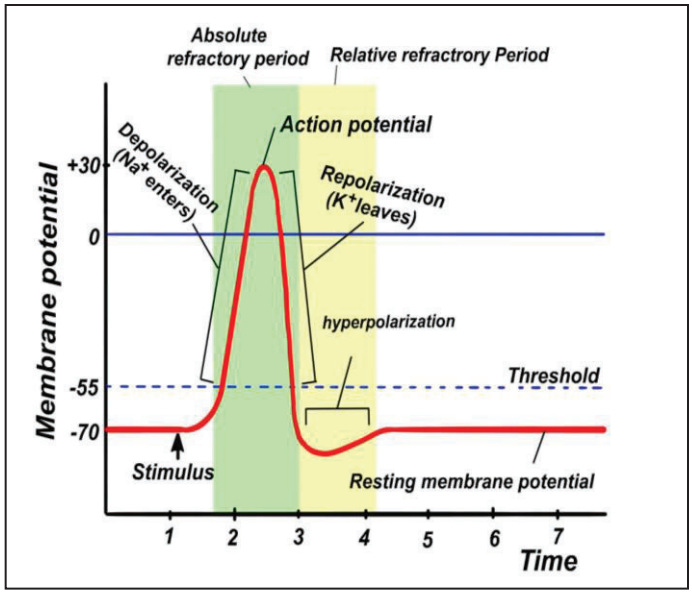
This is the time during which another stimulus given to the neuron (no matter how strong) will not lead to a second action potential. The period "1-2 m sec" from the initiation of the action potential to immediately after the peak is referred to as the absolute refractory period (ARP).

Opening of the Na+ channels, spontaneously and rapidly leads to their inactivation. At the peak of the action potential, all Na+ channels become inactivated. It cannot be immediately re-opened again. Recovery from inactivation is a time- and voltage-dependent process, and full recovery usually takes about 3-4 m sec. Therefore, it takes about 3-4 m sec for all Na+ channels to come out of inactivation in order to be ready for activation (opening) again.

➢ **Relative refractory Period**

The period during which a stronger than normal stimulus is needed in order to elicit an action potential is referred to as the relative refractory period (RRP)

(Nerve anatpmy & physiology)



Types of receptor nerve endings (corpuscles) in skin

➢ **Mechano**	Meissner	light touch
	Pacini	Pressure, tactile stimulus, vibration
	Ruffini	vibration, stretch
	Merkel	Deep pressure
➢ **Thermo**	cooling and warming receptors	
➢ **Nociceptor**	for pain	

Nerve Injury classification

<u>Seddon</u>

Classifies nerve injuries into three categories based on:

- Presence of demyelination
- Extent of damage to the axons
- Extent of damage to the connective tissues of the nerve

(Nerve physiology & injury)

➢ Neurapraxia:
The nerve and axon are in continuity
No damage to the axons or the connective tissues
Segmental demyelination
Non-degenerative
Conduction or physiological block – transient, reversible
No Wallerian degeneration
Full recovery in 3-6 months

➢ Axonotmesis
Axonal damage
Continuity of the nerve's connective tissues, intact epineurium
Focal demyelination
Degenerative type
Wallerian degeneration

- Neurotmesis: Connective tissue and axons are fully transected with disruption of epineurium
  Degenerative type
  No recovery unless surgical intervention with repair

Sunderland

Expanded Seddon's classification to distinguish extent of damage in the connective tissue covering the nerve into five grades:

- Grade I: corresponds to Seddon's neurapraxia
- Grade V: corresponds to Seddon's neurotmesis

  Grades II to IV: all are forms of axonotmesis, with increasing amounts of connective tissue damage
- Grade II axon damage with no damage in the connective tissue
- Grade III involves damage to the endoneurium
- Grade IV includes damage to the perineurium

Birch & Bonney

- Degenerative Direct cut to nerve
- Conduction Can progress to degenerative if not treated

Injury and Repair

- Retrograde degeneration "proximal":
  - Shortly after axonal transection, the proximal axon undergoes traumatic degeneration within the zone of injury. The zone of injury extends proximally **1 to 2 nodes from the injury site to the next node of Ranvier**.
  - The cell body swells and undergoes **chromatolysis**, a process in which the Nissl granules (the basophilic neurotransmitter synthetic machinery) disperse, and the cell body becomes relatively eosinophilic.
  - The cell **nucleus is displaced peripherally**. This reflects a change in metabolic priority from production of neurotransmitters to production of structural materials needed for axon repair and growth, such as messenger RNA, lipids, actin, tubulin, and growth-associated proteins
- Wallerian degeneration "distal":
  - **Breakdown of the axon** distal to the site of injury is initiated 48 to 96 hours after transection.
  - After the clearance of myelin debris, the de-differentiated Schwann cells proliferate on the remaining endoneurial tubes of the extracellular matrix creating columns of cells called **bands of Bungner**
  - The hollow tube that is formed provides a path for the regenerating axon to re-grow
  - At the tip of the regenerating axon is the **growth cone**, from which emerges the finger like projections called **Filopodia**

There are three main mechanisms that guide the growth of the Filopodia:

- Neurotrophism Proteins present on denervated motor and sensory receptors and Schwan cells
- Neurotropism Affinity towards neural tissue
- Contact Guidance Affinity towards basal lamina of Schwann cells and Fibronectin

Nerve grow 1 mm/day

Can be followed up by an advancing Tinel's sign

Tinel sign pathognomonic of degenerative nerve lesion
Can also indicate progression of axonal regeneration

Loss of sweating in autonomic dysfunction

Mechanism of injury Stretching
Compression/crush, ischaemia leads to demyelination
Laceration
Tumour

Treatment /ladder of reconstruction

- **Neurolysis** Nerve in continuity release from scar tissue
- **Primary repair** **(Epineural)**
  Fascicular clean transaction of a trunk /large nerve
  Under microscope
  Best for median, ulnar and sciatic
  Use 8-0 monofilament (Nylon)
  Resect proximal neuroma
  No tension
  Accurate opposition
- **Nerve graft** Defect >2.5 cm - requires graft
  Donor sites Medial & lateral cutaneous N of forearm, sural, saphenous
  Length 15% longer than gap
  Collagen conduits allow for nutrient exchange and accessibility of neurotrophic factors to axonal growth zone during regeneration
  Original nerve is still supplying the motor endplate
- **Nerve transfer** For very large defects
  E.g. spinal accessory or nerve
- **Tendon transfer** After 1 year
- **Muscular neurotisation** insert proximal nerve stump into affected muscle belly

<u>**Prognosis depends on**</u> General factors Age most important factor influencing success of nerve recovery
Good results in children
Comorbidities, smoking
Local Energy transfer - Crush injury have worse prognosis
a clean cut has good outcome
Delay to repair - early repair has better outcome
Associated vascular injury
Tension on repair site
Level of injury - proximal injuries worse outcome
Type of nerve Motor nerves do better (PIN, musculocutaneous)
Mixed nerves have worse outcome

Peripheral Nerve Injury

- BOAST-Peripheral Nerve Injury
  - Seek advice from a specialist
  - Fix bones first if appropriate, and explore nerves – a record in notes is mandatory
  - Urgent repair best; if not able, then appose ends with fine coloured suture
  - If palsy post-op, reduce dressings/reposition limb. If no improvement – specialist advice for re-exploration
  - Painful post-op paralysis – urgently re-explore (exclude Compartment syndrome)
  - EMGs/NCS rarely needed acutely
  - Seek advice for brachial plexus injury within 3 days

TOURNIQUETS

Device which is applied proximal to site of surgery to achieve bloodless field or to control hemorrhage

Types

1) Non-pneumatic — on digits
2) Pneumatic — Automatic timer and audio-visual alarm for abnormal pressure, air leakage and time

(Courtesy of F Arnaout)

Surgical Tourniquets in Orthopaedics

Inflation pressure

Factors taken into account - Age, skin condition, circumference of limb and co-morbidities

Cuff width: At least equal diameter of the limb
Wider cuffs require lower pressures to stop blood flow

Cuff length: 3 to 6 inches of overlap

Cuff pressure: There is no consensus regarding what pressure the tourniquet should be inflated to
Ideally as low pressure as will provide arterial and venous occlusion
Upper limb 50 – 75 mmHg above systolic pressure
Lower limb 100 – 150 mmHg above systolic pressure

LOP (Limb Occlusion Pressure):
Minimum pressure required to occlude arterial blood flow distal to cuff
Dependent on systolic BP, limb circumference and shape
Higher at subcutaneous tissues and mid-point of tourniquet

Tourniquet time The absolute limit of tourniquet time has never been firmly established, **2 hours** is the most widely accepted.

Exsanguination External compression using Reece-Davis exsanguinator or esmarch bandage
Simple elevation of the limb for one minute
Digital pressure over brachial artery in cubital fossa plus elevation
Contraindications: infection, malignancy

Padding: 2-3 layers of soft padding to distribute pressure evenly deep to cuff and to avoid pinching of skin

Contraindications Infection, can enhance anaerobic infection
Peripheral vascular disease
Sickle cell disease - hypoxia, stasis and acidosis may lead to sickling
Poor skin
Crush injuries

Relative Contraindications
IM nailing to decrease thermal injury
Open fractures

Complications Nerves are most susceptible to mechanical pressure and muscle most susceptible to ischemia

Local	Increased with increasing time (2hr is the maximum)
	Post-tourniquet paralysis
	Bone and muscle necrosis
	Direct vascular injury
	Post-op swelling and stiffness
	Wound haematoma
	Re-perfusion injury **Post tourniquet syndrome**
	Characterized by Oedema, stiffness, pallor, weakness, numbness and pain
Systemic	Cardio-respiratory decompensation
	Increased CVP
	Altered Acid Base

ELECTROSURGERY

Transform electricity into heat
Cutting and coagulation of body tissue with high frequency current
Main current in UK is 240 Volts and 55 Hertz
Frequency > 100 kHz safe to avoid nerve and muscle stimulation – electrocution does not occur
Called Radio-Frequency because the frequency is similar to the domestic radio band
Active and return electrodes
Generator, foot/hand switch

Pad position can lengthen or shorten the circuit and increae or decrease impedence changing efficiency of operating electrode
10 000 times larger surface area than the electrode to reduce chance of burning
Shave underneath as hair reduce contact area
Apply on large smooth skin with large underlying muscle
Don't apply on a scar or bony prominences or over prosthesis

Types

- **Mono-polar** current established between diathermy electrode and electrical plate (large to minimise heating)
  Larger impedance – higher voltage (1000s)
  Heating inversely proportional to area of contact
  Cut continuous current
  Vaporises cells
  Pure narrow cut that can be used on skin
  Blended associated with coagulation
  Coag intermittent (pulsed) current at higher voltage
  Burns
- **Bi-polar** Current between two electrodes within diathermy forceps – lower impedance
  Lower voltage (100s)
  Safer - Avoids risk of damage from passage of current through surrounding tissues
  Use in - peripheral areas (fingers, toes, and penis) due to effect of channelling, Pacemaker

Use with pacemaker & ICD (Implantable Cardioverter Defibrillator)

Risk of electrical interference can lead to inhibition/increase in pacing
Preoperative check
Self-adhesive return electrode away from cardiac device implant site
Deactivate ICD and monitor with ECG and have external defibrillator in close proximity
Use magnet in emergency

Complications:

- Burn from contact with metal or alcoholic skin preparations
  Spirit-based skin preparation fluid should not pool and should be dry or dried before electrosurgery commences
  Current passes through passage of lower impedance such as metal
- Exposure to smoke products can contain infectious organisms
  Use high filtration face mask
- Explosion from anaesthetic or bowel gases

IMPLANT MANUFACTURING

- **Casting** pouring molten metal into mould
- **Annealing** Heating to just below melting temperature with subsequent cooling and then cold-working
  Decreases free radicals
  Heat treatment alters material to increase ductility and make it more workable
- **Work hardening** Also called cold working
  Repeated tensile loading of metal alloy until it plastically deforms
  This will reduce voids and increase stiffness
- **Alloying** adding small amounts of other elements to pure metal to alter qualities
- **When asked to talk about a material** Manufacturing
  Surface properties
  Material properties

Titanium

Titanium, aluminium & Vanadium – **TiAL6V4**

Uses Plates, Screws, Nails, femoral stems

- **Advantages:**
- Biocompatible
- Closely match stiffness of bone (½ young modulus of Stainless steel)- prevent stress shielding
- Titanium is 1.6 times tougher than SS
- Self-passivation (self-oxidation) - formation of adherent oxide coating on titanium implants
  Enable titanium to become corrosion resistant
- High fatigue resistance, ideal for load bearing implants such as nails
- **Disadvantages:**
- Low resistance to wear
- Notch sensitivity
- Rough
- Cold welding - when physical disruption of passivation layer with locking screws

Tritanium (Stryker) reticulated porous titanium coating for titanium alloy components
Porosity of 65-70% compared with titanium (30-35%) and cobalt-chrome (35-40%),
Excellent bone ingrowth in animal studies

Stainless Steel

Carbon + iron = Steel

Steel + > 4% Chromium = Stainless Steel

316L 3 % Molybdenum, 16% Nickel, L (low carbon) < 0.03% (High carbon makes material more brittle), 20% Chromium
Molybdenum - reduces pitting corrosion

- **Advantages**: Ductile, stiff, and cheap, good fatigue resistance
- **Disadvantages**: Susceptible to crevice corrosion & galvanic corrosion (with Co-Cr heads)
  Does not self passivate

Cobalt alloy

Contain molybdenum and chromium
Made by casting

- **Advantages:** Excellent resistance to crevice corrosion
  Excellent biocompatibility
  Ductile
  Imperfect lattice structure - work hardening & annealing allow dislocation
- **Disadvantages:** Poor scratch profile
  Co-Cr generally used for cemented implants

Ceramic

Metallic and non-metallic elements bonded ioincally in highly oxidized environment

Types

- Bioactive Ca HA, silicon, TCP – Tri-Calcium Phosphate
- Bioinert
  - Alumina (Aluminium oxide) 1st generation
    Yellow
  - Zirconia (Zerconium oxide) 2nd generation
    Reduced grain size, reduce porosity
  - Delta (alumina + Zirconium)
    Strontium to stop crack propagation
    Yttrium-stabilized tetragonal zirconia particles – platelet like crystals to prevent initiation and propagation of cracks
    Pink colour is due to the chromium oxide (Cr2 O3) that improves the hardness of the composite material
  - Oxinium - Surface made of oxidized zirconium over a metal core

Manufacturing

Sintering ceramic powder and water into pre-fabricated casts (smaller grain size – stronger ceramic), sintering (hot isostatic pressing binds individual grains more tightly – increases density and toughness), powder heated to below melting and subjected to high isostatic pressure. This will improve density and avoid defects

Advantages

- Hard - Scratch resistant, 3rd hardest material known
- Smooth Low co-efficient of friction, good scratch profile
- Wettable - Strong hydrogen bond with synovial fluid - fluid film lubrication
- Low surface roughness
- Good scratch profile

As a result of these surface properties

- High wear resistance- The lowest wear rates of any bearing combination. Wear debris particles smaller than PE wear particles, less biologically active particles, less abrasive and linear wear
- Bioinert (Chemically inactive)- no risk of cancer
- High young's modulus of elasticity - stiff, resists deformation, not subject to creep
- Does not corrode

Disadvantages

- Brittle - no plastic deformation before failure
- Fracture – increased risk with high BMI and smaller head size, fracture produces multiple hard sharp debris, can damage morse taper, revision includes synovectomy to remove debris (0.04% fracture risk with newer ceramics)
- Not tough
- Squeaking- due to edge loading from malpositioning leading to loss of fluid film lubrication
- Less modularity- fewer neck length options
- Stripe wear- caused by contact between femoral head and rim of cup during partial subluxation, Result in crescent shaped line on femoral head, Clinical significance unknown
- Expensive


(Courtesy of S Mansukhani)

When revising THR with a pre-existing ceramic implant, it is recommended to use ceramic again because there will be ceramic debris from the original ceramic and the ceramic has the best hardness

Oxinium

Metal alloy of Zirconium with surface transformed to ceramic by oxidation in air
Thus ceramic is a part of the material and not a coating
Superior resistance to abrasion compared to metal without risk of brittle fracture
Used as bearing surface in people with metal allergy
Expensive

FREE BODY DIAGRAM

- Method of determining static forces and moments acting on a body (fulcrum) by isolating the body part and ensuring that it is in static equilibrium (i.e. sum of forces and moments is zero)

Can't be used for dynamic equilibrium
Centre of gravity of human in standing position is just anterior to S2
Force = mass x distance
Weight = mass × gravity
1 Newton = force required to give 1 kg mass an acceleration of 1 m/s2

- **Assumptions** bones are rigid rods
  Joints are frictionless hinges
  No antagonistic muscles action
  Weight of body is at centre of body mass
  Muscle force in direction of belly
  Only external forces and moments considered
  Muscle act only in tension and JRF in compression
  JRF are presumed to be compressive only
- **Joint Reaction Force (JRF)** Vector sum of all forces acting on the joint
  Force generated within a joint in response to external forces
  Muscle contractions and weight are major contributors
  JRF = FBW + F (Muscle)
  Vector - directed quantity, one with both magnitude, direction and line of action

If force applied in line with fulcrum it will cause translation, but if applied at a distance it will cause rotation
Anti-clockwise forces should be equal to clock-wise forces

- **How to Draw** pivot at joint of interest
  Fixed segment
  Mobile segment
  Draw levers and forces to scale
  Moments are perpendicular to force
  Forces can be clockwise or anticlockwise

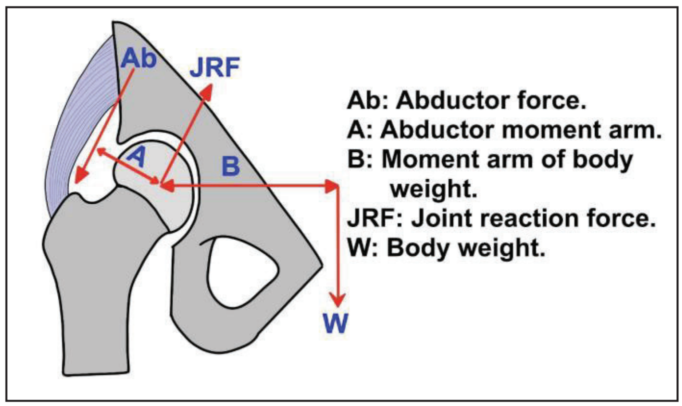
Hip

- Fixed is femur and mobile is pelvis
- Abductor force vector is anticlockwise to balance pelvis
- Weight force vector is clockwise
- 1^{st} class lever between body weight and abductor force
    - Coxa vara – reduces FAb – increase abductor force
    - Trendelenburg gait – shift gravity to reduce B (abductor lever arm)
    - Weight of the body and abductors act as compressive forces
- Abductor force is 3 times closer to fulcrum (b=5 cm vs a=15 cm)
- FBw - Weight in single limb stance is 5/6 total body weight

JRF of hip = FBw + FAb
FAb x b = FBw x a
FAb = (5/6th BW x a)/ B
FAb = (5/6) BW x 15 / 5 = 2.5 x body weight

To reduce hip joint reaction forces

- Lose weight - reduce FBw – reduce JRF
- Help abductors, Stick on other hand.
  Some body-weight transferred through it provides additional moment to reduce torque (coupling principle) -Reduce JRF up to 60%
- Weight on same side
- Valgus osteotomy- Increase lever arm of abductors
  Normal neck shaft angle is 125^0, but hip is made 135^0
- THR – medialise cup and increase offset
  Lateralise greater trochanter

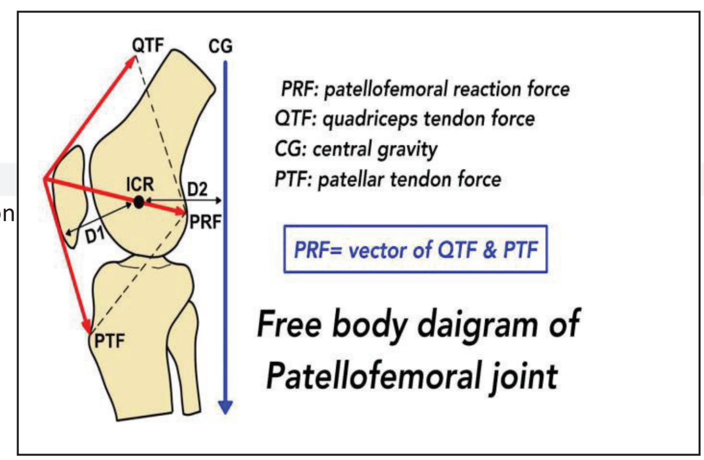


Knee joint

Pivot is knee
Fixed component is tibia
Mobile component is the femur
GRF opposite to body weight
Increased JRF with knee in flexion

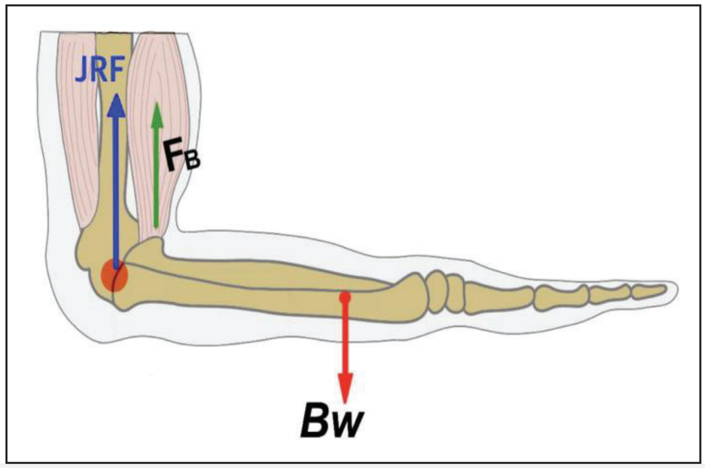
PFJ

- Force of quads equivalent to force of patellar tendon
- Patellectomy reduces quadriceps moment arm and therefore increases quadriceps force



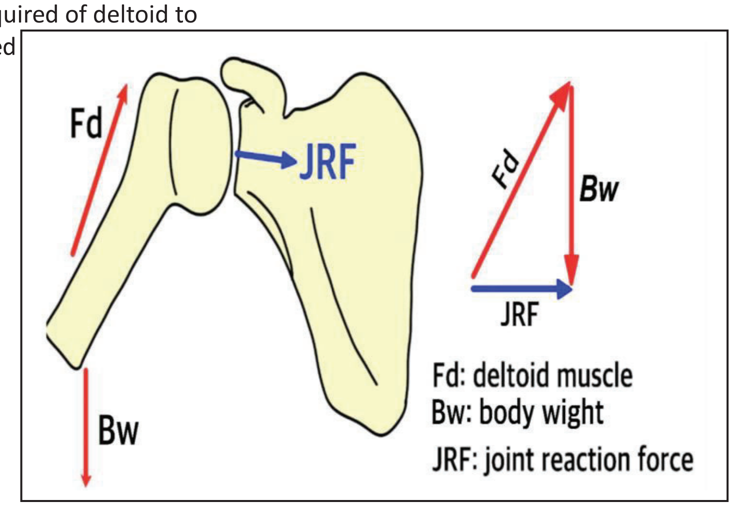
Elbow

- Class 3 lever
- 90^0 with weight in hand
- Pivot is ulnohumeral articulation
- Biceps insertion 5 cm distal to elbow
- Centre of gravity of forearm (weight) is 15 cm from elbow

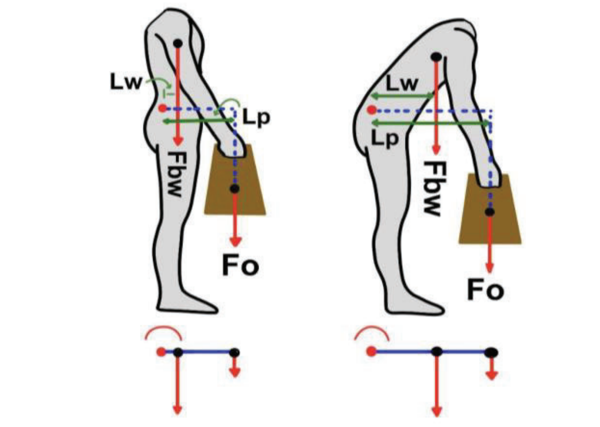


Shoulder

- Deltoid has to counteract weight of arm and weight in person's hand
- If person bends elbow - reduce moment arm of weight in the hand and force required of deltoid to elevate arm will be reduced



Spine



Free body diagram of the lumber spine when lifting a weight with the spine extended and flexed
Lw: lever arm for body weight
Lp: moment arm of the weight carried in hand

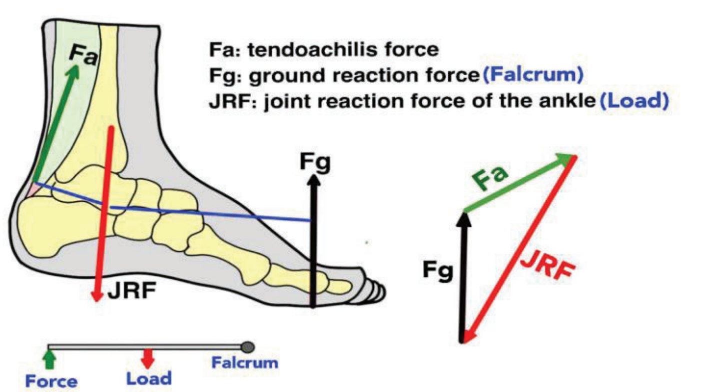
- Pivot point in middle of disc
- Fixed is L5 and mobile is L4
- Weight vector to front — Clock wise; Draw moment arm
- Erector spinae force — Counter-clockwise; Draw the short moment arm
- Bending knees and holding objects close to body will reduce weight moment arm and therefore reduce force of weight and counterforce of spinal muscles will be reduced resulting in reduced JRF

Ankle

Fulcrum is ankle, class 2 lever
Fixed is foot and mobile is tibia
Ground reaction force is equivalent and in opposite direction to body weight
Used instead as the foot is attached to ground

- It is a method to determine force and moment acting on a body by isolating body part & ensuring it is in equilibrium
- Line of gravity is a few cm in front of the ankle joint that produces dorsiflexion torque
- The main compression force in the ankle comes from Gastrocnemius and Tendoachilles
- JRF is proportional to the amount of muscle force
- Calculating the JRF during a single-limb stance
- Standing on the tip toe increases the JRF significantly, hence making it difficult for ankle OA patients to stand on tip toes

d: Distance
TA x d = GRF (BW) x 4d
TA = 4 BW
Total JRF = TA + BW = 5Bw



Ankle joint reaction force

BACTERIOLOGY

Gram +ve	Thick wall made of peptidoglycan Stained purple by crystal violet & indium Then alcohol/Acetone rinse
Gram -ve	Thin wall Stained pink with Safranin/Carbol Fuchsin

Gram staining

1) Heat the slide to fix the smear
2) Apply crystal violet dye
3) Apply iodine which binds the crystal violet to the petidoglycans of the gram positive bacteria
4) Acetone or alcohol wash which removes the crystal violet dye from the gram negative organisms but gram positive retains it
5) COUNTERSTAIN with SAFRANIN (pink dye) gram negative are stained pink

Bacterial Resistance

- Mechanisms
  1) Phagocytosis of the drug (beta lactamase)
  2) Genetic mutation (MEC A gene MRSA)
  3) Altered cell wall permeability
  4) Biofilm Formation
  5) Ribosome Alteration
  6) Active efflux pumps

Bacteriology & infection)

- There are two main types of resistance

Intrinsic resistance	The bacteria has properties that prevent antibiotics to act on it E.g. changes in cell wall permeability, efflux pumps, enzyme production
Extrinsic Resistance	The bacteria develop resistance to an antibiotic to which it was previously sensitive e.g. chance mutations, drug resistance gene (this is mediated via Plasmids)

G +ve cocci

Retain Indium dye

Staphylococcus aureus

MRSA	Carry MecA gene encodes for Penicillin binding protein providing antibiotic resistance Disallows cell wall-Penicillin bond rendering penicillin ineffective in destroying cell wall Methicillin used in 1950s instead of Penicillin for resistance Lives in nose and throat and skin, 2% of population colonised Nasal Mupirocin and bath in 4% Chlorhexidine Teicoplanin, Vancomycin, Linezolid PVL toxin produced by some strains of Staph Aureus More aggressive - kill white blood cells and cause severe soft tissue and bone infections
MSSA	Clinical strains higher risk of carrying PVL gene 30% of population are carriers
Staph epidermidis	encapsulated organism – need implant removal to cure
Enterococcus	
Strep A and B	Pneumoniae (mecA), viridans

G +ve bacilli (rods)

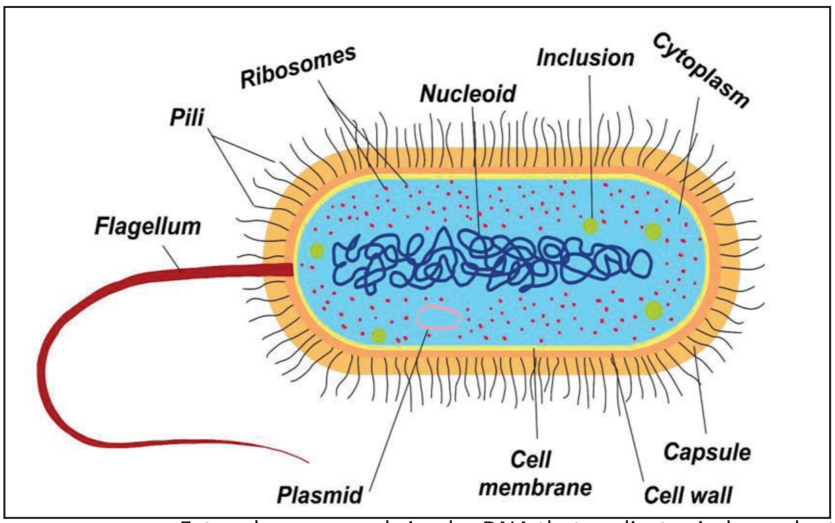
Clostridium (anaerobic) Tetani, Perfringens, Difficile
Spores resistant to disinfectants - Wash hand with soap
Anthrax Listeria Diphtheroid
Propionibacterium acne in shoulders Present late - Subtle presentation
14 days for +ve culture
Clindamycin, Vancomycin, Teicoplanin

G -ve cocci

Neisseria gonorrhoea and meningitides

G -ve bacilli

Pseudomonas IVDU puncture wound to foot
E Coli, Haemophilus, Salmonella, Serratia proteus, Eikenella Corrodens, Kingella
Gram-negative aerobic coccobacillus
Colonise URT in children
Identified using PCR
Sensitive to penicillin
ESBL extended-spectrum beta-lactamases
Resistant to many penicillin and cephalosporin antibiotics
The 2 main bacteria that produce ESBLs are Escherichia coli (E. coli) and Klebsiella



Plasmid Extra-chromosomal circular DNA that replicates independently of host DNA carries genes that benefit survival of organism, such as antibiotic resistance genes

Types of bacterial infections Pyogenic
Granulomatous

Testing Gram staining
Culture
Blot analysis detects DNA
Antigen testing Monteux

Actions of bacteria Colonise Skin & Bowel
Infect
Release toxins

Viral

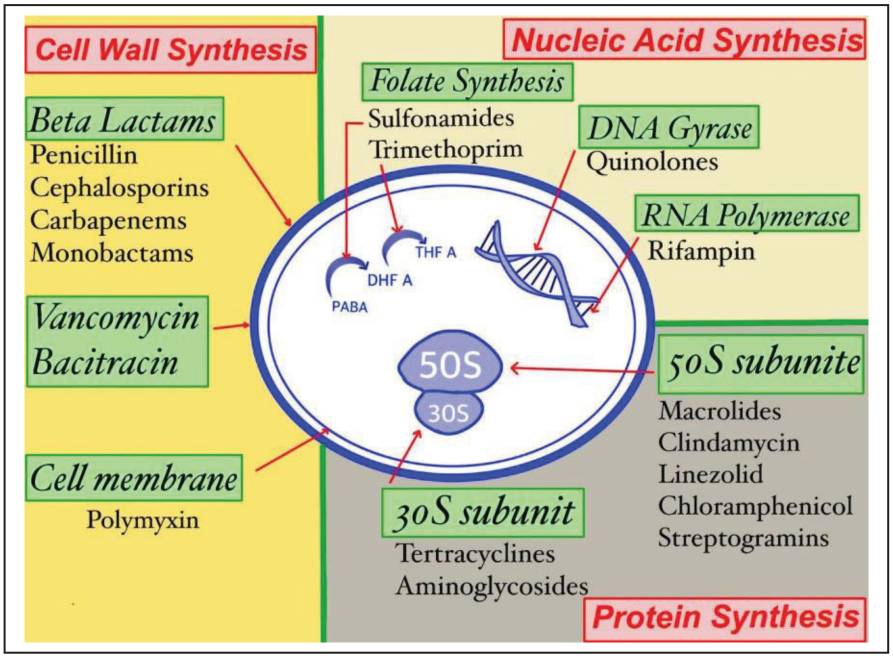
➢ Herpes	fluid-filled blisters Acyclovir
➢ Mononucleosis	EBV Pharyngitis and fatigue and splenomegaly Mono-spot test No contact sports until splenomegaly resolved – risk of rupture

Fungal

Tinea scaly red patches in circular formation

Antibiotics

➢ **Beta-lactam**	Penicillin, Cephalosporin, Carbapenems (Imipenem, Ertapenem) Inhibit bacterial cell wall synthesis G +ve Ecoli
➢ **Glycopeptide**	Vancomycin Teicoplanin Inhibit bacterial cell wall synthesis Good for MRSA Oral not absorbed used for C.Diff
➢ **Aminoglycoside**	Gentamicin - 5mg/Kg OD For G –ve Effective against S.Epidermidis with good bone penetration Inhibit protein synthesis 30s Nephrotoxic
➢ **Macrolides**	Clindamycin High bone concentration but risk of Pseudomembranous colitis Erythromycin Clarithromycin Inhibit ribosomal protein synthesis 50s
➢ **Quinolones**	Ciprofloxacin Inhibit DNA synthesis Tendinopathy & tendon ruptures – Triceps, Achilles Inhibit early fracture healing through a toxic effect on chondrocytes
➢ **Oxazolidinones**	Linezolid Inhibit ribosomal protein synthesis 50s MRSA oral or IV Can cause myelosuppression – maximum given for 4 weeks and repeated blood tests
➢ **Rifampicin**	against intracellular phagocytised Staphylococcus aureus in macrophages Inhibit bacterial RNA synthesis Causes body fluid discoloration Anti-tuberculous drug Make urine turn orange
➢ **Tetracyclines**	bacteriostatic, 30s ribosome Doxycycline, for Lyme disease



Dental Procedure Abx Prophylaxis in Total Joint Arthroplasty Patients

British Society of antibacterial chemotherapy - no routine Abx required for patients with prosthetic joints who undergo dental work

Comorbidities including
- immunocompromised patients
- Previous prosthetic joint infection
- Type I (insulin-dependent) diabetes
- Malnourishment
- Haemophilia
- HIV
- Malignancy

SKIN GRAFT

- **Classification of grafts** (composition) bone
  Skin
  Tendon

Avascular graft to cover deep structures and for bacterial barrier and prevent joint contracture

- **Indications** Primary wound closure can't be achieved
  Wound healed with problematic scarring
- **Contraindications** Wounds with exposed bone, tendon, nerves, or blood vessels
- **Partial/split thickness** perfused wound bed with good vascularisation over muscle or subcutaneous tissues
  Glabrous lacks hair follicles
  Donor sites anterolateral thigh
  Nutrition obtained by diffusion from wound bed, imbibition followed by inosculation
  Can be used for dorsum of hand
- **Full thickness** Volar hand wounds and fingertips
  Contain full thickness of dermis and epidermis, containing hair follicles and sweat glands
  Donor sites - proximal forearm, hypothenar eminence of hand
  Better innervation and sensation
  Less scar contracture
  More durable and resistant to shear stresses

Technique

Hand held or electric dermatome
Liquid paraffin
Skin under tension
Meshed graft provide greater surface area
Lower incidence of hematoma formation and infection
Immobilize
Leave donor site undisturbed for two weeks until not painful as newly formed epithelium will rip off with dressing
Mepilex dressing can be removed with less risk of damaging the wound
Prevent infection

Skin flap

Unit of tissue transferred from donor site to recipient site while maintaining its own vascular supply
Pedicle - vascular portion of transferred tissue contains one artery and one or more veins

- **Indications** soft tissue injury with exposed bone, tendons, cartilage or orthopaedic implants

- **Tissue type classification**
  - Cutaneous include skin and subcutaneous tissue
  - Fasciocutaneous flap include fascia with overlying skin
  - Muscle flaps usually requires additional transfer of skin graft to cover muscle
    Or transposed as part of musculocutaneous flap (composite)
    If motor nerve not preserved the flap will atrophy to 50% of its original size
  - Vascularised bone graft
  - Composite flaps consist of multiple tissue types

- **Mobilization type classification**
  - Local flap tissue transferred from an area adjacent to defect
  - Rotational or advancement or transposition (Z plasty) - Sural flap
  - Distal/regional flap transfer of tissue to non-contiguous anatomic site
  - Free tissue transfer local or distant tissue not sufficient

- **Complications** flap failure, vasospasm often leads to thombosis at anastamosis
  Donor site morbidity pain, cosmesis
  Non-union for vascularised bone graft

SHOCKWAVE THERAPY

Creates neovascularisation

Indications Plantar fasciitis
Tennis elbow
Patella, Achilles & supraspinatus tendinosis

PLATELETS RICH PLASMA

Ultracentrifuge of patient own blood with high concentration of platelets & growth factors above normal serum baseline
Possible stimulation of bone and soft tissue healing

HICKMAN LINE

Central venous catheter for administration of medications (long term ABx/chemotherapy)
Tunnel created under skin to insert catheter in superior vena cava vein
Flush regularly with heparinised saline

PERIPHERALLY INSERTED CENTRAL CATHETER (PICC)

Indications
Chemotherapy
TPN
Long term Abx
From basilic or cephalic veins but rests in superior vena cava
Regular flushing to maintain patency
CXR to confirm placement before use

MID-LINE

Rests in axillary vein, distal to shoulder
Radiographic confirmation is not requires prior to use

RADIO STARIOMETRIC ANALYSIS (RSA)

Assessment of 3D migration and micro motion of joint replacement prosthesis relative to bone
Also evaluates polyethylene wear
Useful tool for evaluating new prosthesis

- **Stages** Radio opaque markers (Tantalum beads) attached to bone at time of surgery
  Subject placed in calibration cage which contains Tantalum marker beads placed at measured points
  Stereo image obtained (biplanar radiographs)
  Asses change of position using special RSA software
- **Finite Element Analysis** Computer generated analysis of forces between two bodies such as bone implant interface
  Mesh used to divide material into smaller elements
  Forces individually calculated and then combined

BONE CEMENT

Synthetic material commonly used for implant fixation or used as filler
Viscoelastic material – exhibits creep and stress relaxation
High compressive strength
Poor tensile and shear strength

Uses

- **Fixation grout rather than adhesive**, friction or hoop stresses at interface with implant
  Interdigitation with bone
- Void filler non-maliganat lesions
  Osteoporotic vertebral collapse
  Revision THR and TKR
- Masquelet technique

Ingredients

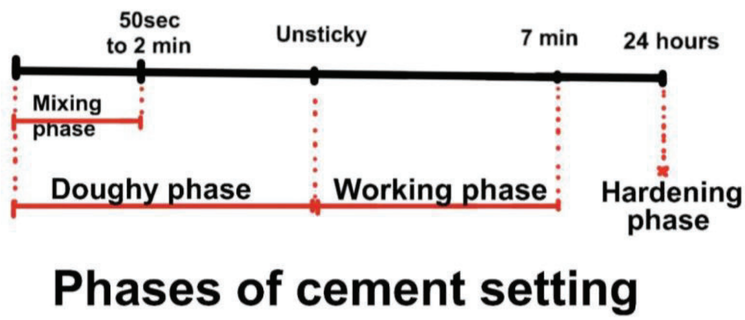
- **Powder** Methylmethacrylate **polymer** for strength
  Barium Sulphate or zirconium for radio opaqueness
  Initiator (Benzoyl Peroxide) of exothermic polymerisation once liquid contacts with powder
  Impregnated with Aminoglycosides
  Cement loses some ductility when mixed with ABx
  Chlorophyll dye (in Palacos) and ethanol and ascorbic acid (in CMW DePuy)
  Abx must be thermally stable
  Wide spectrum
  Long elution time, 6-8 weeks
  Not compromise mechanical stability of cement
- **Liquid** colourless
  Packaged in ampoules
  Methylmethacrylate **monomer** (PMMA) for handling
  Accelerator (N-diMethyl-p-toluidine) and **inhibitor** (hydroquinone)

The process called **polymerisation**

- The reaction is exothermic and energy inefficient
- Carbon to Carbon double bonds are broken down and new single bonds are formed to give long chain polymers that are linear and relatively free of cross-linking

Phases of cement setting

- **Mixing phase** 50 sec - 2min for low viscosity
- **Dough phase** from mix to phase when cement is non-sticky, includes mixing time
  If the cement is inserted too early, blood mixes into it reducing its strength
  Increased humidity lengthens dough phase
- **Working phase** Implantation phase, from end of dough time to begening of setting
  Up to 7 minutes from start
  Increased temp & increased mixing and handling reduces working phase
- **Hardening phase** Implant should be kept still, as cement is still notch sensitive
- **Setting time** From mixing till it reaches maximum heat and becomes hard
  In vivo temperatures are reported to be between 40 and 56
  Increased theatre temperature and humidity reduces setting time



Types

Viscosity is a measure of the resistance of a fluid to deformation under shear forces

- Low viscosity long doughy phase
- Medium viscosity reaches doughy stage later than high viscosity
- High viscosity

Optipac (Biomet) Closed vacuum mixing system
Minimizes exposure to monomer fumes

Simplex (Stryker) Medium viscosity cement
High fatigue strength and low creep (plastic deformation)
Gamma irradiation for sterilization – higher risk of fatigue
1 g Tobramycin

Palacos (Heraeus) High viscosity. Green dye
Shorter waiting period and extra-long working phase
R+G – with Gentamycin

(Courtesy of F Arnaout)

Copal (Heraeus) Gentamycin + Clindamycin or G + Vancomycin

CMW (DePuy)

Pulse lavage Reduce risk of fat embolism
Strengthen bone cement interface

Vacuum reduce pores (bubbles) – reduce cracks & increase tensile strength

Pressurization - to enhance interlock at bone cement interface

Bone cement syndrome

Hypoxia - hypotension - cardiac arrhythmia - cardiac arrest

Causes Not fully understood. Several mechanisms have been proposed

1- MMA monomer mediated model
2- embolic model
3- histamine release and hypersensitivity
4- complement activation
5- Multimodal model

Recommendations (BOA and BGS + AAGBI guidelines)

There should be **a three-stage process** to reduce the incidence of problems in patients undergoing cemented hemiarthroplasty for hip fracture:

1. Identification of patients at high risk of cardiorespiratory compromise:

a) Increasing age
b) Significant cardiopulmonary disease

2. Preparation of team(s) and identification of roles in case of severe reaction:

a) Pre-operative multidisciplinary discussion when appropriate
b) Pre-list briefing and World Health Organization Safe Surgery checklist 'time-out'

3. Specific intra-operative roles:

a) Surgeon:
- Inform the anaesthetist that you are about to insert cement
- Thoroughly wash and dry the femoral canal
- Apply cement in retrograde fashion using the cement gun with a suction catheter and intra-medullary plug in the femoral shaft
- Avoid vigorous pressurisation of cement in patients judged to be at risk of cardiovascular compromise

b) Anaesthetist
- Ensure adequate resuscitation pre- and intra-operatively
- Confirm to surgeon that you are aware that he/she is about to prepare/apply cement
- Maintain vigilance for signs of cardiorespiratory compromise.
- Aim for a systolic blood pressure within 20% of pre-induction value
- Prepare vasopressors in case of cardiovascular collapse

Barrack & Harris radiographic grading of cement technique

A	whiteout	no distinguishable border between bone and cement
B	radiolucent line between cement and bone <50%	
C	>50% radiolucency	
D	100% radiolucency	or absence of cement distal to tip

Which cement would you use?

Palacos R+G
- High Viscosity — short dough time and long working time
- Green colour — from Chlorophyll– greater visibility
- Carrier is peanut oil
- Gentamicin — consistent Abx release 0.5 g; Broad spectrum covering G +ve and G -ve

Sterilized using Ethylene Oxide – preserve mechanical integrity

NJR risk of revision
THR 3.3% in 10 years Vs 4.2 % with other cement
TKR 4.1 % Vs 4.4

(Cement for FRCS)

IMMUNOLOGY

Immune Responses

Biological structures and processes that protect against disease

- Innate — Non-specific — no memory
  - Anatomic barriers (skin)
  - Inflammation
  - Complement cascade, circulating proteins
    - Chemotaxis — attract inflammatory cells
    - Opsonisation — attach to pathogen to make it susceptible to phagocytosis
    - Lysis of cell membrane
    - Assist clearance of immune complexes by liver and spleen
- Acquired — has memory
  - Pathogen and antigen specific mechanism
  - B cells, CD8, T lymphocyte, T helper

Can also be classified as Humoral - Antibody mediated OR Cell mediated

- **Immunoglobulins (antibodies)**
  - Ig M — First in acute infection; In the foetus; Rheu Factor is IgM
  - Ig G — later in acute infection; Most abundant
  - Ig E — Allergic reactions and against parasites
  - Ig A — External secretions
  - Ig D — Unknown role
- **Immunological reactions**
  - **Type I** — Immediate anaphylactic reaction; Associated with allergy; Mediated by IgE antibody; Activation of mast cells and basophils
  - **Type II** — Antibody dependent hypersensitivity; Mediated by IgG and IgM antibodies
  - **Type III** — Immune complex (antigen bound to antibody); Mediated by IgG and IgM antibodies
  - **Type IV** — Delayed-type or cell-mediated hypersensitivity; Mediated by T cells, monocytes and macrophages; Take several days to develop; Examples include tuberculosis skin test; Response to metallic orthopaedic implants

SURGICAL INSTRUMENTS

- **Blades** No 11 elongated triangular with pointed tip - for stab incisions (arthroscopy)
  No 10 for skin & muscle
  No 15 for precise incisions, e.g. in hand surgeries
  No 20 Large version of 10
- **Forceps** toothed for skin, e.g. Adson's for everting skin
  Un-toothed for blood vessels, nerves, visceral organs, DeBakey – non- traumatic
  Allis to grasp connective tissue
  Mosquito for haemostasis
- **Scissors** Mayo for fascia
- **Needle holder** maintain firm grip on the needle
  The jaws are often textured and short compared to the shank
- **Suction** Frazier for small amount of bleeding
  Yankauer
- **Retractors** West Blade depth 18mm
  Norfolk-Norwich Blade depth 26mm
  Davis Blade depth 50mm
- **Chucks** **AO** quick coupling for drill bits, screw drivers
  Jacob Chuck

CASTS

Mechanism of action: neutralization of forces by stopping the movement (bending, torsion and compression) of the joint above and below

Types:

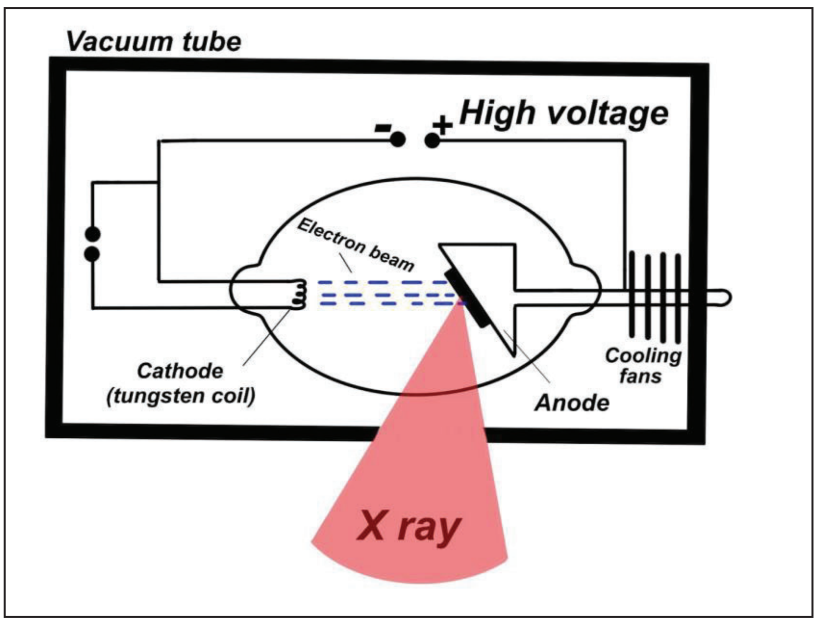
- Plaster of Paris
- Fibreglass SoftCast
  Flexible & conforming
  Can unwind
- Polyester (DeltaCast/ScotchCast)
  More rigid – can crack

Applied over stockinet, Velband or Softban

IMAGING

X rays

- Release of electrons from heated Tungsten cathode in vacuum which are drawn towards Tungsten Anode at high speed, as they strike, energy is generated in the form of heat (99%) and X-Rays.
- Differentially absorbed by objects of different radio-density
- Tissues containing high atomic nucleus absorb high proportion of X-rays (high attenuation coefficient)
- Digital imaging obtained by use of flat panel detector FPD made from Silicon/Phosphor
  The fluoroscopic receptor
- Primary radiation – beam directed from tube to x-ray plate
- Secondary radiation – scatter that causes blurring and exposes staff and patient to radiation
- **Advantages** cheap and readily available
- **Disadvantages** radiation limited for soft tissue, limited use in subtle bony injuries
- **Factors to decrease radiation exposure to patient and surgeon (TDS)**
  - Maximizing **Distance** between surgeon and radiation beam
  - Minimizing exposure **Time**
  - Orienting fluoroscopic beam with intensifier close to body part to reduce scatter of radiation and also to cover more body area in one image
  - Use of protective **Shielding** of lead apron (0.25 mm thick) and thyroid shield
  - **Collimation** reduction of size of window to reduce radiation dose and produce sharper radiographs



1 Sievert = 1 Gray 1 mSv is dose produced by exposure to 1 milliGray of radiation
1 Gray = 100 Rad Gray Unit of ionising radiation
Whole body exposure of **20mSv is maximum acceptable radiation dose/year**
1 mSV gives 1:20 000 chance of cancer induction
Natural background radiation 2.7 mSv/year (100 CXRs)
Transatlantic flight 0.08 mSv

DEXA	0.001 mSv
CXR	0.02 mSv
Lumbar spine	1 mSv
Bone scans	4 mSv
CT head	2 mSv
CT chest	8 mSv
CT abdo/pelvis	10 mSv
1 minute of fluoroscopy	1 mSv

MRI

Hydrogen nuclei (protons) spin and wobble (precession) at Larmor frequency

Magnetic field with strong magnet to align / synchronise spin of water protons (H+ align themselves parallel to magnetic field – longitudinal magnetization)

RF pulse applied which force protons to change alignment (tilt 90^0 – transverse magnetization)

RF switched off - energy released (relaxation) during realignment of protons used to create MRI image

Contrast used is Gadolinium enhances oedematous tissues on T1
Risk of nephrogenic fibrosis in patient with stage 4 CKD – not administer if eGFR <30

Contraindicationsto contrast Pregnancy
Previous sensitivity to contrast media
Kidney diseases

Magnetic field strength measured in **Tesla (currently 1.5T, 3T scanners normally used)**

- **Advantages** Excellent soft tissues contrast, good for tumours and occult fractures, no ionizing radiation
- **Disadvantages** Claustrophobia (open MRI or alternative imaging), not as good as CT for cortical bone
  Cost, size, slower image acquisition times
- **Contraindicated in** Pacemaker and defibrillators
  Cochlear implants and internal hearing aids
  Implanted nerve stimulators
  Metal objects in eyes
  Intra-cranial clips
  Mechanical heart valves

Tissue	T1	T2
Fat	Bright (enhanced signal)	Bright
Bone cortex	Dark (low signal)	Dark
Bone marrow	White	Grey (intermediate signal)
Muscle	Grey	Grey
Tendon & lig	Dark	Dark
Fibrocartilage	Dark	Dark
Hyaline cartilage	Grey	Grey
Water	Dark (hypointense signal)	Bright (high signal) WWII (Water White in T2)

- **TR** rate of application of RF pulse
- **TE** Echo time of signal acquisition recording

- **T1** time taken by 63% of protons to achieve longitudinal magnetization under RF pulse
  Uses a short repetition time (TR) < 1000ms time between 2 RF pulses and short echo time (TE) <60 ms between pulse administration and detection
  Good for anatomy, for bone marrow – meniscus. Gadolinium contrast used in T1 (bright)
  Most pathologies including tumour have high water content – low signal on T1
- **STIR** Short tau inversion recovery T1 with fat suppression
  Sensitive to abnormal fluid for tumours & trauma
- **PD** proton density weighted used to image menisci
- **T2** time it takes to de-phase 37% of transverse magnetization on switching off RF field
  Uses a long TR and long TE
  Better for showing pathology
  For soft tissue, most pathology have high water content – high signal on T2
  Tendon tear – gap filled with high signal oedema
- **Fast – Spin/MARS** Metal artefact reduction sequence
  Artefact much worse with steel than titanium

Knee On sagittal view medial tibial condyle is triangular and lateral is rectangular

Spine Malignancy T1 Low
T2 High

Ultrasound

- **Definition** Form of imaging that **utilises high frequency sound waves** to image interfaces between tissues with different acoustic properties (Described as echogenic or hypoechoic)

Fluid filled tissues have low echogenicity
Fat is highly echogenic
Passage of electric current through **piezoelectric crystal** (within a transducer) produces sound waves which is generated by transducer and reflected back to the transducer
Frequency 3 – 50 MHz (above audible limit) high frequency probe for deep and low for superficial tissues
Duration between sound wave emission and detection reflect depth of tissue
The wave voltage changes shape of piezoelectric crystal that gets converted to electrical signals, which are converted to image

- **Doppler Effect** assess whether blood is moving towards or away from probe, and its relative velocity
- **Modes** A mode Amplitude mode ophthalmology
  B mode Brightness mode most widely undertaken 2D images
  M mode time-motion mode Cardiac valve
- **Advantages** No ionising radiation, inexpensive, portable, dynamic, non-invasive
- **Disadvantages** Operator dependant, dynamic element lost following scan, limited for bone

CT scan

- **Definition** 3-dimensional image acquisition using **rotating x-ray source** that allows multiplanar reconstructions

Medical CT invented by Sir Hounsfield in 1973 – awarded noble prize
Hounsfield units measure of attenuation coefficient of tissues
Ionizing radiation
Same principle as X-ray but with use of X-ray tube producing collimated (aligned) fan shaped X-ray beam that helically rotates around patient
Described as high or low attenuation
Contrast used is iodine
CT Myelography with intra-thecal injection
Views axial
3D sagittal & coronal reconstruction
Windowing centering on particular attenuation value
Water = 0, air = -1000, bone = +1000

- **Advantages** Detailed 3D images excellent bone contrast
- **Disadvantages** Metallic artefact, limited soft tissue contrast, high radiation dose

Quantitative CT for bone density

Nuclear medicine

- **Bone scan** imaging that detects distribution of injected radioisotope on camera sensitive to emitted gamma rays to assess rate of bone turnover
- **Technetium99** MDP has affinity for osteoblasts, metabolically active bone (bone turnover)
  Half-life 6 hrs
- **Gallium** affinity for inflammatory cells (Leucocytes) and bacteria
- **Indium** affinity for Leucocytes

<u>**3 phases**</u>

- **Blood flow** angiogram 1-2 min
- **Blood pool** for soft tissues 30 min
  Increased vascularity when capillaries dilate due to inflammation
  Infection
- **Bone phase** 4 hrs
  Tracer in bone
  Infection, tumour, AVN, Paget, stress #, non-union
  Aseptic loosening

Cold scan MM (50%), Mets from renal & thyroid
Flare phenomenon paradoxical increase in uptake following chemotherapy as result of bony repair
Superscan intense symmetric activity in bones with diminished renal and soft tissue activity
Occurs in diffuse metastatic spread, lymphoma, metabolic bone diseases – renal osteodystrophy, hyperparathyroidism, wide spread Paget's, Osteomalacia

- **Disadvantages** Radiation dose equivalent to 63 CXR, non-specific
  Lasts 6 months following commencement of chemotherapy – use PET scan
- **WBC (Leukocyte) scan** WBC removed from patient – tagged with indium – reinjected
  2-3 hrs later – patient scanned 6-24 hrs later
- **Patient instructions** drink lots of water to allow renal excretion
  Use different loo to rest of family until isotope flushed out
  Flush toilet twice
  Avoid contact with pregnant women
  Will be detected by airport detectors for 1 week
- **SPECT scan** Single Photon Emission Computed Tomography
  3D bone scan
  Images reconstructed in axial, coronal and sagittal planes
  Useful for posterior spinal elements and areas of decreased uptake
  Reduce obstruction by underlying tissues
  Modern SPECT available with integrated CT scanner to locate abnormalities more precisely
- **PET scan** Positron Emission Tomgraphy
  For tumour diagnosis
  Inject FDG (glucose analogue) – transported and accumulates in areas of high metabolic activity
  Emit positron (positively charged) that react with nearby electron to result in photons
  Successful chemotherapy causes decrease in uptake
  Specific radioisotopes – C11, O15, F18

ANAESTHESIA

- **GA** Aims loss of conciseness result in loss of reflexes
  Amnesia
  Analgesia – Fentanyl, Morphine, Propofol, Ketamine
  Muscle relaxation, by blocking acetylcholine - paralysis of respiratory muscles

Induction IV or inhalation
Maintenance sedation with Propofol or Midazolam
Respiratory tract infection increase risk of laryngospasm and bronchospasm

- **Malignant hyperthermia** Autosomal dominant
  Triggered by inhalational agents or depolarizing muscle relaxant (Suxamethonium)
  Prolonged muscle contraction
  Release of K+ can lead to MI
  Release of myoglobin can lead to renal failure
  Antidote is Dantrolene

- **Regional**
  - Spinal mixture of Morphine & Bupivacaine
    Propofol sedation
    Reduced confusion and lethargy compared to GA
  - Epidural Indwelling catheter
  - Interscalene for shoulder surgery, sensory neuropathy is most common complication
  - Supraclavicular or axillary - for elbow surgery
  - Facia iliaca
  - Adductor canal block

- Meta-analysis (BJJ, 2009) – A comparison of regional and general anaesthesia for Total Replacement of Hip or Knee
Regional anaesthesia seems to improve the outcome of patients undergoing total hip or knee replacement (reduced need for transfusion, reduced incidence of thromboembolic disease
- NJR data analysis in **J. Arthroplasty 2020 –** suggested reduced LoS, reduced risk of re-admission, UTI, SSIs with regional anaesthesia when compared with general anaesthesia

- **Sedation** Midazolam fast acting & short duration of action
  Antagonist is Flumazenil
- **Local Anaesthesia**
  - Block nerve conduction by reversibly binding with Na/K channels in nerve membrane and blocking action potential initiation and propagation
  - **Ester LA** Benzocaine, procaine for topical anaesthesia of skin
  - **Amide LA** Lidocaine (lignocaine, xylocaine)
    intra-articular infusion can cause chondrolysis
    Max dose 3mg/Kg (6mg/Kg with Adrenaline)
    1% contains 10 mg/ml
    Bupivacaine (Marcaine, Chirocain) cardiac risk
    0.25 % not chondrotoxic
    Ropivacaine (Naropin)
    Prilocaine (0.5 or 1%) without preservative or adrenaline – 3mg/kg

American Society of Anaesthesiologists (ASA) physical status classification

1	Normal healthy patient
2	Patient with a mild systemic disease
3	Patient with a severe systemic disease that limits activity, but is not incapacitating
4	Patient with an incapacitating systemic disease that is a constant threat to life
5	Moribund patient not expected to survive > 24 hours with or without operation
6	Brain dead operated on for organ donation

PO2 Partial pressure of O2
FiO2 Fraction (percentage) of inspired O2
Surgical Outcome Risk Tool (SORT)provide estimate of risk of death within 30 days of operation

- **New England Journal of Medicine**

Rate of death 1.5% before WHO checklist introduced and declined to 0.8% afterward (P = 0.003)
Inpatient complications occurred in 11% of patients at baseline and in 7% after introduction of checklist

PAIN

- **Afferent pain pathways**
  - Peripheral nerves type A & C peripheral nerve fibers
  - Spinal cord dorsal column and spinothalamic tracts
  - Brainstem thalamus, site of pain modulation

Paracetamol Weak inhibitor of prostaglandin

NSAIDS Inhibit COX

Arachidonic acid metabolized by cyclooxygenase into prostaglandins and thromboxane

COX-1 results in prostaglandins responsible for maintenance and protection of GI tract

COX inhibitors can cause GI damage

COX-2 results in prostaglandins responsible for inflammation and pain

Causes mesenchymal progenitor cells to differentiate into osteoblasts

COX 2 inhibitors can cause decreased endochondral ossification

Selective COX2 inhibitors (Celecoxib) maintain gastric mucosa

No renal dysfunction

Giannoudis (BJJ, 2000) – study about non-union of femoral diaphysis showed marked association between non-union and use of NSAIDs

Opioids Cause prolonged activation of opioid receptors (Mu agonist)

Histamine release - Postural hypotension, biliary spasm, pruritus, bronchoconstriction

PCA for obese based on ideal body weight is best

To help soft tissue recovery

Cryo therapy
Heat therapy
Massage
US
Electrical stimulation
Ionophoresis - use electrical current to drive medicine through skin into deep tissues
Phonophoresis - when ultrasound used to deliver medicine

WHO step-ladder pain management (1986)

- Non-opioid – paracetamol, NSAIDs (Ibuprofen/Naproxen)
- Weak opioid – Codeine, tramadol
- Strong opioid – Morphine, oxycodone, fentanyl/buprenorphine patches

NICE Guidelines (Osteoarthritis pain management)

- Regular dosing paracetamol
- Topical NSAIDs
- Oral NSAIDs – COX-2 inhibitors, co-prescribe PPI
- Opioids
- Intra-articular steroid injections – for moderate to severe pin
- **DO NOT OFFER intra-articular hyaluronan injections (2014)**

DRESSINGS

- **Purpose** - prevent post-operative contamination by providing barrier, absorb exudate

Normal dry skin contains up to 1000 bacteria per gram of tissue
Skin in exposed and moist areas contains up to 100,000 bacteria per gram of tissue

- **Classification** Permeable (non-occlusive) Vs impermeable (occlusive) to water and O2

Sorbsan & kaltostat	rope or ribbon or pad, for infected wounds/cavities Used for exudating wounds Derived from seaweed
Intrasite gel	Hydrogel dressing Rehydrate hard necrotic tissue Absorb slough and exudate Also soften eschar (dead tissue) Free flowing and fill cavity space Use secondary foam dressing to retain moisture Can come in sheets
Jelonet, Mepitel, Adaptic	reduce adherence in granulating wounds Used as transfer medium for skin graft
Tegaderm & Opsite	non-adherent absorbent pad bonded to larger thin film transparent dressing Allow passage of moist vapour & oxygen but impermeable to water & micro-organisms
Transparent film	can cause skin maceration – use sealant
Aquacel	Sealed, creates acidic and hypoxic environment - reduces In-growth of bacteria Hydrofiber technology – soft absorbent material transforms into gel on contact with wound fluid, entraps bacteria and absorbs exudate fluid
Foam dressing	Absorbs exudates Permeable to O2 and vapour but not to water
Melolin	Alginate (salt) - Low adherent & highly absorbent
Inadin	Antimicrobial
Surgicel	Absorbable haemostat Made of an oxidized cellulose polymer
Surgiflo	Haemostatic matrix with thrombin Provides matrix for platelet adherence Accelerates formation of platelet-fibrin clot
Maggot therapy (larva therapy)	Debride wounds by dissolving necrotic, infected tissue
VAC	Vacuum Assisted Closure Remove excess fluid, promote granulation tissue formation Sterile reticulated polyurethane sponge cut to conform to surface of wound Adhesive plastic sheet applied over the skin and sponge Vacuum can be set from -50 to -200 mm Hg (125 most common) Incisional VAC for closed wounds at risk
PICO	-ve pressure wound therapy Fluid absorbed into the dressing

- WOLLF trial - RCT, JAMA (2018) Matthew Costa et al.
Effect of negative pressure wound therapy vs standard wound management on 12 month disability among adults with severe open fracture of lower limb
Showed no significant difference on self-reported disability index, deep SSI, or quality of life at 12 months
- WHIST trial – JAMA (2020) Matthew Costa et al.
Effect of Incisional negative pressure wound therapy vs standard wound dressing on deep surgical site infection after surgery for lower limb fractures associated with major trauma
Findings do not support use of incisional negative pressure wound therapy

THEATRE DESIGN


(Courtesy of H Elbardesy)

Location accessible but separate from main hospital traffic
Floor Antistatic to reduce accumulation of particulate matter
Temp 20^0 for surgeon, increased to 25^0 for patient with warming blanket
Humidity 40 – 60%, any lower can risk electrostatic sparks

Ventilation

Air should contain < 0.5 CFU/m^3 (colony-forming units per cubic meter)

- **Plenum** Positive pressure gradient in theatre
  Opening of doors/moving personnel make this system less efficient
  Higher pressure within theatre relative to outside
  Clean air fed via ceiling and let out via vents placed just above floor
  20 air changes/hr to obtain 150 – 300 CFU/m^3
  $\geq$ 5 MicroM particles are removed
- **Laminar air-flow** entire body of air within designated space moves with uniform velocity in single direction along parallel flow lines
  Horizontal or vertical or ex-flow
  Restricted to areas in center of operating theatre (room within room principle)
  Theatres usually designed with vertical downward air flow concept
  300 air changes/hr
  Obstacles create turbulence especially at the edges of air-flow
- **Ultraclean** **HEPA** - High Efficient Particulate Air filters to remove bacteria
  Enclosed by panels (should extend to within 2 m of floor)
  $\geq$ 0.3 MicroM particles are removed
  < 20 CFU/ m^3 at periphery and <10 CFU/ m^3 at center of enclosure

- Lancet (2017) Effect of laminar airflow ventilation on surgical site infections: systematic review and meta-analysis. Evidence does not show benefit when compared with conventional turbulent ventilation of operating room in reducing risk of SSIs in THR, TKR, and abdominal surgeries

- AM Thomas and Simmons (Birmingham UK, BJJ 2018)

Ultraclean theatres if not used correctly may have poor microbiological performance (e.g. not wearing masks, opening instruments outside the enclosures, and not able to limit theatre traffic)

- Hooper et al. (JBJS Br 2011) –

New Zealand registry, showed no effect of ultraclean theatres or space suits in reducing early deep SSIs

- Charnley 1972

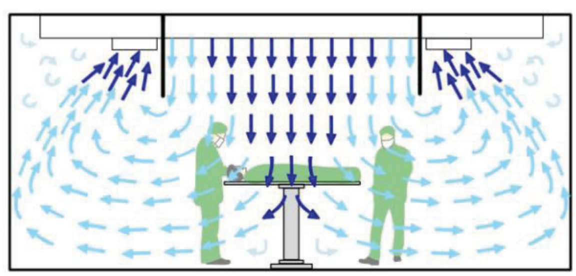
Following the introduction of vertical laminar flow, Charnley (1972) reported a reduction in the incidence of deep infection from 7% to 0.5% in the period 1960–70, during which time 5800 total hip arthroplasties were performed. Charnley attributed the decreased incidence to air factors in combination with better surgical wound closure and surgical apparel.

- Lidwell (MRC trial, 1984)

8000 patients included
Prophylactic Abx reduced infection from 2.3% to 0.6%
Further reduced to 0.2% with the addition of ultraclean air and exhaust suit
Vertical laminar flow performed better
< 10 CFU/m^3 at center and < 20 at periphery

- **Ex-flow (Howorth enclosure)** exponential flow of air downwards and outwards in shape of inverted trumpet
  High flow in centre to carry away contamination generated by surgical team
  More efficient form of laminar flow, entrainment less of a problem
  Requires less number of air changes per hour

(Theatre design)



Exponential air flow in a Howorth enclosure

Illumination Need 30 000 – 40 000 lux

Clothing Hair covered at all times
Masks in operating room – BOA all to wear + change after each operation
No outside clothes in theatre
Drapes and gowns made of impervious material

Open weave 80 microns
Easy air circulation
Allow skin scales to pass through
Low liquid penetration resistance

Close weave 20 microns
Reduce bacterial dispersion especially when wet
Inhibit air circulation – uncomfortable

Disposable non-woven Spun-laced fibres, wood pulp and polyester fibre compressed to provide fabric integrity
Most common
Bacteria get trapped
Low air permeability and moisture vapour transmission rate Single use, expensive

Theatre Zones

- **Outer** General access - Patient reception, Office corridor, changing room
  Open to foot & trolley access
- **Clean** theatre complex
  Limited access, between reception and theatre
- **Restricted** Anaesthetic room, scrub room
  Aseptic operating theatre
  Hat and masks, minimum personnel
- **Ultraclean** Inside laminar flow area
  Only scrubbed and gowned personnel
- **Dirty** Disposal, sluice

Sources of contamination

- Air-borne contamination accounts for 95% of infection risk
  Tested using microbiological volumetric slit sampler done regularly every 3 months
  Culture plates incubated for 48 hrs at 37^0
  Done inside and outside enclosed area
- Patient skin
- Theatre personnel Bacteriological count related to number of persons and their movement
  From upper respiratory tract
- Instruments and theatre fixtures

HOW TO REDUCE INTRA-OPERATIVE BLEEDING

- **Pre op** Erythropoietin erythrocyte–stimulating glycoprotein
  Made by kidneys
  Tranexamic acid - 1g prior to incision
  Iron, Vit B12 and Folate supplemnts
- **Intra op** diathermy
  Tourniquet
  Controlled hypotensive anaesthesia
  Local adrenaline injection
  Cell salvage
  Topical haemostatic agents, fibrin sealant
  TXA for topical usage 3g introduce this solution into the cavity of the joint before deflating tourniquet
  Leave to bath the bony surfaces and peri-articular tissue for five minutes
  Then remove with the sucker before routine irrigation and closure.
- **Post op** reinfusion drains

Strategies for reducing peri-operative blood loss in total knee arthroplasty – **BJJ, 2016**

SURGICAL PREPARATION

Shaving

- Only if necessary
- Preoperative shaving of surgical site night before operation associated with higher SSI risk than other methods of hair removal or no hair removal at all
- Increased SSI risk associated with shaving attributed to microscopic cuts in skin that provide portal of entry for bacteria and focus for bacterial multiplication
- If hair removed, it should be as close to incision time as possible
- Use clipper

Skin decontamination

Alcohol	Active bactericidal, cell death by desiccation	
	Good solvent, should not be used on open wounds because it could burn tissues	
Chlorhexidine	wider spectrum than Betadine	
	Lasts longer	2% (Chloraprep) lasts 48 hrs
		0.5 % lasts several hours
	Safe and does not interfere with wound healing	
Acetic Acid	Vinegar	
Povidon Iodine	should be allowed to dry	
	Lasts 30 – 40 min	
NEJM, 2010	Preoperative cleansing of patient's skin with Chlorhexidine–Alcohol is superior to cleansing with	
Povidone		-Iodine for preventing surgical-site infection

Skin closure

Meta-analysis, BMJ (2010) After orthopaedic surgery, significantly higher risk of developing wound infection when wound closed with staples rather than sutures

- **Sutures**
  - Absorbable: Monofilament — PDS, Monocryl, Biosyn; Braided — Vicryl
  - Non-absorbable: Monofilament — Nylon, Prolene; Braided — Ethibond, Fiberwire

Dyed or undyed

Round bodied (for friable tissues) or cutting needle (for closure of wounds)

- **Donati-Allgöwer suture pattern**

  Mattress suture with one side in subcutaneous tissue

  Does not result in kinking or folding of skin and, thus, does not compromise blood flow

DRAINS

Cochrane – 2007 closed suction surgical wound drainage after orthopaedic surgery

No significant difference in incidence of wound infection, haematoma, dehiscence or re-operations between those allocated to drains and un-drained wounds

Blood transfusion required more frequently in those who received drains

Need for reinforcement of wound dressings and bruising were more common in group without drains

PREVENTION OF SURGICAL SITE INFECTIONS

Stop further operating and investigate if recurrent problem
Root-cause analysis if high incidence of SSI

Pre op

- Adequate nutrition
- Optimise medical conditions — HbA1c should be < 7%
  Hold short-acting insulin and oral medications on morning of surgery
  Give half dose of long-acting insulin
- Shower NICE shows no evidence of benefit for preoperative showering or bathing with chlorhexidine over other wash products (e.g soap) or placebo, to reduce SSI
- Treat infection
- Shaving
- Equipment sterilization
- Screening for MSSA and MRSA
- Stop smoking, Serum Cotinine

Intra op

- Ultraclean air
- Minimise traffic and personnel
- Theatre personnel and patient clothing
- Prophylactic Abx
- Hand decontamination
- Skin preparation – alcohol-based solution of chlorhexidine first choice unless contraindicated and surgical site not next to mucous membrane

Meticulous tissue handling, haemostasis
Closure methods

Post op

- Occlusive dressing, allow hypoxic & acidic environment which retards growth of skin pathogens
- Dedicated elective wards

Sterilization	Autoclave	Steam
	Gamma irradiation	
	UV light	for surface sterilization only
	Gas	Ethylene Oxide

BLOOD TRANSFUSION

Autologus (cell salvage)

- **Jehovah's Witnesses**
  - Will not accept any allogeneic blood products transfusion from volunteer blood donation
  - May accept autologous blood salvaged during surgery, not donated before hand
  - Consider Erythropoietin that stimulate bone marrow to produce RBCs
- **WBC (Leukocytes)**
  - Types
    - Polymorphs — Neutophils — target bacteria
    - Eosinophils — target parasites
    - Basophils — Release histamine in inflammation
  - Lymphocytes
    - B cells — release antibodies
    - T cells
      - helper — activate macrophages and B cells
      - Cytotoxic — induce death of infected cells
      - Suppressor — regulation of B and T cells
  - Monocytes (macrophages) — Phagocytosis
    - Produce lytic enzymes (Protease), Cytokines (IL1, TNF)

SUPPLEMENTS

- **Creatin** — derived from glycine, arginine, and methionine
  - Muscle and power building supplement, source of ATP
  - Can cause muscle cramps due to dehydration
- **Anabolic steroids** — muscle growth, increases muscle strength
  - Growth hormone, Androstenedione, Erythropoietin, testosterone
  - Testicular atrophy, Reduced Testosterone & Estrogen, Oligospermia
  - Gynaecomastia
  - Deepening of female voice
  - Acne
  - Increased LDL and decreased HDL, Hypertension

GENETICS

46 chromosomes (23 pairs, 22 autosomal and 1 sex) within cell nucleus, contain DNA and RNA

- **DNA** Double helical structure with hydrogen bonds between two chains
  Forms genes
  Nucleotide bases are thymine, adenine, guanine, and cytosine
- **RNA** Nucleotide bases are uracil, adenine, guanine, and cytosine
- Allele one member of pair of genes that occupy specific position on specific chromosome
  Homozygous if 2 alleles are identical
  Heterozygous if 2 alleles differ
- Genome Pair of matched chromosomes
- Genotype what is genetically encoded
- Phenotype what is observed
- Penetrance percentage of individuals who express phenotype of dominant allele
- Variable penetrance might not have phenotype even if they have genotype
- **Metabolic condition** most likely **recessive**
- **Structural condition** most likely **dominant**
- Mitosis Growth and division of somatic cells
- Aneuploidy Loss or gain of whole chromosome
  Monosomy loss of one chromosome Turner XO
  Trisomy Extra chromosome Trisomy 21 – Down's
- HLA system found on chromosome 6
  Comprises genes which form cell surface antigen presenting proteins
  B27 ankylosing sponylitis & psoriatic arthritis
  DR1 & DR4 RA
- Tests PCR - prenatal diagnosis of sickle cell anaemia
  Molecular biology tool used to generate many copies of DNA sequence
- Apoptosis Programmed cell death, lost in cancer
- Genetic counselling for inherited conditions
  Advised of consequences and nature of disorder
  Probability of transmitting it
  Options in management and family planning
- Haploid amount of DNA in human egg or sperm cell half amount of DNA in normal cell
- Cell cycle consists of 4 phases - initial growth (G1), DNA replication/synthesis (S), gap (G2), mitosis (M)
- Anticipation disorders that present earlier and more severely in affected subjects than in their affected parent
- Tumour suppressor genes Inhibit cell proliferation, prevent neoplasia
  Absence leads to unregulated cell growth

Genetic aberrations

Chromosomal	structural	deletion
		Translation
	Numerical	Trisomy, e.g. Down's
		Monosomy, e.g. Turner's
Single gene	Mendelian inheritance	
Polygenic	multifactorial	

(Genetics for FRCS)

DDH, CTEV

- **Mendelian inheritance** Traits inherited by genes located on autosomal or sex chromosomes
  - **Autosomal dominant** Only need to get gene from 1 parent to inherit phenotype
    Structural
    50% of off springs affected
    Achondroplasia, Marfan, Ehlers-Danlos, MHE
  - **Autosomal recessive** 2 copies of abnormal gene must be present to develop the disease
    Enzyme/physiological deficiencies
    Affected (phenotype) are homozygous
    Carriers are heterozygous
    Sickle cell anaemia
  - **Sex linked** Most of sex-linked traits are on X chromosome
    Dominant Hypophosphataemic rickets - the only X linked dominant ortho condition
    Recessive Single recessive gene on X chromosome cause disease in males
    Carrier mothers transmit to male children
    Haemophilia, Duchenne muscular dystrophy

INFLAMMATION

Acute Red, Hot, Pain, swelling, loss of function
In response to pathogens – macrophages and histiocytes release inflammatory mediators
These cause vasodilatation and leakage of fluids from capillaries
Outcome – resolution, scar tissue, chronic inflammation

Chronic

BMI

Body mass index body mass divided by square of body height expressed in units of kg/m^2

Accepted BMI ranges		
	underweight	< 18.5
	Normal weight	18.5 to 25
	Overweight	25 to 30
	Obese	> 30

STIMULANTS

Caffeine
Amphetamine
Ephedrine

ORTHOTICS

Orthosis is a device that is externally applied or attached to a body segment that facilitates or improves function by supporting, correcting, or compensating for skeletal deformity or weakness

Ideal Orthosis

- Biomechanically effective
- Lightweight
- Durable
- Cosmetically pleasing
- Easy to apply and take off
- Rapid Provision and replacement
- Inexpensive
- Washable
- Adjustable
- Comfortable
- Free of pressure areas

➢ **Functional Characteristics**

- Provision of Support
- Limitation of motion
- Correction of deformity
- Assistance of motion
- Miscellaneous e.g. Warmth, placebo
- Combination
- Static versus dynamic

➢ **Principle of application**

- At least 3 points of pressure
- Joint must be maintained in optimal anatomical position
- Principal force applied at joint
- Opposed by two forces , one proximal and one distal
- The sum from all applied forces must be Zero to achieve equilibrium

➢ Types: Static Rigid
Dynamic Allow joint movements

➢ **Basic biomechanical concepts**

- Newtons laws
    - 3rd law - for every action, there is an equal and opposite reaction
- Gait Patterns
    - May require gait lab
- Ground Reaction Force (GRF)
    - If not passing through the centre of joint, it will create a moment arm on the joint
        - Midstance
            - ✓ GRF posterior to hip therefore causes extension

Resisted by anterior capsule
- ✓ GRF anterior to knee therefore causes extension
  Resisted by posterior capsule
- ✓ GRF anterior to ankle therefore causes dorsiflexion
  Resisted by Gastrocnemius soleus complex
- o Pre-swing
  - ✓ GRF posterior to knee therefore causes flexion
- Coupling: concept of affecting one joint by the position of another
- Use Free Body diagrams to resolve forces about joint with orthosis

➢ **Biomechanics**
- Control moments about joint
  - Three point fixation using rigid frame, straps and pads
  - Sir Charnley principle for fracture immobilisation
  - Only prevents movement in one plane, and one direction
  - Example: Knee Orthosis for medial ligament injury
- Control of translational forces across a joint
  - 4 point fixation to prevent translation
  - Example: Knee orthosis for PCL injury
- Control of Axial Forces across a joint
  - Load sharing device
  - Example: Exoskeleton for arthritic joints
- Control of line of action of GRF
  - Modification of point of action and the line of action of the GRF
  - Example: lateral heel wedge for medial knee OA

➢ **Materials**
- Leather: used in shoes
- Rubber: padding, shock absorbing
- Plaster of Paris
- Metal: rigid and adjustable
- Thermosetting plastics
  - Moulded to a permanent shape
  - Liquid plastic, with catalyst which polymerizes resin into rigid form
  - High temperature required to mould, difficult to fabricate
  - Durable, used for prosthesis/orthosis which are under great stress
- Thermoforming plastics
  - Reshape when heated, advantage
  - based on moulding temperature
    - o High temp. 120-190^{o}C (polyethylene or polypropylene)
      - ✓ Ideal for high stress activities
      - ✓ Variability in molecular weight, tensile strength, fatigue resistance and mouldability
    - o Moderate temp. 100-120^{o}C

- ✓ Can be applied to patient as cooling as to allow moulding, due to low conductivity of heat
- o Low Temp <80 ^{o}C, polymers such as polyisoprene and polycaprolactone
  - ✓ Can be warmed in hot water bath, easily applied
  - ✓ Less rigid and durable
  - ✓ Easily used as hand therapy splints.
  - ✓ Modified by hair dryer or heating in water
- Self generating Polyurethane foam
  - Allows shapping on the patient, hardens after application
  - Corsets/braces
  - Moulded cushions for wheel chair

➢ **Common Orthosis**

- **Foot** (Corrective or Accommodative)
  - Insoles
    - o Simple: off shelf, fabricated without casting, poor contact, little control
    - o Total Contact: made from imprint of patients foot
    - o Functional: foot held in corrected position when cast is taken
      - ✓ When flexible deformity, insole corrects deformity
      - ✓ Fixed deformity - accommodative insole
  - Shoes
    - o External
      - ✓ Heels
        - ✓ Cushioned
        - ✓ Flared medial vs lateral (resists eversion vs inversion)
        - ✓ Wedged medial to promote inversion, lateral to promote eversion
        - ✓ Extended, for support
        - ✓ Elevated for LL discrepancy or equinus deformity
      - ✓ Soles
        - ✓ Rocker bars
        - ✓ Metatarsal bars
        - ✓ Wedges
        - ✓ Flares
    - o Internal
      - ✓ Heels
        - ✓ Cushioned relief
        - ✓ Cups
        - ✓ **University of California at Berkeley Laboratory (UCBL) insert**, used to control hindfoot valgus and midfoot pronation
      - ✓ Soles
        - ✓ Metatarsal pads
        - ✓ Inner sole excavations
        - ✓ Arch supports
        - ✓

- **Ankle-Foot Orthoses**
  - Used to prevent or correct deformities and reduce weight bearing.
  - Ankle position affects knee stability
  - Shown to reduce energy cost of ambulation (CP spastic diplegia, post polio syndrome, sCVA related spastic hemiplegia)
  - Consist of shoe insert, calf shell, a heel retaining strap, and calf strap.
    - Posterior leaf spring, used for compensating for weak ankle dorsiflexors
    - Solid AFO holds ankle and foot position
    - Hinged AFO, set to desired ankle position, e.g. prevents plantarflexion but allows dorsiflexion
    - GRAFO: prevents knee hyperextension by creating flexion moment around the knee (requirements: Full knee extension, ankle dorsiflexion to neutral with and extended knee, no significant rotational deformity in tibia or foot)
    - DAFO or TRAFO principle of inhibitive casting. Reduces tone in muscles groups in CP
- **Knee Ankle Foot Orthosis KAFO**
  - An extended AFO, joint at knee,
  - Used in patients who are unable to maintain knee stability.
- **Trunk-Hip-Knee-Ankle Foot Orthosis**
  - Extends to spine
  - Paraplegic


(Courtesy of S Mansukhani)

- **Miscellaneous**
  - Weight bearing orthoses (PTBO for diabetic ulcers)
  - Charcot Restraint Orthotic Walker (DM, Syphilis, Leprosy)
  - Fracture Orthosis (Sarmiento Hydrostatic compression)
  - Angular and Deformity orthosis (Denis Brown orthosis as part of Ponseti treatment)
  - Hip orthoses for paediatric disorders (Pavlik harness)

- **Complications**
  - Psychosocial
  - Physical
    - Compression phenomena
    - Heat and water retention
    - Patient orthosis interfacial effects – Interface is the junction between orthosis and patient
      - Patient intrinsic factors – paralysis, decreased sensation, PVD
      - Extrinsic factors – bony prominences, thin subcutaneous tissue
      - Avoided by
        - ✓ Proper contouring to increase contact area
        - ✓ Good mechanical design
        - ✓ Reduce shearing
        - ✓ Adequate padding

When you are asked to describe an orthosis:

- This can be anything! It could be something you have never seen. It doesn't really matter .Chances are that the examiner also didn't know before the start of the exam.
- Stick to the below principles and you will impress any examiner.
    - Start describing the part of the body it supports such as AFO, KAFO etc
    - Described by the joint or region of the body it encompasses.
        - Upper limb: S = shoulder
          E = elbow
          W = wrist
          H = hand
        - Spine: C = cervical
          T = thoracic
          L = lumbar
          S =sacroiliac
        - Lower limb H = hip
          K = knee
          A =ankle
          F = foot
- Then describe whether it is corrective or accommodative
- Then describe whether it is static or dynamic
- Then describe the materials it is made from

Functional Classification of orthosis

- Orthosis can be classified according to function into corrective and accommodative
    - **Corrective** tend to be hard. They limit joint motion and stabilize flexible deformities. An example is the rocker sole that can lessen the bending forces on an arthritic or stiff midfoot during the midstance as the foot changes from accepting the weight-bearing load to pushing off. It is also useful in treating metatarsalgia and hallux rigidus.
    - **Accommodative** tend to be soft to allow them to shock-absorb and to accommodate fixed deformities such as various pressure-relieving insoles that are used to dissipate local pressures over bony prominences to treat diabetic foot.
    - Sometimes the same orthotic can be used for support and/or correction
      The TLSO which can be supportive in the case of fractures or corrective in the case of idiopathic scoliosis
      AFO which can be supportive for weak muscle in polio or corrective in cerebral palsy.

How does an orthotic work?

- They work according to the three-point pressure principle to control the forces on the body part. This is the same principle that was proposed by Sir Charnley for fracture immobilization.
- To control joint movements, one force should be over the joint and the other acts in the opposite direction
- 'It would be preferable here to ask for a piece of paper and draw as you talk'

GRAFO (Ground Reaction Ankle and Foot Orthosis)

- Ground Reaction Force (GRF) is a force that is exerted by the ground on the body. It is equal in magnitude but opposite in direction to the force exerted on the ground by the body.
- This is based on Newton's 3rd law;. Therefore, by controlling distal joints one can effect more proximal joints. The concept of affecting one joint by the position of another is called coupling. E.g. knee extension-ankle plantarflexion coupling
- Crouch gait in CP – excessive knee flexion and ankle dorsiflexion
- GRAFO is formed from a toe plate and rigid ankle in neutral position, and a rigid anterior tibial shell. It provides knee supports for patients with weak quadriceps and Gastrocsoleus. It provides an extension moment arc at the knee joint (as the GRF passes anteriorly to the knee) when the ankle is fixed in plantarflexion.So preventing foreword tibia progression and knee collapse
- By fixing the angle of the ankle (in plantarflexion or dorsiflexion) the ground reaction force can be positioned either anterior or posterior to the knee joint to encourage flexion or extension.

Functional bracing

- This was advocated by **Sarmiento** from the USA
- In a review paper he published in the BJJ in 2006, he described how his technique. He believes that rigid immobilisation of fractures of long bones is un-physiological, and that movements and continued functional activities encourages osteogenesis , and that continuing function while a fracture is uniting encourages ,and that intermittent loading of the fracture by muscle activity/weight bearing promotes local blood flow
- The principle is to stabilize the fracture while allowing weight bearing and joint movements. Motion at the fracture site is prevented through circumferential compression of the soft tissues.
- Examples PTB :triangular shape proximally to cover medial flare of tibia and patellar tendon

UCBL (University of California Biomechanics Laboratory)

It is a rigid plastic insert that is fabricated over a cast of the foot with rigid and high posterior, medial and lateral walls to provide a deep cup.

It is used to control severe hind foot valgus and midfoot pronation

Used for Adult acquired flatfoot, PTTD, flexible pes planus, plantar fasciitis

(courtesy of F Arnaout)

Boston brace

It is used to treat paediatric scoliosis. It is custom made and works on the principles of three-point fixation. The bottom part is fixed around the pelvis, and the top part has raised sides for improved sideways support to avoid lateral shift of the spine. Extra padding can also be used in certain areas to help improve the corrective forces.

Charcot Restraint Orthotic Walker (CROW)

Used in the end-stage foot disease of diabetes

Boots

1- Simple walking boot with Velcro straps
2- Air cast boot : air inflated with little pump to make it snug fit

Principles to minimize orthotic-limb interface pressures are

1 - Maximize lever arm
2 - Maximize surface contact area
3 - Maximize conformity
4 - Protect bony prominences
5 - Moist absorbent lining

PROSTHETICS

- **Definition:**
  - A device or artificial substitute designed to replace the function or appearance of a missing body part
  - Aim to maximise the patient's functional independence
- **Outcomes dependant on**
  - Patient
    - Pre-morbid level of activity
    - Level of amputation
    - Ability to learn new skills
    - Pathology of contralateral limb
    - Static and dynamic balance
    - Sufficient trunk control (and upper-limb strength)
    - Other comorbidities
  - Prosthesis
    - Comfortable to wear
    - Well suspended with minimal pistoning movement
    - Easy to put on and take off
    - Appropriate components
    - Lightweight, durable and reliable
    - Cosmetically pleasing
  - Teamwork
    - MDT (Surgeon, Rehab Physician, Prosthetist, Specialist physio, Occupational Therapist, and psychologist
    - Pre-amputation assessment with rehab team (where possible)
    - Early rehabilitation and MDT approach
    - Joint decision for operation, with stump fashioned for prosthesis in mind

(Prosthetics for FRCS)

- **Prostheses classifications**
    - Level of amputation
    - Structure

Structure	Exoskeleton	Rigid outer shell with hollow prosthesis
	Endoskeleton	Modular, internal strut covered in soft external cosmesis

    - Function
- **Common elements**
  - **Socket**
    - Connection between prosthesis and residual limb
    - Protects residual stump and transmits force
    - Manufactured by a plaster mould or computer assisted mapping of stump
    - May need to be serially adjusted to the volume of stump as it changes
    - Silicon is commonly used as it provides airtight seal between prosthesis and amputated stump
    - Weight bearing areas for the socket include the heel pad, trans-tibial, patellar tendon, lateral tibial flare, medial tibial flare, trans-femoral, and Ischial tuberosity
  - **Suspension**
    - Attaches the prosthesis to stump
      - ✓ Easy to apply and remove
      - ✓ Minimal pistoning

- Classified as
  - ✓ Anatomic or self-suspension, grips the bulbous stumps
  - ✓ Belts, straps or sleeves
  - ✓ Roll-on locking liners (liner on stump has pin on end which locks into stump)
  - ✓ Suction suspension (look for valve on prosthesis)

- **The Link (shank)**
  - Connects socket with terminal device
  - May be a metal or carbon-fibre pilon connecting socket to terminal device
  - May include articulation
  - May include a dynamic device for shock absorption
- **The Terminal device**
  - Weight bearing (foot) - energy storing or non-energy storing
  - Function providing(hand)
  - Static (Cosmetic)
  - Dynamic(functional)

How is the load transferred from the prosthesis to the limb?

There are two types of load transfer; direct and indirect:

- **Direct load transfer or end-weight bearing** is accomplished with knee disarticulation or ankle disarticulation (Syme's). Intimacy of the prosthetic socket is necessary only for suspension.
- **Indirect load transfer** is when amputation is performed through a long bone (BKA or AKA) and the end of the stump does not take all the weight and the load is transferred indirectly by the **total contact method**. This process requires an intimate prosthetic socket fit.

What are the different types of knee joint mechanism?

- This can be single axis which has the advantage of being light weighted, or polycentric with four bars linkage and a moving centre of rotation that provides controlled flexion during the gait cycle, this is good for longer residual limbs.
- There is also the Hydraulic knee which allows variable cadence via piston mechanism and is suitable for shorter residual limbs in patients with higher activity levels.
- Or simply a manual locking knee which consists of a constant friction knee hinge with a positive lock in extension that can be unlocked to allow function, this is used primarily in weak, unstable patients and those just learning to use prosthetics and for blind amputees.
- The new design development includes micro-processor controlled knee plus a motor. Battery life, weight and cost are significant limiting factors.

Different types of foot prosthesis

- **Solid Ankle Cushioned Heel prosthesis (SACH)**

This is a non-energy storing device used for patients with low activity levels as it is light in weight, cost effective and requires little maintenance. It can lead to overload on the non-amputated limb and therefore has been replaced by a Single-axis foot which is based on ankle hinge that provides dorsiflexion and plantar flexion.

- **Energy storing non-articulating foot prosthesis**

It is made of carbon fibre. Components are compressible which provides some energy return.

- **Energy storing articulating hydraulic prosthesis**

It allows inversion, eversion, and rotation of foot and is useful for walking on uneven floor.

- **Motor-powered ankle**

Rechargeable batteries and controlled by micro-processor. Reduce energy requirements of walking but are heavy and costly.

Complications of the prosthesis

- The most common complication is **pistoning**, which can occur during the swing phase due to **ineffective suspension** or during the stance phase due to **poor socket fit** or due to **stump volume changes**. The shear forces from pistoning can cause **skin damage** and can make the prostheses feels heavier.
- Skin damage, blisters and ulcers. To avoid these, plaster of Paris mould is made by the prosthetist to mark the pressure areas which are to be taken into account when the prosthetic is being fashioned trying to minimize the pressure through unprotected bony prominences. More recently, computer-assisted technology is used to map the stump.

  Maximize the surface area through which the forces are applied to the skin and maximize the conformity between the orthotic and the underlying limb. The material at the interface should be moisture absorbent to avoid skin maceration.

Types of upper limb prostheses

Upper limb prostheses can be cosmetic, functional or myoelectric.

- Cosmetic are passive with no moving parts but can have some function such as turning a light on. They also improve gait
- Functional prostheses can be body powered, activated by shoulder movements via a harness and cables, these tend to have poor cosmesis.
- Myoelectric which are powered by muscles sending signals via attached electrodes to the prosthesis. These signals are magnified and passed to a microprocessor to operate the terminal device. These prostheses are heavy and therefore best suited for trans-radial amputations. They also require maintenance and training, but provide better cosmetic appearance and tend to be more functional with better movements.

  The terminal device can be a split hook powered by body or a powered device.

STATISTICS

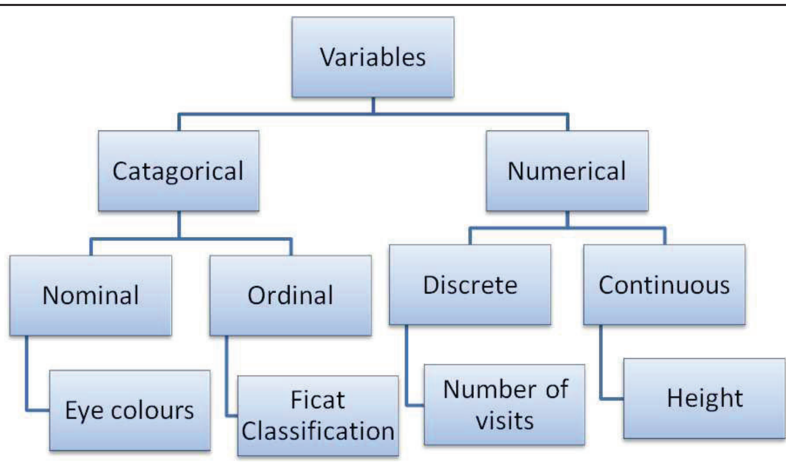
Data
It is observation of variables

Types of data (variable)

- Categorical (Words) Objects grouped into categories
  - Types **Ordinal** ordered
    Disease severity (mild, moderate, severe), Ficat stage
  - **Nominal** un-ordered each category is equal
    Gender, eye colour, type of prosthesis
  - Displayed in bar or pie charts
  - Analysed using Chi squared or exact fisher tests
  - Binary variable - has two values only
- Numerical **Continuous** normally distributed, can take any value
  Weight , height, BP
  Described using parametric tests such as student t test
  - **Non-continuous** (discrete): also called count, whole numerical value, number of children
    Described using Mann-Whitney or Wilcoxon tests
  - Displayed in a histogram or scatter plot graph or box-whisker
  - Described using mean, median, mode and interquartile range

(Statistics in orthopaedic papers)

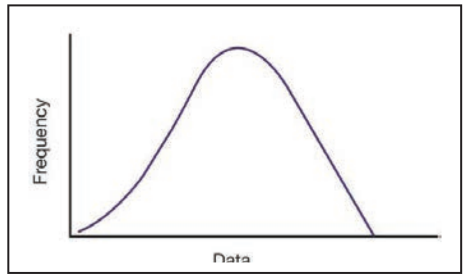
Unpaired data Observations from separate subjects
Paired data Observations are from same subject



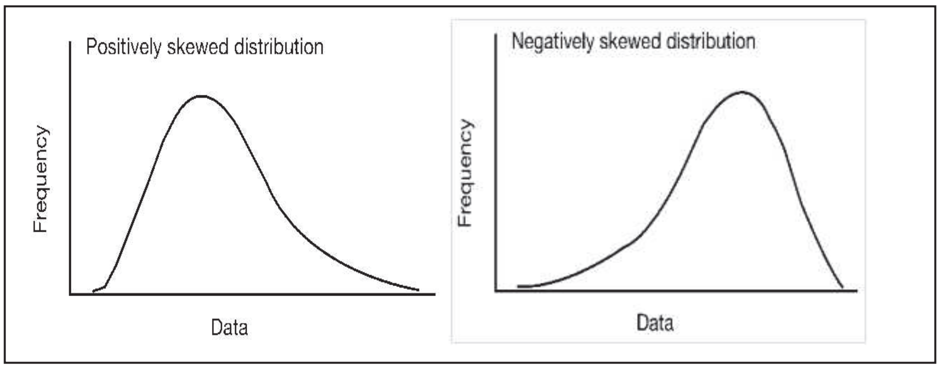
(Courtesy of A Hanoun)

Data distribution

Normal (Gaussian) distribution: bell-shaped curve



Skewed distribution has a tail, which is eitherpositive or negATIVE

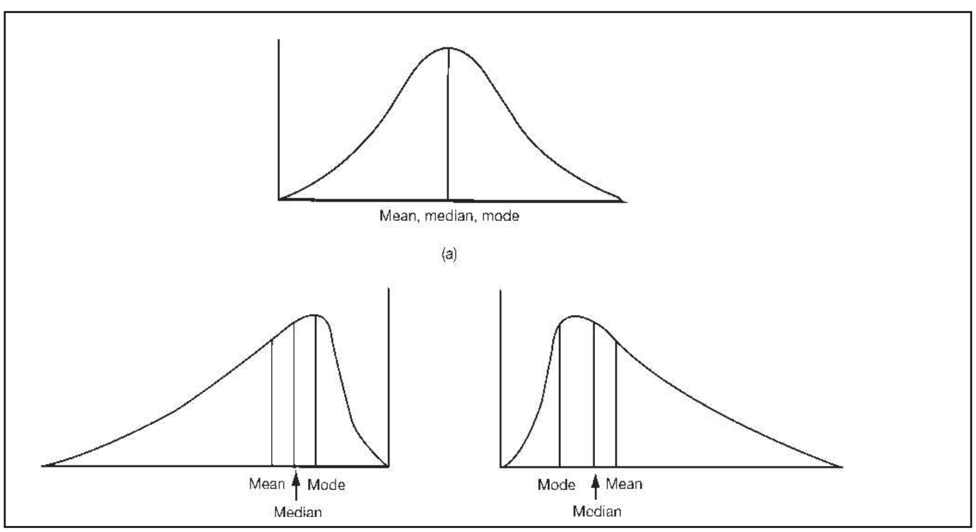


If data distribution is skewed, then the median or mode has to be used to measure central tendency.
If there is doubt about the normality of a distribution, then it is best to assume that any given distribution is not normal and, therefore, data should be tested for normality.
Transformation is the method by which non-normal data can be normalized in order to allow parametric testing.

Measures of central tendency

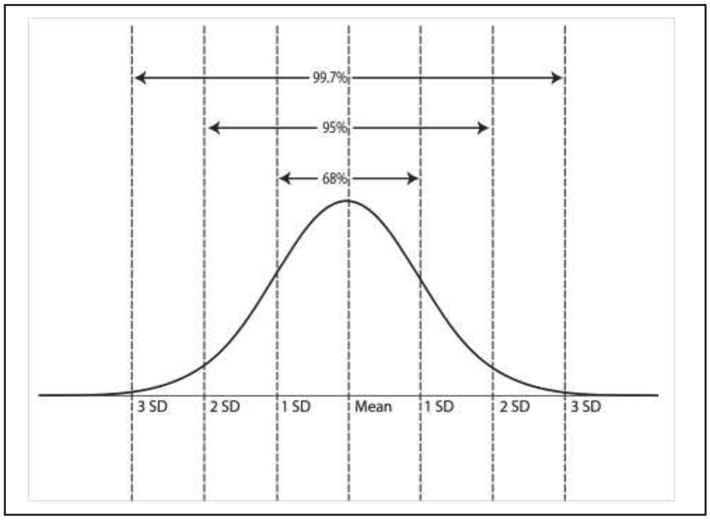
a) **Mode**: value which occurs more frequently, used for categorical data
b) **Median**: 50th percentile, middle value or average, used when there are values that might skew your data
c) **Mean**: average of values, used for parametric data (normally distributed)

For perfectly normally distributed data, the mean, median and mode are the same.

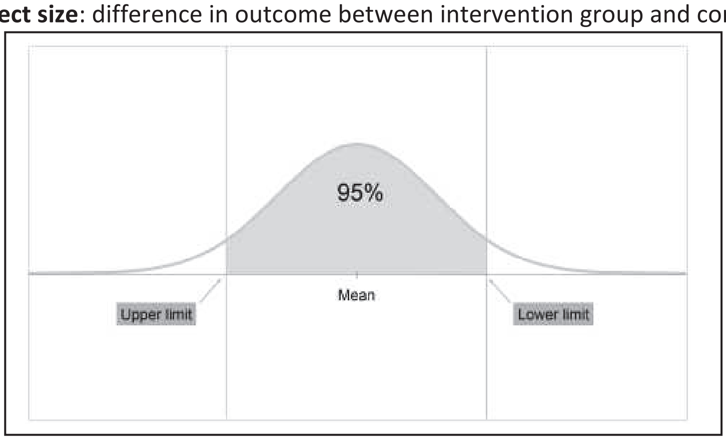


Measure of spread/variability

- **Range**: the lowest and highest values of the data
- **Percentiles**: groupings of data into brackets of 1 %, 10 % or, more commonly, 25 % (known as quartiles)
- **Variance**: is the average of the corrected sum of squares about the mean
- **Standard deviation (σ):** the **square root of the variance** (the use of the square root gives the same dimension as the data). It is a measure of deviation of individual values from mean.
  For reasonably symmetrical bell-shaped data, one standard deviation (SD) contains roughly 68 % of the data, two SD contain roughly 95 % of the data and three SD contains around 99.7 % of the data.



- **Confidence Interval (CI)**:
  - Interval that includes value with specified probability (95%), 2 SD on either side of mean
  - Measure of variation and describe where results are likely to be.
  - Widens when increased uncertainty from reduced number of patients
  - **Effect size**: difference in outcome between intervention group and control group divided by standard deviation



Data Interpretation

All good studies test hypotheses

Null hypothesis: where a primary assumption is made that any difference seen occurred purely by chance.

P value Probability that results occurred by chance (ranges between 0-1)
If < 0.05 = null hypothesis rejected
Represents false +ve
The smaller the P value, the stronger evidence against null hypothesis

Orthopaedic surgeons are usually willing to accept a 5 % probability that the difference seen was due to chance (P = 0.05)

Errors

- Type I (alpha) error false (+ve)
  Incorrectly rejecting null hypothesis
  Because of confounding factors (other causes) or using too many tests
  This is the P value; acceptable level is 5 % or 0.05
- Type II (beta) error false (-ve)
  Incorrectly accepting the null hypothesis
  Because of small sample size (inadequately powered)

Power probability of finding significant association if it exists
Estimate of probability that a study will be able to detect true effect of intervention, usually
Accepted at 80% for 20% type II error
Power = 1 - (probability of a type-II, or beta error)

Pearson correlation r value measures relation between 2 variables which are normally distributed
Recurrent falls and number of fractures
Rages from -1 to +1
+ve value means that association is +ve. i.e. if X increases Y increases

Spearman correlation test association between two variables when data is ordinal

Regression analysis to estimate association between two variables
Independent variable causes change in dependent variable
Graph plotted with data concentrated along an imaginary straight line
Shows correlation between the variables

Power analysis

Method of determining number of subjects (sample size) needed in order to have reasonable chance of showing difference if it exists

Factors affecting power analyses

1. Size of the difference between the means (the larger the difference, the easier it is to detect a difference and the greater the power)
2. Spread of the data (the larger the spread, the less likely a difference will be detected)
3. Acceptable level of significance (i.e. the P value that is set)
4. Sample size (power increases with increasing sample size)
5. Variability in observations (the larger the variability, the lower the power)
6. Experimental design (e.g. within subjects versus between subjects)
7. Type of data (parametric versus non-parametric)

(Statistics for FRCS)

Study designs
- Observational: the investigator observes rather than alters events (PE after THR)
- Experimental: the investigator applies a manoeuvre and then observes the outcome (Heparin versus Placebo for DVT prophylaxis in THR)

Study timelines
- Retrospective study: the outcome of interest has already occurred
- Prospective study: follows the patient or cohort forward in time
- Cross-sectional study: examines patients or events at one point in time without follow-up

Significance testing

To test for statistical significance, think about the following:
1. What type of data has been used in the study?
2. What is the sample size?
3. Are the groups distributed normally?
4. Do the data need to be transformed so that we can make a normality assumption?
5. Are the groups interdependent? (Is a paired test required?)
6. Is a single- or two-tailed P value necessary? (Two-tailed tests are most common, though if looking for a unidirectional association then a single-tailed test may be used.)

Tests can be Parametric: data were sampled from a normal distribution
Non-parametric: makes no such assumption

Parametric tests	Non-parametric tests
Assumes data were sampled from normal population Observations must be independent. Populations must have the same variance. Can use absolute difference between data points. Increased power for a given sample size (n).	No assumptions made about the origins of the data. No limitations on types of data. Rank order of values. Less likely to be significant. Decreased power for a given sample size

- **Paired t-test**

  This should be used when there is a pair of observations **on a single subject**, e.g blood pressure before and after application of a tourniquet.

  If there are multiple observations, then analysis of one-way variance (ANOVA) should be used.
- **Unpaired t-test**

  This can be used to compare **two random samples** provided they both follow a normal distribution.
- **Chi-squared test**

  The chi-squared (X2) test can be used for qualitative data.

  The test is unreliable if any of the expected values is less than five (in which case, use **Fisher's exact test** instead

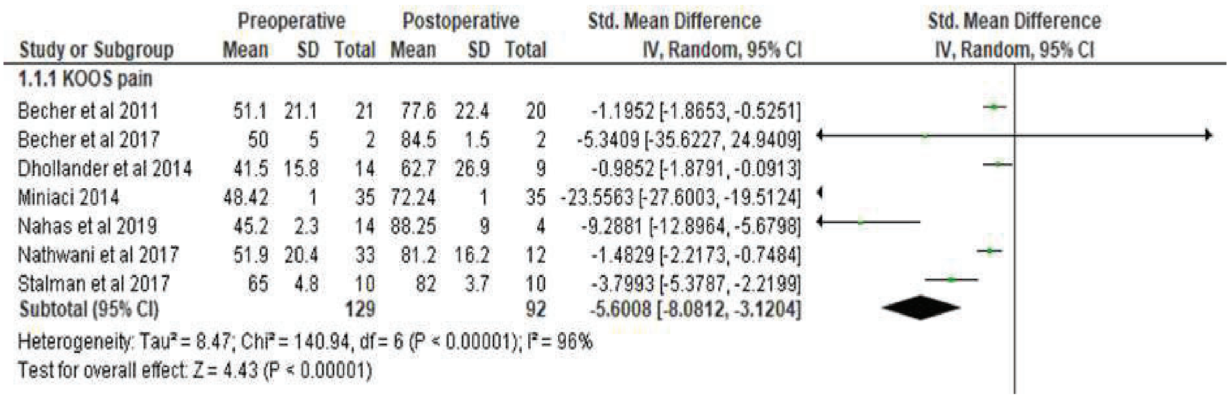
Levels of evidence

Evidence based medicine uses the best evidence in making decisions about care of individual

Meta-analyses (Quantitative)

Statistical analysis that combines the results of multiple scientific studies that address the same question

- The results are usually presented in the form of a **forest plot**
- The left-hand column includes the studies reviewed, and the right measures of the effect size for each study with a CI
- The area of each 'square' indicates the weight of the study (i.e. fatter squares are from bigger studies)
- A vertical line indicates the line of no effect i.e. odds ratio = 1, so if the CIs cross this line then the study demonstrated no significant effect
- An overall effect size is denoted by a diamond, the size of which is determined by the overall 95% CI.



(Forest plot of meta analysis (courtesy of H Elbardesy))

Heterogeneity Is a problem that can arise when attempting to undertake a meta-analysis.

Ideally, the studies whose results are being combined in the meta-analysis should all be undertaken in the same way and to the same experimental protocols.

Study heterogeneity is a term used to indicate that this ideal is not fully met, for example we can combine apples even from different colours (red, green and yellow) but we couldn't combine apples and oranges.

Low Heterogeneity: 0-25%

Medium Heterogeneity: 25-75%

High Heterogeneity: > 75%

Statistics for FRCS)

Systematic reviews (Qualitative)

Systematic and explicit methods to identify, select and critically appraise relevant research, and collect and analyse data from the studies that are included in the review.

Randomized controlled trials

Groups of patients are randomized to either receive or not receive an intervention, and the outcomes are compared in a prospective manner.

Study design features

Randomization:

Ensures that all prognostic variables, both known and unknown will probably be distributed equally among the treatment groups. This avoids bias in treatment assignment.

Types of randomization include the following:

- **Simple**: computer-generated tables (days of the week), this method may not be appropriate in small or multicentre trials, as it doesn't ensure that each group has the same population (age, sex, etc.)
- **Stratified**: ensures equal distribution between treatment groups, only two or three variables are stratified (age, sex, etc.). Stratification is practical only in large trials and should be performed by each centre in multicentre trials.
- **Block**: treatment is allocated by blocks of set size. This ensures that an equal number of patients are assigned to each treatment. For example, if the block size is six, then three receive treatment A and three receive treatment B.

Bias:

Flaw in impartiality that introduces systematic error into the methodology that has potential to affect the results of a study. Bias can be reduced in several ways, including randomization, masking (previously known as blinding), and meticulous attention to the study protocol.

Types of bias:

- **Selection bias**: an individual may or may not be included in the study if the investigator believes that one particular treatment would favour the individual over the other. This can be overcome by allocation concealment.
- **Ascertainment bias**: knowledge of the intervention (by either the researcher or the participant) may distort the results, because a belief is held that one treatment is better than the other. This can be overcome by masking/blinding.
- **Recall bias**: a person's recall may change based on the presence of disease (i.e. if a child is diagnosed with transient synovitis, then the parents are more likely to remember that the child had a cough last week, compared with parents whose child doesn't have the condition). This is best overcome by prospective data collection, and/or biological measures where possible to validate results.

- **Publication bias**: higher publication success amongst those studies with positive findings. Error in way cases selected or measurement undertaken
- **Systematic** incorrectly calibrated instruments
- **Observer** assessor, placebo effect, use validated P&C ROMs
- **Information** DNAs usually have better outcomes
- **Publication** positive studies published more
- **Verification** results of diagnostic test influence whether patients assigned to treatment group
- **Recall** patients who experience adverse outcome have different likelihood of recalling exposure than others that don't have adverse outcome

Confounding factors:

When a variable is independently associated with both the outcome and the exposure, such that false conclusions are reached. One example may be that grey hair is associated with osteoarthritis (OA), which of course is confounded by age (age is associated with grey hair and OA). Confounding can be reduced by matching or measuring (i.e. stratification can be done looking at people at different ages with and without grey hair to see if hair colour really is independently associated with OA).

Masking/blinding:

Protects against ascertainment bias. Blinding can be single (only the patient is blinded) or double (both the patient and the investigator are blinded) or triple blind (knowledge of treatment assignment is concealed from patient, investigators, and analysts/statisticians)

Cohort studies

- The best available scientific method for measuring the effects of a suspected risk factor.
- Prospective cohort study, the researchers raise a question and form a hypothesis about what might cause a disease. Then they observe a group of people, known as the cohort, over a period of time that may take several years.
- Problems with cohort studies include lengthy follow-up (i.e. a disease may only become apparent after many years following exposure), expense and the difficulty in examining rare diseases/outcomes as the practicalities of the study limit the initial size of the cohort.
- Not randomized

Case–control studies

Studies where individuals with a certain outcome (cases) are compared to individuals without the outcome (controls)

- A historic (retrospective) analysis of 'exposures' (i.e. the things that may have triggered the disease outcome) is made.
- These studies are quick and cheap to perform and, if constructed carefully, can yield clinically relevant information, e.g. odds ratios.
- They are particularly useful in trying to identify the causes of uncommon diseases
- Unfortunately, case–control studies have many methodological biases

Case series

- The outcomes of a group are reported, but there is no comparison group
- They should act as a stimulus for more powerful studies

Expert opinions

An expert in the field gives opinion on a given subject

Critical appraisal of published paper

- Does study address important relevant clinical question?
  Null hypothesis: two interventions are equally effective, and any difference is by chance
- Is research question complete (study design)? (PICO)

Population	What are inclusion /exclusion (eligibility) criteria
Intervention	
Comparison	control group
Outcome	

- Aim of the study?
- What type of study is it? (Level of evidence)
- Design of the study? Observational descriptive
  Or experimental
- What is the study time-line: Retrospective, prospective or cross-sectional?
- What type of research is it?

Quantitative - Objective, RCT, categorical, hypothesis (Interventional or observational)
Qualitative - Subjective, interview/questionnaire, open-ended questions, and no hypothesis

- Validated Primary and secondary outcome measures used
  - Have high inter-observer and intra-observer reliability and reproducible
  - Primary outcome measure decides success/failure of intervention
  - Validity extent to which test or outcome measure actually measures what it purports to measure
- Supported by high quality research studies
- Reliability consistent measurement
- Where was study performed? Multicentre increase external validity
- Details of how procedures were done
- Any bias? How sample size was determined?
  Large enough to detect significant treatment effect if exists, but not too large to waste resources and have unnecessary number of patients receiving inferior treatment
- What are methods of data collection?
  - Randomised stratified randomisation by age, gender, etc
    Minimizes selection bias, facilitates blinding
  - Controlled To prevent type I error (false +ve) caused by confounding factor
    Confounding variable other than the one studied that can cause or prevent the outcome
  - Blinded to avoid assessment bias - participants don't know whether they are in control group or not
  - Hawthorne effect - behaviour changed when participants have knowledge that their behaviour is monitored
- Were appropriate statistical tests used?
- Were all patients who entered the study accounted for at the end?
- Was Intention To Treat (ITT) analysis performed?
  - Patients who dropped out were still analysed in their original group
  - Minimizes non-responder bias
  - Or was it as per-protocol analysis
- Are conclusions justified by results?
- Could the results be generalized?

Phases of clinical trials

0 First-in-human trials
Sub-therapeutic doses of drug given to small number of subjects (10 to 15) to gather data on pharmacodynamics (what drug does to body) and pharmacokinetics (what body does to drugs)

1 Researcher test experimental drug or treatment in small group of people (20-80) to evaluate safety, determine safe dosage range, and identify side effects

2 Experimental treatment given to larger group of people (100-300) to see if effective & further evaluate safety

3 Treatments given to large groups of people (1,000-3,000) to confirm effectiveness, monitor side effects, compare it to commonly used treatments

4 Post marketing studies delineate information, including treatment's risks, benefits, and optimal use

How to conduct trial

1. Identify problem (hypothesis)
2. Identify gold standard (literature search)
3. Design study
    - population
    - Randomization
    - Inclusion/exclusion criteria
    - Comparison
    - Methodology
    - Observational (observe daily practice)
    - experimental (does we intervene)
    - Cohort, cross sectional, case-control
4. Study time-line
5. Power analysis:
6. Ethical approval (Integrated Research Application System)

   The ethical committee is formed of university's professors

   The application must include
    - Study details and protocol
    - Co-Investigators detail
    - Study Sponsor
    - Does the Chief Investigator personally gain financially from this funding?
    - Study Insurance
    - Details of the Procedures to which humans will be subjected
    - Potential benefits to subjects and/or society
    - Potential risks to subjects and precautions taken to minimize risk
    - Alternative procedures, if any, available to subjects
    - Will participants receive payment/reward for participation in the study
    - Information on previous Ethics Applications
    - Funding
7. Collect data
8. Analyse results to draw conclusions
9. Write up and publish to apply knowledge gained

Publications

The Impact factor IF - measure of citations to science and social science journals over 2 years period
Used as a proxy for importance of journal to its field
JBJS topped field of orthopaedic journals with IF of 5.13
PubMed - Platform to give access to Medline

Structure of paper

Abstract

- Background
- Objectives
- Setting
- Design & methods
- Patients
- Outcome measures
- Results
- Conclusion

Introduction

- Problem
- Incidence
- Current treatments
- New treatments
- Consequences
- Current practice in my workplace

Aims & objectives

Methodology & design

Results : What did we find?

Discussion

- Interpretation of results of this study
- Correlation between study results and results reported in literature
- Complications associated with other treatments
- Advantages of new treatment
- Limitations of study
- Conclusion

References

Appendices

Screening tests

To identify unrecognised disease in people without signs or symptoms

Must have **very high sensitivity & specificity**

WHO guidelines

1. There should be treatment for condition
2. Facilities for diagnosis and treatment should be available
3. There should be latent stage of disease
4. Test should be acceptable to population
5. Natural history of disease adequately understood
6. Should be an agreed policy on whom to treat
7. Cost of finding case economically balanced to medical expenditure
8. Treatment started early of more benefit than started later

Results

Reproducible: low Interobserver error

K (kappa) score: measures interobserver error, ranges from 0-1

- **Sensitivity** probability that *tes*t results will be positive in patients with disease
  True +ve/all people with disease
  Sensitivity = TP / (TP + FN)
  Sensitive tests are useful for screening
- **Specificity** Probability test result will be negative in patients without disease
  True –ve/all people without disease
  Specificity = TN / (FP + TN)
  Useful for confirmation as they don't result in treatment of an unaffected individual
- **Positive predictive value PPV** probability of patient having disease when result is positive
  +ve with disease/ +ve with and without disease
  PPV = TP / (TP + FP)
- **Negative predictive value NPV** probability of patient not having disease when result is negative
  -ve without disease/-ve with and without disease
  NPP = TN/TN+FN
- **Accuracy** Tells about how often the test is correct
  Number of correct diagnosis (positive and negative) as proportion of total number of diagnostic results recorded
  TP + TN / TP+FP+TN+FN

		Condition		
		Positive	**Negative**	
Test	**Positive**	True Positive	False Positive (Type I error)	**Positive Predictive Value**
	Negative	False Negative (Type II error)	True Negative	**Negative Predictive Value**
		Sensitivity	**Specificity**	

- **Incidence** Percentage of new causes in defined population in given period of time
- **Prevalence** percentage of population who suffer from disease at given point in time
- **Number Needed to Treat (NNT)** Expresses effectiveness of intervention
  Number of patients treated to achieve outcome once

Absolute risk

- Probability that individual will experience specified outcome during specific period
- Usually 0-1 or percentage
- If absolute risk of developing condition is very low (say, 0.001%), then even if relative risk large, risk still very small if factor present

Relative risk

- Ratio between incidences of an outcome in two cohorts
- Risk in those exposed to risk factor (experimental group) divided by that in those not exposed (control group)
- If it is >1 risk of disease higher in those with factor
- If RR is > 5, individual five times more likely to develop disease if factor present
- Used in cohort studies – tells about association between exposure and outcome
- Incidence of disease in exposed group/incidence of disease in non-exposed group

Odds ratio

- Probability of having risk factor in those who developed condition
- Used with case-control (retrospective) studies
- Displayed in forest plot graph, square demonstrates size of population
- Likelihood of positive outcome in study group/likelihood of positive outcome in control group
- Tells about strength between exposure and outcome

Relative Risk Reduction (RRR)

Percentage of outcome in intervention group compared to control experimental event ratio / control event ratio

e.g. 100 patients with 30 deaths
Risk Ratio = 30 / 100
Odds Ratio= 30 / 70

Box and whisker plot

- Used to display information about range, median and interquartile, central tendency and spread
- Used for numerical data
- Horizontal line in box represents median value
- Interquartile range indicated by box
- Whiskers represent upper and lower values beyond considered outliers
- Horizontal dotted line indicates the mean value

Bar chart used for ordinal, nominal or discrete numerical data

Histogram Illustrate distribution of continuous numerical variable (data)
Unlike bar charts, bars touch each other, illustrating that data are continuous

Survival analysis

Study in which the outcome of an intervention is plotted over time, which allows for variable dates of entry and different lengths of follow-up

Data can be analysed at

- Fixed intervals (**actuarial life-table method**)
- Times of failure (**Kaplan–Meier** product limit method)

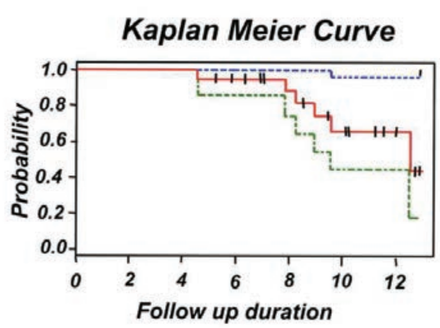
The definition of failure must be clear from the outset

How to construct a life table for joint replacements?

- The endpoint needs to be defined, which is usually 'revision'
- The number of joints being followed and the number of failures are determined for each year after operation
- For each time period, number of patients at risk, number of failures and number of withdrawals are recorded

Kaplan–Meier survival analysis

- Life table analysis of continuously analyzed data at pre-determined intervals and at time of failure
- Outcome of intervention plotted over time
- Looking at cumulative probability of survival
- Allows variable dates of entry and follow up over different lengths of time
- Need start and end dates e.g. THR and revision
- Dip (step) when joint revised (failure), diagnosis of cancer and death
- The percentage failure rate for each period is determined from the number at risk and the number of failures (by dividing the number of failures during the interval by the number of patients at risk); from this, the percentage success rate is calculated
- **X axis** shows time elapsed
- **Y axis** represents percentage of study population surviving
- **Dotted lines** are CI
  - Increased over time due to decreased number of patients – less reliable data towards the right of the plot
  - Represent best- and worst-case scenario
  - Upper assume all lost to follow up survived and lower assume they all failed
  - Important to compare between 2 prosthesis
  - Can tell difference if there is no overlap
- **Censored (lost) patients**
  - Identified with little mark
  - subjects that are uncooperative or refused to remain in study or they do not experience the event or die before the end of study or those lost to follow up
  - They do not count as failures
- Must not extrapolate the results beyond the defined time periods, and only specific hard endpoints must be used.



OUTCOME SCORES

Questionnaires are given to patients both pre and post procedure, in relation to the outome relating to the intervention.

Why we need it:

- Research
- Quality improvement
- Audit
- Economic evaluation

How to choose

- Reliability
- Validity
- Pirior use in similar patients demographic

Types:

A. Patient Reported Outcome Measures (PROMs)

1. Patient specific

- Subjective
- Short
- Self completed questionnaires which measure symptoms, function and QoL from patient perspective (McMaster Toronto Arthritis Patient Preference Questionnaire - why THR)

2. Disease specific

- Harris Hip Score : 0 – 100 (pain, function, activities, clinical examination)
- WOMAC for OA

3. Generic

- EuroQoL measure, SF36, good to look at long-term outcome, SF12

4. Region Specific

- **Oxford Hip Score, 12 Qs**
  Severity of pain, night pain, any sudden pain
  Limping, walking distance, stairs, socks, stiffness
  Getting in/out car, washing, shopping, work
  0 – 48 total score, < 20 indicate severe hip arthritis
- **Oxford Knee Score, 12 Qs**
  Severity of pain, night pain, sudden pain
  Limping, walking distance, stairs, kneel, stiffness
  Getting in/out car, give way, shopping, work
  0 – 48 total score, < 20 indicate severe knee arthritis

Rothwell et al. JBJS Br 2010 – New Zealand registry

Patients undergoing TKR

Lower PROM at 6 months post-op is useful predictors of increased risk of revision in 2 years

Knee Society Score

DASH score Disabilities of Arm, Shoulder and Hand questionnaire
30 items that look at ability of pt to perform certain upper extremity activities
Higher scores indicate a greater level of disability
Ranges from 0 to 100, Constant score

B. Clinician-based Outcome Measure (CROMs)

Examiner dependent

Orthopaedic Pathology

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CONTENTS

ONCOLOGY

Definitions

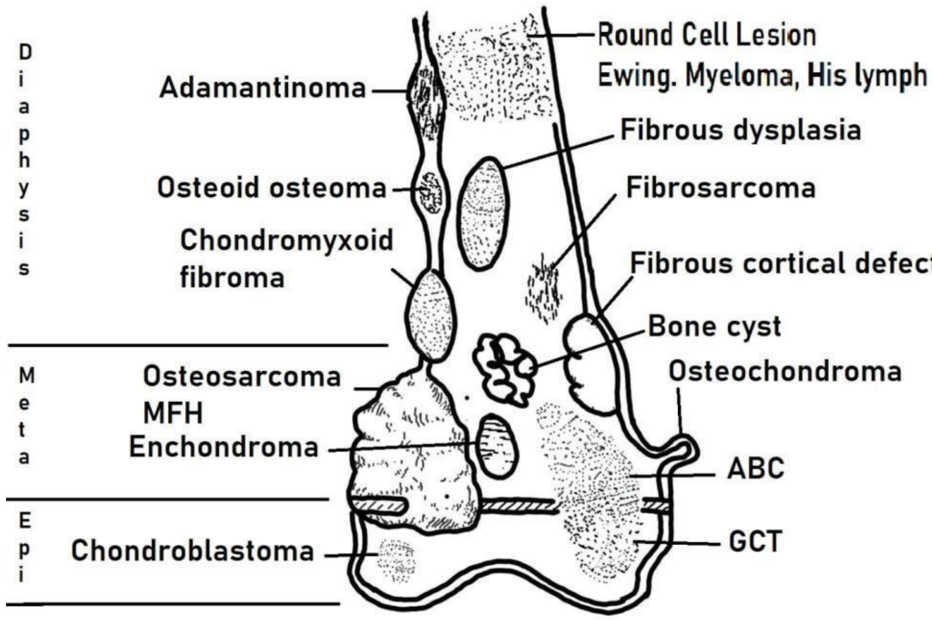
- **Neoplasm (tumour)** - abnormal growth due to unregulated cellular proliferation that continues to enlarge even after the initiating stimulus has ceased. It lacks structural organization and function
  - Malignant (cancerous): invasive and destructive locally and distant
  - Benign: does not invade locally tissue, (except for Giant Cell) does not metastasize
- **Sarcoma** - cancer arising from cells of mesenchymal origin
- Musculoskeletal tumours can present following injuries (such as with a pathological fracture) and there should be high index of suspicion in patients with red flag signs
- Red Flag signs to look out for
  - Night pain or non-mechanical pain
  - Unintentional weight loss
  - Thoracic back pain
  - Age (<20 or >50 years old)
  - Previous history of malignancy

Histology Type	Benign	Malignant
Hematopoietic		Myeloma
Chondrogenic	Osteochondroma Chondroma Chondroblastoma Chondromyxoid fibroma	Primary Chondrosarcoma Secondary Chondrosarcoma Dedifferentiated Chondrosarcoma Mesenchymal Chondrosarcoma
Osteogenic	Osteoid Osteoma Benign Osteoblastoma	Osteosarcoma Parosteal Osteogenic Sarcoma
Unknown Origin	Giant Cell Tumour	Ewing Tumour Malignant Giant cell Tumour Adamantinoma
Fibrogenic	Fibroma Desmoplastic fibroma	Fibrosarcoma
Notochordal		Chordoma
Vascular	Haemangioma	Haemangioendothelioma Haemangiopericytoma
Lipogenic	Lipoma	Liposarcoma

How to describe bone lesions on radiographs

- **Bone & site:**
  - What is included in radiograph (what bone, what joint, side, view)
  - Epiphysis, metaphysis, or diaphysis
  - Mature vs. Immature
- **Lesion:**
  - Osteoid, chondroid or fibrous (ground glass)
  - What is the lesion doing to the bone? (sclerotic/lytic/mixed/calcification)
  - What is the bone doing to the lesion? (periosteal reaction/Codman's triangle/onion skinning)

- **Margins:**
    - Well defined (narrow zone of transition) - slow growing – less aggressive
    - Poorly defined (wide zone of transition – likely progressive (malignant)
    - Cortical breach
- You should be able to comment on radiographs if the likely diagnosis is non-aggressive or aggressive lesion
- Although a definite diagnosis may not be expected, the appropriate recognition and work up for a potentially malignant condition is



Work-Up of Suspected Neoplasm

- **Image whole limb:**
    - local staging: MRI of whole limb (to assess spread of tumour, compartments involved, check for skip lesions and look for neurovascular proximity)
    - systemic workup: CT chest, abdomen and pelvis to identify primary or metastatic lesions
    - Bone scan - to check for skeletal metastases
    - Don't fix fracture until sure of pathology
    - **Staging vs. Grading**:
        - Stage – degree of spread of the tumour
        - Grade – Degree of cellular differentiation
- **Biopsy:**
    - **Only** after a discussion with bone tumour unit
    - *Types*
        - FNAC Not enough
        - Core biopsy can be performed under LA
        - Can be combined with imaging (US for soft tissue, CT for bone)
        - Diagnostic accuracy 85%

- Tru-Cut needle for soft tissue
- Jamshidi needle for bone
- Open biopsy - Diagnostic accuracy 95%
- For soft tissue - place stitches to orientate sample for pathologist

• *Principles of biopsy:*
  - Must be performed by or under direct instruction of surgeon at specialist bone tumour unit
  - Tract removable within definitive incision
  - Extensile longitudinal incision
  - If using LA, then judicious use to avoid seeding
  - Tourniquet use only with gravity exsanguination, should be deflated prior to definitive closure
  - Direct to bone do not follow planes
  - Don't contaminate > 1 compartment
  - Enough tissue from periphery of tumour to avoid area of central necrosis
  - Meticulous haemostasis to avoid seeding
  - Send in a formalin container
  - If a drain is inserted, it should come out through or in line the surgical incision
  - Do not forget to biopsy every infection and culture every tumour
  - Sutures close to wound margin to allow inclusion for excision of tract later

• **Mankin et al. (JBJS, 1996)** Errors, complications, and changes in course of treatment and outcome were 2 - 12 times greater ($p < 0.001$) when biopsy done in referring institution instead treatment centre

TREATMENT OPTIONS

Chemotherapy

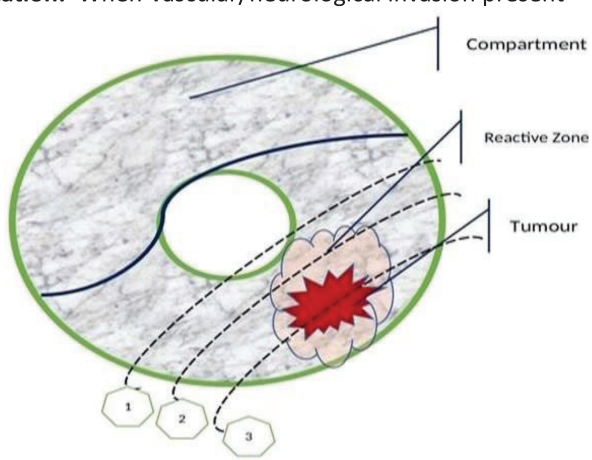
➢ Induces apoptosis
➢ Targets rapidly dividing cells, such as those found in neoplasms, therefore not effective against slow dividing cells e.g. Cartilage
➢ Lack of specificity – therefore other rapidly dividing cells also affected (lining of gut, bone marrow, hair, and skin)
➢ Eliminates micro-metastases in lungs
➢ Indications: Osteosarcoma, Ewing's sarcoma, metastatic soft tissue sarcoma
➢ 6 – 12 weeks pre-op and 6 – 12 months postop
➢ Agent specific side effects:
  • Doxorubicin (cardiac toxicity)
  • Ifosfamide: (neurological toxicity)
  • Cyclophosphamide: (myelosuppression and urotoxicity)
  • Bleomycin: (pulmonary fibrosis)

Radiotherapy

- Production of free radicals leading to direct genetic damage
- Indications:
    - Ewing sarcoma, lymphoma of bone, Multiple Myeloma, Soft tissue sarcoma
    - Metastatic bone disease - breast & prostate
- Radio-resistant: renal & GI metastases
- Complications: delayed bone healing, infection, fracture, sarcoma, AVN, growth arrest

Surgical excision

- Indications for surgery in benign tumours:
    - Thinning of >50% of cortex
    - Mass effect
- Types of surgery:
    - **Intralesional:** Excisional biopsy for benign lesions
    - **Marginal:**
        - Resection passes through reactive zone
        - Outside tumour pseudocapsule where inflammatory and tumour cells are present
        - Between cancer and normal tissues, micro-metastasis may persist
    - **Wide:**
        - Outside reactive zone with cuff of normal tissue
        - Intra-compartmental possibility of skip lesions
        - Careful planning of surgical approach to ensure tumour clearance
    - **Radical:**
        - En-bloc excision of entire compartment
        - Reconstruction endoprosthesis, custom-made or modular
    - **Amputation:** When Vascular/neurological invasion present



(Courtesy of A Hanoun)

Batson venous plexus Valveless venous plexus of spine
Provides vascular spread rout of metastasis from organs to axial skeleton

Classification of Neoplasms

- **The Musculoskeletal Tumour Society MSTS (Enneking) staging system for sarcomas**
    - **Histologically**
        - Stage 1 - Low grade cellular dysplasia (<15% risk of metastasis
        - Stage 2 - High grade cellular dysplasia (>15% risk of metastasis)
        - Stage 3 – Any grade lesion *with* metastases
    - **Anatomically**
        - A - Intra-compartmental (within cortex)
        - B - Extra compartmental (penetrates cortex into soft tissues)
- **Classification according to behaviour**
    - Benign latent (NOF)
    - Benign active (ABC)
    - Benign aggressive (GCT)
    - Malignant low grade (Parosteal osteosarcoma)
    - Malignant high grade (Osteosarcoma)

Cystic lesions

Unicameral (simple) Bone cyst (UBC)

- Benign
- < 20 years
- Can cause pathological fracture of proximal humerus in children
- **<u>Types:</u>**
    - Active: cyst adjacent to physis
    - Latent: normal bone separates cyst from physis
- Serous/serosanguinous fluid filled cavity
- **<u>Radiographs:</u>**
    - Proximal humerus metaphysis/shaft, central lytic and unilocular with thinning of cortex
        - Fallen leaf sign: pathologic fracture with fallen cortical fragment
        - Not expansile beyond physeal margins

(Courtesy of M Elgendy)

- **Treatment:**
  - Fracture can encourage healing and cyst resolution
  - Immobilization and observation, exception weight bearing bones
  - Other options include:
    - Intra-cystic bone marrow injection
    - Curettage and bone graft, +/- fixation in lower limb
    - Phenolization or cortisone injection
    - *Cementing* (chemical and thermal ablation)

Aneurysmal Bone Cyst (ABC)

- Benign osteolytic expansile lesion
- Potential for aggressive behaviour
- <30 years old
- Pain and swelling common
- Two Type
  - Primary:
    - due to osseous arteriovenous fistula creating erosive lesion
    - up regulation of the USP6 (Tre2) gene on 17p13 when combined by translocation with a promoter pairing, most commonly described translocation t(16;17)(q22;p13) leading to juxtaposition of promoter region CDH11 on 16q22
  - Secondary
    - Occurs as result of cystic change in other bone lesion (esp. Giant Cell0
    - No chromosomal abnormalities, less aggressive
- **Imaging**
  - Radiographs
    - Metaphysis, eccentric
    - Lytic with soap bubble appearance (septations)
    - Expansile (wider than physis) – cortical erosion
  - MRI
    - Demonstrates high signal intensity on T2 images
    - Blood filled loculations demonstrated by multiple fluid levels
  - CT
    - Useful for Spinal ABCs

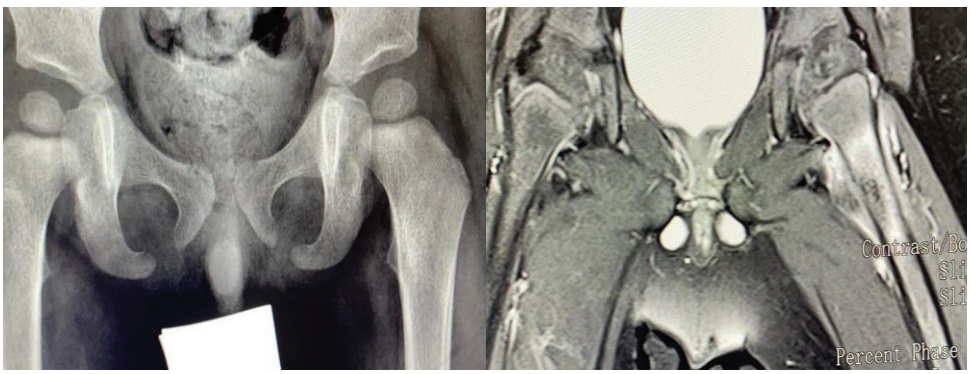
(ABC)

- **Treatment**
  - Impending fracture or symptomatic: intralesional excision (curettage) & bone grafting/ cementing/ Phenol
  - Combine with high speed burring
  - Radiotherapy contraindicated as could lead to sarcoma
  - Embolization to slow progression and decrease blood loss may be considered

Benign Osteogenic Tumors

Osteoid Osteoma

- Night pain due to prostaglandin secretion & COX1/2 expression
- Pain from osteoid osteoma is usually relieved with Aspirin
- Presents in 2nd decade of life
- Diaphysis or metaphysis of long bones of lower extremity or spine
- Spinal lesions may cause scoliosis (most common cause of painful scoliosis
- Imaging
    - Radiographs sclerosis around radio-lucent nidus (nidus >2cm = Osteoblastoma)
      May only see cortical thickening (sclerosis)
    - CT Scan (2-3mm slices)
      Modality of choice for spine
    - MRI: When nidus density is similar to surrounding bone
    - Bone scan Double density sign
      Increased uptake (Hot)



(Courtesy of M Elgendy)

- Treatment
    - Spontaneous resolution in 5 years
    - CT guided Radiofrequency ablation
    - En-bloc excision if accessible

Osteoblastoma - Osteoid Osteoma ≥ 2cm

- Most commonly in posterior elements of spine
- X-rays:
    - lytic with sclerotic rim
    - Mineralization within lesion
    - Metaphysis
- Hot bone scan
- Treatment:
    - Curettage & bone graft
    - Radiofrequency ablation
    - En-bloc excision

Fibrous Tumors of Bone

Fibrous Dysplasia

(Courtesy of S Chenow)

- Failure of production of normal lamellar bone
- Cyclic adenosine monophosphate (cAMP) formation gene defect
- Congenital and usually found as incidental finding on radiographs
- **Types -**
  - **Monostotic (Nonossifying fibroma/fibrous cortical defect)**
    - Asymptomatic, common in children 5-15 years old
    - Incidental finding after pathological facture
    - *Most common* benign tumour in children
    - Eccentric – lytic - bubbly appearance - sclerotic margin
  - **Poly-ostotic** - Shepherd's crook deformity (causes varus in proximal femur)
  - **McCune-Albright syndrome** (Poly-ostotic fibrous dysplasia)
    - Associated with precocious puberty and café au lait spots
    - Endocrine hyper-function
- **Complications:**
    - Subtrochanteric fracture (internal fixation and bone grafting)
    - Malignant transformation (1%)
- **Treatment –**
  - Monostotic resolve spontaneously (monitor for evidence of impending pathologic fracture)
  - Curettage & bone grafting
  - Bisphosphonates

Osteofibrous Dysplasia

- Benign lesions in children
- Anterior cortex of tibia – causing Anterolateral bowing of the tibia
- Also called **ossifying fibroma**
- Painless swelling
- Radiograph:
  - anterior intracortical involvement proximal 1/3 tibia
  - Variable size and osteolytic appearance
  - No soft tissue extension or periosteal reaction
- Treatment:
  - Observation as can progress to adamantinoma
  - May need bracing

Adamantinoma

- Low grade malignant tumour of unknown origin
- Most commonly in anterior tibia diaphysis
- "Soap bubble" appearance on radiographs
- Wide surgical excision

Benign Chondrogenic Tumors

- MRI for diagnosis and to characterise lesion

Exostosis (Osteochondroma)

- Cartilage capped bony projection, arising from external surface of bone, containing a marrow cavity with that of the underlying bone
- Growth parallels growth of bone, halts at skeletal maturity
- Most common benign bone tumour
- Pedunculated or sessile
- Growth halts at skeletal maturity
- X-rays: Metaphyseal region - Cortex and matrix of lesion is continuous with bone (grows away from physis with bony growth)
- Histologically mature lamellar bone, usually caused by herniation of a fragment of physis
- **Solitary:**
    - Painless, slow growing
    - Adolescents, common around knee
    - Excise if very large (? Chondrosarcoma) or affecting joint movement or causing neurovascular symptoms
    - Risk of malignant transformation to Chondrosarcoma 1%

- **Multiple Hereditary Exostoses (MHE):**
    - Autosomal dominant caused by mutations in EXT1, EXT2, and EXT3 genes
        - Loss of regulation of Indian Hedgehog protein
    - **Malignant transformation risk 10%**
        - New pain in previously known lesions
        - Increasing size after skeletal maturity
        - Cartilage cap > 1.5cm need to be investigated
- Associated Symptoms
    - femoral shortening
    - Coxa Valga, Genu valgus, ankle valgus
    - Patellar dislocation
    - Short, Asymmetrical growth
    - Multiple scars from excision of lumps
    - Ulnar shortening and radial bowing
    - Radial head dislocation
    - Can cause limb deformity
    - Excise only those causing symptoms

(Courtesy of M Elgendi)

Enostosis

- Also called **Bone Island**
- Islands of cortical bone within medullary cavity
- Benign
- Metaphysis
- Called Osteopoikilosis when multiple (rule out infection and metastases)
- Cold bone scan
- Well circumscribed (narrow zone of transition)
- No periosteal reaction

(Courtesy of L Prakash)

Enchondroma

- Abnormality of chondroblast function, thought to arise from migrating piece of physeal cartilage
- 2nd most common benign cartilage tumour after osteochondroma
- Composed of hyaline cartilage
- 20 – 50 years old
- Most common in hand (phalanges>metacarpals), also in distal femur, foot and proximal humerus
- Asymptomatic but may disrupt growth plates
- Hand - proximal phalanx, may present as pathological fracture
- X-rays: Lytic lesion – popcorn calcification (chondroid matrix), well defined thin cortices and bone expansion
- Allowing fracture to heal which might allow ossification
- Curettage with burr and chemical cauterisation with phenol and pack with bone graft
- Follow up for 2 years -recurrence of 10%

(Courtesy of M Elgendy)

- **Differentiate from bone infarct:**
  - Smoke up chimney radiographic appearance
  - Related to intrinsic vascular compromise
  - Asymptomatic and doesn't require treatment
- **Treatment**:
  - Observe with serial radiographs
  - Risk of cancer - solitary 1%
  - Curettage and bone grafting for painful or growing lesion

(Bone infarcts)

- **Ollier disease**
  - Non-hereditary congenital error
  - multiple enchondromatosis
  - skeletal dysplasia with failure of normal endochondral ossification
  - enchondromas throughout the metaphysis and diaphysis of long bones
  - involved bones are dysplastic, with shortening and bowing
  - 20-30% risk of chondrosarcoma
- **Maffucci syndrome**
  - Non-hereditary congenital error
  - Multiple enchondromatosis & multiple haemangioma & lymphangiomas
  - Risk of sarcoma (up to 100 %)
  - Features that suggest chondrosarcoma transformation:
    - Lucency developing within calcification
    - Periosteal reaction
  - also has increased risk of visceral malignancies (astrocytoma, GI malignancy)

Chondroblastoma

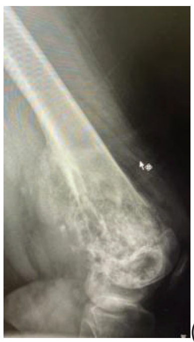
- Epiphysis of long bones with *open* physis - skeletally immature
- Benign aggressive lesion, painful
- X-rays:
  - Epiphysis of immature bone (may cross physis)
  - Lytic lesion
  - Well-circumscribed - thin rim of sclerotic bone (sharply demarcated from normal medullary cavity)
  - CXR mandatory, evaluate for possible metastatic lesions
- Treatment
  - Curettage and bone graft

(Courtesy of M Elgendy)

Malignant bone tumours

Osteosarcoma

- Most commonly around the knee (distal femur) and shoulder, usually within the metaphysis
- Bimodal peaks in incidence, adolescents and elderly (which is associated with Paget disease)
- Usually presents with pain and swelling
- Osteoblasts become the malignant cells
- Bone and pulmonary metastases – 10-20% pulmonary metastasis on presentation-
- Radiographs – sclerotic lesion, with a wide zone of transition and surrounding soft tissue involvement


(Courtesy of M Elgendi)

Codman triangle
Laying down of bone under elevated periosteum

Sunray spicules
Calcification of periosteal blood vessels

- **Bloods**: Elevated ALP
- **Types**:
  - Intramedullary:
    - high grade, painful (most common)Genetics
    - patients who carry the Retinoblastoma tumour suppressor gene (Rb) are predisposed to osteosarcoma
    - risk increased in Rothmund Thomson syndrome
      - ✓ AR inheritance, mutations in RECQL4 gene.
      - ✓ sun-sensitive facial rash (pigmentation, thinned skin, prominent blood vessels)
      - ✓ absent eyelashes, eyebrows and hair
      - ✓ juvenile cataracts, teeth abnormalities
      - ✓ osteosarcoma, fibrosarcoma, gastric adenocarcinoma, cutaneous BCC and SCC
  - Parosteal:
    - Arises from outer layer of periosteum
    - Low grade, painless
    - Posterior surface of metaphysis of distal femur
    - Appearance of lesion stuck on bone
  - Periosteal:
    - Arises from inner layer of periosteum Sun-burst type lesion
    - Proximal tibia
    - Moderate grade
  - Telangiectatic:
    - High grade, aggressive
    - Lakes of blood mixed with malignant cell
    - Main diff diagnosis is aneurysmal bone cyst
    - Secondary to Paget or radiation exposure

- **Staging**
  - Local: (MRI):
    - To evaluate extension into bone and soft tissues
    - Whole limb to look for skip lesions
  - Distant (CT):
    - Lung, brain, kidney
    - Whole body bone scan

Prognosis:

- 76% survival with new advance treatment
- Poor prognostic factors include:
  - advanced stage at diagnosis
  - poor response to chemotherapy
  - high serum ALP
  - high serum LDH
  - expression of p-glycoprotein
  - absence of antibodies to Heat Shock Protein 90 after chemotherapy

- **Management:**
  - MDT approach
  - Neo-adjuvant and maintenance chemotherapy for 6-12 months post resection
  - Agents commonly used Doxorubicin, Cisplatin and Methotrexate
  - Neo-adjuvant
    - To treat occult micro metastasis
    - To reduce inflammation around tumour and to aid resection
    - To assess response to predict prognosis
  - LDH to monitor response
  - Osteonecrosis is good prognostic factor to response to chemotherapy
  - Limb salvage (wide local excision) vs. amputation – decision to be made following multidisciplinary input
  - Indications for amputation (pathological fracture/neurovascular involvement/increase size during chemotherapy)

Ewing sarcoma

- Unknown origin
- Common in adolescents
- 2nd most common tumour in children
- Genetics
  - t(11:22) translocation
  - found in 95% of cases
  - leads to the formation of a fusion protein (EWS-FLI1)
  - can be identified with PCR and useful to differentiate Ewing sarcoma from other round cell lesions
- X-Rays:
  - Periosteal reaction may give onion-skinning or a Codman triangle appearance
  - Diaphysis of long and flat bones -
  - Destructive lesion with a moth-eaten appearance
  - Poorly defined
  - Can look and behave like infection

- Metastasis to lungs
- Management:
  - Neo-adjuvant Chemo
  - Radiotherapy
  - Surgerical prognosis
  - 60-70% long term survival with isolated extremity disease
  - 40% long term survival with pelvis lesions
  - 15% long term survival if patient presents with metastatic disease


(Courtesy of M Elgendy)

Chondrosarcoma

- Malignant
- Affects adults, more common in males, age (40-75)
- Types -
  - Primary (low grade/high grade/dedifferentiated)
  - Secondary:
    - Osteochondroma (risk < 1%)
    - MHE (1-10% risk)
    - Solitary Enchondromas (1% risk)
    - Ollier's disease (25-40% risk)
    - Maffuci syndrome (100% risk)
- X-Rays:
  - Metaphyseal lesion, also flat bones (pelvis)
  - Popcorn appearance
  - Poorly defined
  - Clear-cell chondrosarcoma usually presents in epiphyseal region


(Courtesy of H Hermina)

- Proximal femur
- Can metastasise to lungs
- Majority are low grade and do not respond to chemotherapy or radiotherapy
- Difficult to diagnose histologically
- **Management**:
  - Surgical through a wide surgical excision
- **Prognosis**:
  - Low grade (90% survival at 5years)
  - High grade/metastatic (30% survival at 5 years)

Giant cell tumour (Osteoclastoma)

- Benign aggressive tumour of unknown origin
- Large multi-nucleated cells
- Genetics
  - Mutations in c-myc oncogene .
- primary malignant giant cell tumour
  - metastatic to lung in 2-4% of cases
  - wrist and hand lesions have greater chance of metastasis
  - secondary malignant giant cell tumour
  - occurs following radiation or multiple resections of giant cell tumour

- Mononuclear cells are proliferating and expresses RANKL
- X-Rays: Eccentric location in epiphysis and metaphysis of skeletally mature long bone with a closed physis
- Knee - most common, Spine involvement - vertebral bodies
- Common age group affected: 30-50 years
- Can metastasize to lungs
- Malignant transformation in 10%
- Recurrence 5%
- Differentiate from Brown tumour of hyperparathyroidism (multiple lesions)
- **Treatment**:
  - Anti RANKL with Denosumab, anti-osteoclast activity of Bisphosphonates
  - Curettage/intra-lesional excision if cortex intact
  - Adjuvant phenol or hydrogen peroxide
  - High speed burr for margins (extended curettage)
  - Marginal excision and reconstruction
  - Radiotherapy for inoperable lesions


(Courtesy of M Yousff)

Soft tissue sarcoma

- Soft-tissue lump with any of the following characteristics should be considered malignant until proven otherwise
  - Larger than 5 cm
  - Increasing in size
  - Deep to deep fascia
  - Painful
  - Recurrent after previous excision
- Lobulated and cystic
- **Risk factors:**
  - Chemical: Asbestos
  - Viral: EBV, HSV
  - Irradiation
  - Genetic
- **Guidelines for the management of soft tissue sarcomas**
  - If MRI is diagnostic, mass is benign and symptomatic - can be removed without biopsy
  - If MRI indeterminate or suggestive of sarcoma - core or open biopsy must be obtained before further treatment
- Soft tissue sarcoma can look like haematoma - be cautious of a haematoma which occurs without trauma
- **Treatment:**
  - Radiotherapy
    - Adjuvant or neo-adjuvant
    - Pre-operative associated with 30% risk of wound complication
    - Post-operative associated with increased risk of radiation induced sarcoma
  - Chemo (for metastasis)
  - Surgery (wide surgical excision most important factor)

Synovial tumours

- **Chondromatosis**:
  - Metaplasia of synovium into hyaline cartilage
  - Leads to loose cartilage fragments
  - Associated with pain, swelling and/or locking
  - Knee is the most common location
  - X-rays: popcorn calcification, multiple loose bodies
  - Treatment: open or arthroscopic synovectomy and loose body resection

(Courtesy of L Prakash)

- **PVNS**:
  - Proliferative villo-nodular Synovitis (called GCT when extra-articular)
  - Benign or invasive
  - Knee is the most common location
  - Histologically same as GCT of tendon sheath
  - Highly vascular villi with hyperplastic synovial cells
  - Recurrent haemarthrosis with mechanical pain
  - MRI & US guided biopsy to confirm diagnosis
  - Treatment:
    - Radiotherapy
    - Synovectomy - recurrence is common
    - Thorough resection arthroscopically
    - Open for posterior joint
- **Synovial sarcoma**
  - Malignant, arises near joints, but rarely within joint
  - Origin *not synovial cell* (misnomer)
  - Most common malignant sarcoma of foot
  - Most common sarcoma found in young adults
  - Wide surgical resection & radiotherapy

Muscular tumours

- **Intramuscular myxoma:**
  - Benign, homogenous - excise if symptomatic
  - MRI: Bright T2 dark T1
- **Rhabdomyosarcoma:**
  - Malignant
  - Most common soft tissue sarcoma in children
  - Rapidly growing painless mass
  - Treatment:
    - Chemo for metastasis
    - Radio for inoperable
    - Excision
- **Leiomyosarcoma**:
  - Aggressive malignant, from smooth muscle cells lining small blood vessels
  - Osteolytic lesions, moth-eaten in metaphysis of long bones
  - Chemotherapy + wide surgical resection

Fibrogenic tumours

- **Dermatofibrosarcoma Protuberans**:
  - Fibrogenic cutaneous sarcoma
  - Can result from neurofibromatosis
- **Fibrosarcoma of Soft Tissue & bone (Malignant Fibrous Histiocytoma)**
  - Most common soft tissue sarcoma in adults
  - Pain and swelling
  - High grade - looks like osteosarcoma
  - Treatment: same as osteosarcoma
- **Undifferentiated Pleomorphic Sarcoma:**
  - Painless enlarging mass
  - Wide local resection and radiation
- **Nodular Fasciitis:** Reactive lesion
- **Extra-abdominal Desmoid Tumour:**
  - Aggressive fibromatosis
  - Most invasive of benign soft tissue tumours
  - Associated conditions :Dupuytren's disease, Ledderhose disease
  - Familial adenomatous polyposis (FAP)
  - Distinctive "rock hard" mass on palpation
  - Positive for oestrogen receptor expression
  - Treatment:
    - Tamoxifen (Oestrogen receptor blocker)
    - Radiotherapy
- **Plantar Fibromatosis (Ledderhose):**
  - Myofibroblast and collagen proliferation
  - Similar process to Dupuytren's fibromatosis (ask about hand involvement and Peyronies Disease in men)
- **Calcifying Aponeurotic Fibroma:**
  - Painless mass in hands and feet of children and young adults

Vascular tumours

- **Haemangioma:**
  - Benign vascular neoplasm in soft tissue and bone
  - May be cutaneous, subcutaneous, or intramuscular
  - Common in hands, also occur in vertebral bodies
  - Can be incidental finding on MRI
  - Isolated or multiple
  - Can be painful unlike liposarcoma and synovial sarcoma
  - Radiographs:
    - Phleboliths (calcification within blood vessels)
    - Vertical striations in vertebral body (jail-bar appearance)
  - MRI: (high signal on MRI due to High fat content)

- Treatment:
  - Observe
  - Analgesia
  - Embolization or Sclerotherapy
  - Low dose irradiation
  - Curettage and bone grafting if lesion is accessible
  - Excision

➢ **Angiosarcoma**
- From endothelium of blood vessels
- Invades bone, overlying skin changes
- Treatment: Radiotherapy & Resection

Fat tissue tumours

➢ **Lipoma**
- Benign tumour of mature adipocytes
- Age 40 – 60
- Painless mobile mass
- Lobulated, *homogeneous* signal intensity same as fat – Bright on T1 & T2 and dark on STIR
- Excision indications:
  - Symptomatic
  - Rapidly growing
  - Located deep to fascia or in retro-peritoneum (liposarcoma risk)

➢ **Liposarcoma**
- *Heterogeneous* - bright on T1 and dark on T2
- Treatment: Excision with adjuvant radiotherapy

Neural tumours

➢ **Neurilemmoma**
- Benign Schwannoma
- Types of Schwann cells:
  - Myelinating (in large nerves)
  - Non-myelinating (in small nerves)
- Paraesthesia in distribution of peripheral nerve
- Treatment:
  - Observe
  - Excise with high rate of sensory deficit
  - Careful dissection, excise lesion parallel to nerve fascicles


(Courtesy of H Hermina)

➢ **Neurofibroma**
- Benign nerve sheath tumour
- Involves non-myelinating Schwann cells *and other* perineural cells
- Sporadic
- Differentiate from Schwannoma, which is ECCENTRIC to nerve fibres
- Solitary Neurofibroma is more CENTRAL to nerve fibres
- Excision with nerve graft if symptomatic

- **Neurofibromatosis**
  - Autosomal dominant disorder of neural crest
  - Spine: Scoliosis, Kyphosis, Atlantoaxial instability
  - Extremity: Congenital anterolateral bowing of tibia and forearm (tibial hemimelia is also anterolateral)
    - Tibia can progress to pseudoarthrosis
    - Hemi-hypertrophy
  - Classification:
    - Type I:
      - ✓ Von Recklinghausen
      - ✓ Tibia pseudoarthrosis
      - ✓ Chromosome 17
      - ✓ Spine most common skeletal involvement – causes dystrophic scoliosis & dural ectasia
    - Type II:
      - ✓ Associated with bilateral vestibular Schwannoma
      - ✓ Chromosome 22
      - ✓ Central meningioma
      - ✓ No scoliosis
  - Diagnostic criteria for NF1:
    - ≥ 6 café au lait maculae with smooth borders
    - > 5cm in prepubertal,> 15 mm in post pubertal
    - 2 or more cutaneous neurofibromas
    - 1st degree relative
    - Optic glioma
    - ≥2 iris hamartomas (Lisch nodules): pathognomonic for NF1
    - Sphenoid wing dysplasia or thinning of long bone cortex
  - Treatment:
    - Spinal Brace
    - Decompression and fusion with instrumentation (growing rod)
    - Tibia Brace
    - Resect pseudoarthrosis and fix with rod or ex-fix + bone graft (amputation may be required for persistent non-union)
- **Malignant peripheral nerve sheath tumour**
  - Malignant Schwannoma:
    - Arise from large nerves (sciatic, brachial plexus)
    - Motor and sensory deficit of affected nerve
    - Treatment: Wide surgical resection + radiotherapy
  - Neuroblastoma:
    - Malignant from sympathetic neural tissue
    - Most common solid tumour of childhood
    - If adrenal glands affected can lead to tachycardia and abdominal mass
    - Metastasis to bone - common and poor prognostic sign
    - Good prognosis
    - Treatment: Chemotherapy & Stem cell transplant & Surgical excision

Haematopoietic tumours

- **Leukaemia:**
  - Most common malignancy of childhood
  - Arise from bone marrow
  - ALL (4 years)
  - CLL (40 – 60 years)
  - AML (40 – 60 years)
  - CML (40 – 60 years)
  - Symptoms: Infection, bleeding, fatigue, lymphadenopathy, hepatosplenomegaly
  - Treatment: Chemotherapy
- **Lymphoma:**
  - Malignant, can occur in all age groups
  - Develop in lymphatic system
  - Non-Hodgkin - B lymphocyte most common
  - Hodgkin - T lymphocyte
  - 35 - 55 years old males more common
  - Pain neurological compression symptoms
  - X-Rays: Lytic - mottled appearance - Ill defined
  - Ivory vertebrae
  - Bone marrow aspiration and biopsy required for staging
  - Treatment:
    - Multi-agent chemotherapy +/- local irradiation
    - Stabilization of pathologic fractures or prophylactic fracture management
- **Multiple myeloma:**
  - Malignant proliferation of plasma cells (B cells)
  - Most common primary malignant bone cancer
  - Neoplastic plasma cells produce immunoglobulin
  - Heavy chains: (IgG, IgA, IgM) detected with Serum Protein electrophoresis
  - Light chain: Ig kappa or lambda (Bence -Jones proteins) found in urine
  - Also produce IL-6 & RANKL which activate osteoclasts
  - Skeletal survey
  - Can be solitary
  - Only 30% of bone scans are hot due to lack of osteoblastic activity
  - Punched out lytic lesions
  - Hypercalcaemia
  - Bone marrow biopsy
  - **Treatment:**
    - Multi-agent chemotherapy
    - Local irradiation
    - Bisphosphonates
    - Plasmaphoresis
    - Stabilisation of impending fractures

-

- **Differential diagnosis for patient older than 40 with destructive bone lesion**
    - Think: Infection, Tumour, Metabolic
        - Metastatic bone disease
        - Multiple myeloma
        - Lymphoma
        - Less commonly, primary bone tumours

Chordoma

- Arises from notochordal tissue
- Malignant tumour, mainly affects cervical and sacral spine (ends of notochord closes last)
- Most common primary malignant spinal tumour in adults
- Slow growing
- Bowel/bladder changes
- 50% in sacrum and coccyx, 35% in spheno-occiptal region
- 15% in mobile spine
- Metastasis late - needs long term follow up
- Back pain
- Diagnosis:
    - Radiographs - difficult to see lesion due to overlying bowel gas
    - Biopsy

(Courtesy of M Elgendy)

- Treatment:
    - Wide excision + radiotherapy (chemo resistant)
    - Very high local recurrence rate

Eosinophilic granuloma (Langerhans cell histiocytosis)

- Benign aggressive neoplasm of histiocytes
- Lytic punched out skull lesions
- Back pain in <10 years old
- Vertebra plana (differential diagnosis for Vertebra plana)
    - M (Mets, MM)
    - E (Eosinophilic granuloma
    - L (Lumphoma,Leukaemia)
    - T (Trauma , TB)
- Hand-Schuller-Christian disease: multiple lytic skull lesions, diabetes insipidus, exophthalmos

- Treatment:
    - Self-limiting
    - Brace to prevent progressive kyphosis
    - Low dose irradiation: lesions in spine that compromise stability
    - Curettage and bone grafting: for lesions that endanger articular surface or risk impending fractures

Metastatic Disease

- **Origin:** *Be Patient To Be Kind* (Bronchogenic, Prostate, Thyroid, Breast, Kidney)
- **Problems**:
    - Pain ,Instability & Pathological fractures.
- **Common sites:**
    - Proximal femur - Most common to have fracture
    - Suspect if isolated avulsion fracture of lesser trochanter
    - Most common site is thoracic spine
- Osteolytic bone lesions caused by tumour caused by activation of osteoclasts
- Osteoblastic bone metastases due to tumour-secreted endothelin-1
- Metastatic hypercalcaemia - medical emergency

  Evaluation:
    - Examine lymph nodes
    - Confirm diagnosis of solitary lesion before treatment due to risk of spreading primary tumour
    - Never assume solitary lesion is metastasis - biopsy
    - FOB (Faecal Occult Blood)
    - Blood tests - FBC, U&Es, LFTs, bone profile, myeloma screen, CRP, ESR
    - Tumour antigens used in diagnosis, monitoring of treatment response
        - CEA (colorectal carcinoma)
        - CA 19-9 (pancreatic cancer)
        - CA 125(ovarian cancer)
        - CA 15-3 (breast cancer)
        - PSA (Prostate Ca)
        - AFP (hepatocellular carcinomas)
    - Technetium bone scan - to look for other bony lesions
        - Hot due to increased bone turnover
        - Cold in MM and renal cell and thyroid and melanoma
    - Spine X-Ray - winking owl sign
    - CT chest, abdomen and pelvis to look for primary
    - MRI of whole spine to look at lesion and other skip lesions
    - Mass in spinal canal and prevertebral region
    - Compression of dural sac & spinal cord
    - Discuss with musculoskeletal MDT

(Prostate cancer with metastases to bone)
(Courtesy of H Nermina)

- **Biopsy:**
    - Differentiate between infection and neoplasm with biopsies (histology & culture)
    - Also, when primary not known

- **Tokuhashi Score:** Prognostic scoring systems for spinal metastases
  1- General condition of patient – Karnofsky score
  2- Number of spinal & extraspinal metastases
  3- Visceral metastasis
  4- Primary cancer site
  5- Neurological abnormalities
- **Treatment**:
  - Aim to reduce pain and prevent neurological deterioration
  - MSCC (Metastatic Spinal Cord Compression) is oncological emergency – refer to MDT with neurosurgery, oncology +/- radiotherapy
  - Log roll & slipper bed pan until bony stability ensured
  - Other metastatic bone disease is not an emergency – no rush to fix
- **NICE guidelines for spinal mets**
  - MDT approach (palliative care, oncologist, orthopaedic, pathologist)
  - Bisphosphonates
  - Radiotherapy pre & post op
  - Stabilization for instability

(Tumours for FRCS)

- **BOA guidelines for general bony mets**
  - Embolise feeder vessels of renal and thyroid metastasis(hypervascular)
  - Excision of solitary renal metastasis can be curative
  - Indications for surgery
    - Prophylactic fixation
    - Fracture stabilization
    - Spinal decompression and stabilization
    - Neurological deterioration

      Aim for durable reconstruction that will outlive patient
      Stabilize to improve QoL if prognosis > 1 year
- **Evidence: RCT - Lancet (Patchell, 2005)**
  Direct decompressive surgery plus postoperative radiotherapy is superior to radiotherapy alone for spinal cord compression caused by metastasis
- **Post-op radiotherapy to control tumour growth**
  - Start once surgical wound healed (>6 weeks post op)
  - Area of irradiation should include entire fixation device
- **Chemotherapy for breast and lung metastasis:** 16 mg Dexamethasone daily orally
- Pertrochanteric lesion:
  - DHS inappropriate as cut out & stress riser at distal end with disease progression
  - Need long nail or long stem THR or endoprosthesis
- **Mirel's criteria:** Predict risk of pathological fractures in bony metastasis Score > 8 - fracture risk 33%

Score	1	2	3
Site	Upper Limb	Lower Limb	Trochanteric Region
Pain	Mild	Moderate	Functional
Lesion	Blastic	Mixed	Lytic
Size	< ⅓ Cortices	⅓-⅔	>⅔

- **Complications:** Fractures & MSCC & Pain and sensory-motor deficit

FAT EMBOLISM

- Inflammatory response to embolised fat globules from damaged bone marrow fat cells leading to endothelial damage of pulmonary capillaries ,and mechanical blockage to normal gaseous exchange
- **Causes**
  - Long bones fracture
  - Intramedullary instrumentation (nailing, hip & knee arthroplasty)
- **Pathophysiology**
  - Two theories regarding the causes of fat embolism include
    - Mechanical theory:
      - embolism is caused by droplets of bone marrow fat released into venous system
      - CNS effect via patent Ductus Arteriosus (however not every patient with CNS symptoms has patent ductus arteriosus)
    - Metabolic theory:
      - stress from trauma causes changes in chylomicrons which result in formation of fat emboli
- **Onset**: 24-72 hrs (earlier than PE)
- **Prevention:** Early stabilization of long bone fractures
- **Signs:**
  - Respiratory
    - Tachypnoea
    - Pulmonary oedema (from blockage of arterial system causing hypoperfusion)
  - Cardiac: Hypotension, tachycardia
  - CNS:
    - Confusion (From petechial haemorrhage in brain)
  - Skin: Petechiae in anterior axillary fold and retina are pathognomonic
- Investigations
  - D-Dimer:
    - High sensitivity but low specificity
    - Positive in disseminated intravascular coagulation, malignancy, following surgery
  - Nuclear medicine ventilation-perfusion scan (V/Q)
  - CT Pulmonary angiography - gold standard
  - Helical chest CT
  - ECG - Sinus tachycardia, right axis deviation, right bundle branch block
- **Gurd & Wilson diagnostic criteria:** confirmed if 1 major & 4 minor signs are present
  - Major: hypoxemia, CNS depression, petechial rash, pulmonary oedema
  - Minor: Tachycardia, pyrexia, retina emboli, fat in urine/sputum, Decreased HCT and thrombocytopenia,
- **Differential Diagnosis**
  - CVA
  - Hyponatraemia
  - Infection
  - ARDS
  - PE

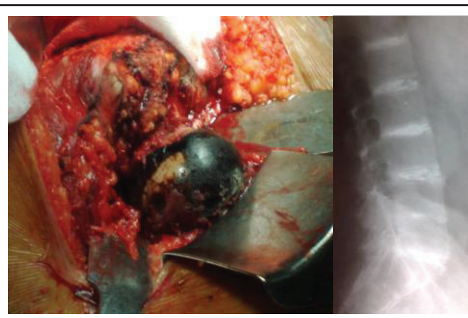
- **Treatment**
    - PEEP ventilation
    - Fluid maintenance
    - Stabilize fractures
    - ECMO (Extracorporeal Membrane Oxygenation

ARDS

- Acute respiratory failure secondary to non-cardiogenic pulmonary oedema
- Inflammatory changes damage alveolar capillary membrane and cause acute endothelial damage
- **Causes:** Trauma, aspiration, shock, infection, fat emboli, thromboembolism
  Multi-system organ failure, pancreatitis
- **Differential diagnosis:** PE, Cardiogenic oedema
- **Imaging:** Diffuse infiltrative changes on CXR
- **Treatment:** (Treat the cause)
    - Early stabilization of long bone fractures
    - Supportive treatment, PEEP, ventilation and steroids

OCHRONOSIS (ALKAPTONURIA)

- Inability to assimilate amino acids phenylalanine and tyrosine – leads to accumulation of homogentisic acid – which is excreted in urine
- Excessive acid deposited in joints leading to early arthritis and spondylitis
- Black urine
- Radiographs: ossification of annulus fibrosis



(Courtesy of M Elgendy)

SOFT TISSUE INFECTIONS

Necrotizing fasciitis

- Life-threatening infection
- Infection spreads along the fascial planes

(Courtesy of M Elgendy)

- Rapidly progresses and can be fatal if missed
- **Surgical emergency**
- **Signs:**
  - Disproportionate pain
  - Bullae (haemorrhagic)
  - Crepitus (surgical emphysema)
  - Skin necrosis
  - Discoloration
  - Fever
  - Swelling – wooden hard feel
- **Bed-side test**: Dishwater-fluid on incising the necrotic skin
- **Classification:**
  - Type I: Polymicrobial Strep & Anaerobes
  - Type II:
    - Monomicrobial Group A: (Beta haemolytic) strep
    - Higher morality
    - Can affect healthy (non-immunocompromised) patients
  - Type III: Marine: Gram neg rods, Produce exotoxins
  - Type IV: fungal (Candida)
- **Lab:**
  - Hypoalbuminaemia (< 2g/dl)
  - Thrombocytopaenia (< 80 000/ml)
  - Neutrophilia
  - Systolic BP < 90 mmHg

(Necrotizing Soft-tissue Infections: An Orthopaedic Emergency)

- **LRINEC (Laboratory Risk Indicator):**
  - Not validated – so cannot exclude Necrotising fasciitis
  - Maximum score 13 > 6 – reasonable cut-off to rule in necrotizing fasciitis

Variable	Unite	Score 0	Score 1	Score 2	Score 4
CRP	mg/L	<150			>150
WBC	$10^{6/L}$	<20	20-30	>30	
Hb	mmol/L	>8.38	6.83-8.38	<6.83	
Na	mmol/L	≥135		<135	
Creatinine	µmol/L	≤141		>141	
Glucose	mmol/L	≤10	>10		

- **Complications:** Septic shock (multiple organ failure) & ARDS & death
- **Treatment:**
  - **Urgent** surgical debridement (Plastic Surgery input is required)
  - Operative findings:

- Liquefied subcutaneous fat
- Easy to dissect subcutaneous tissues- finger-sweep to test dermo-fascial layer integrity
- Dishwater pus
- Muscle fascia necrosis, Lack of bleeding
- Venous thrombosis

- **MDT approach**: Microbiologist, Admit to ITU, fluid resuscitation, Nutritional support
- VAC difficult to apply on large areas and can cause significant blood loss
- IV Abx
- Repeat debridement in 24 hrs

Subcutaneous traumatic haematoma

- If >3cm evacuate to prevent skin necrosis
- Without trauma, consider osteosarcoma

Cellulitis

- Skin and subcutaneous tissue infection
- Group A Strep
- Treatment: Penicillin, Clarithromycin

Gas gangrene

- Clostridium perfringens or proteus / pseudomonas
- Found in gut (history of recent surgery) and soil
- Produces exotoxin which causes necrosis of fat and muscles
- Present with skin necrosis and discolouration in perineum and thighs
- Longer incubation of 3 days
- X-Ray: gas in soft tissues
- Blood culture rarely grows clostridium


(Courtesy of M Elgendy)

Impetigo

- Infection of superficial keratin layer
- Streptococcus Pyogenes, Staphylococcus Aureus
- Fluid filled blister-like lesions
- Can result in post-streptococcal acute glomerulonephritis
- Topical Bactroban (erythromycin) or antiseptics

(Soft tissue infections for FRCS)

OSTEOMYELITIS & SPONDYLODISCITIS

- **Pathogenesis:**
  - Haematogenous spread
  - Direct inoculation: (open wounds, adjacent infections)
  - Affect primary spongiosa
- **Risk factors:** IVDU, immunodeficiency (renal transplant), DM, malnutrition
- **History:**
  - Night pain, irritablity, fever
  - Oedematous, warm, swollen, tender limb, possible sinus.
- **Pathogens**:
  - Most common is Staph Aureus across all groups
  - Staph Aureus, Strep (neonates),
  - Enterobacter species, Salmonella (pathognomic in sickle cell),
  - Pseudomonas (common in IVDU) in puncture wounds to foot
- More common in lumbar spine
- **Classification:**
  - Acute
    - Within 2 months
    - Sub-periosteal abscess
    - Infants <1 year: can spread across growth plate via capillaries passing from metaphysis to epiphysis
  - Sub-acute (Brodie's abscess)):
    - Metaphysis of long bones such as proximal tibia
    - Present as draining abscess through shin
    - Radiology: radiolucent area with reactive sclerosis
    - Treatment: curettage & bone graft


(Courtesy of S Chenow)

  - Chronic
    - **Sequestrum**:
      - ✓ Devitalized necrotic bone that serves as a nidus for continual infection
      - ✓ Avascular and not connected to normal bone via Haversian canals
    - **Involucrum**: formation of reactive new bone around area of bony necrosis
    - **Cloaca**: dead spaces in bone with opening to surface

(Courtesy of M Yousef)

- **Investigations:**
  - WBC: Normal in chronic
  - ESR:
    - Elevated in acute & chronic
    - Rises 3-5 days after onset of infection
  - CRP
    - Decreases faster than ESR in successfully treated patients
    - Best indicator of early treatment success, and normalizes within a week

- Failure to decline after 48 to 72 hours of treatment - treatment may need to be altered
- Produced by liver - might not rise in liver dysfunction
- Blood culture, positive only 30% - 50% of the time
    - Can give a false negative result if after Abx administered prior to culture
    - Look for source: UTI, dental, endocarditis
- X-Rays
    - Bone destruction/osteolysis, haziness of growth plates
    - Spine - disc space narrowing and end-plate erosion
- Bone biopsy:
    - Gold-standard for guiding antibiotic therapy
    - CT guided
    - Send for aerobic, anaerobic, fungal, and acid-fast
    - Histology to rule out Ewing sarcoma
- Technetium bone scan
- MRI Enhanced with Gadolinium - Gold standard non-invasive test
    - Features that lean *towards infection in the spine:*
    - Disc space narrowing
    - End-plate erosion
    - Significant inflammation
    - Collection anterior to vertebral bodies
    - Vertebral collapse and kyphosis

(Courtesy of M Elgendy)

- Bad disc – good prognosis (Infection) & Good disc – bad prognosis (Tumour or TB)

➢ **Treatment:**

- **MDT**
    - ✓ Antibiotic treatment
        - Early disease, no pus on aspiration - no abscess
        - IV Vancomycin covers most common causes
        - Change Abx if culture & microbiologist suggest
        - For 6 weeks
    - ✓ Brace spine to prevent deformity
- **Surgical drainage**
    - ✓ Sub-periosteal/epidural abscess
    - ✓ Obtain pre and post debridement cultures
    - ✓ Indications:
        - Failure to respond to Abx
        - Spinal instability
        - Progressive deformity
        - Progressive neurology
    - ✓ Technique:
        - Evacuate abscess: open window or Drill holes
        - Debride all devitalized & necrotic tissues to bleeding bone
        - Any non-essential hardware should be removed
        - PMMA Abx beads to obliterate dead space
        - Close wound over drain or pack and re-debride in 2 to 3 days

(Spinal Infections)

- Vacuum assisted closure or soft-tissue reconstruction
- Follow with IV Abx and then PO until ESR/CRP return to normal
- Spine - Anterior decompression, debridement (corpectomy) and posterior fusion

- **Papineau Technique:**
  - ✓ Stage I: wound debridement & removal of non-viable infected soft tissue and bone
  - ✓ Stage II:
    - grafting of autogenous cancellous iliac bone
    - Implement vacuum-assisted closure (VAC) device
  - ✓ Stage III: following incorporation of graft, soft tissue coverage may be required
- **Lautenbach technique:**
  - ✓ For long bone chronic osteomyelitis
  - ✓ Debridement intramedullary reaming
  - ✓ Insert double-lumen tube to establish local Abx delivery system & cavity
- Paley described treatment of intramedullary infection with antibiotic-impregnated cement nail
  - ✓ Genta Fleece: Collagen sponge with Gentamycin protection
  - ✓ Collatamp: Collagen impregnated with the Aminoglycoside
  - ✓ Stimulan: Absorbable calcium sulphate for dead space & infection management & add 3×80 mg Gentamicin and 1g Vancomycin
  - ✓ Herafill: Premixed calcium sulphate-calcium carbonate beads with Gentamycin
- **Masqulet technique:**
  - ✓ A two-stage procedure for treatment of large segmental bone defects.
  - ✓ 1st Stage: debridement, PMMA cement spacer in bone defect then reconstruction of soft tissue spacer induces foreign body reaction and formation of vascularised membrane
  - ✓ 2nd stage: after 6-8 weeks, spacer is removed and defect filled with bone graft within the membrane

Tuberculosis

- Caused by Mycobacterium tuberculosis (Acid-Fast Bacilli)
- Haematogenous spread from lungs
- Spine, specifically thoracic is the most common extra-pulmonary site (Pott disease)
- **Diagnosis:**
  - PPD (purified protein derivative of tuberculin) is positive in ~ 80%
  - Liaise with microbiologist and chest physician
  - Culture on Lowenstein-Jensen medium for Acid Fast Bacilli can take up to 8 weeks
  - CT guided biopsy: gold standard shows granuloma
  - Heaf and Mantoux tests
  - Quantiferon test
- **MRI features of TB over non-TB infection**
  - > 2 vertebrae
  - Thoracic spine
  - Disc sparing (skip lesions) (TB likes O2)
  - Para-vertebral abscess: Begins in metaphysis of vertebral body and spreads under ALL
  - Can develop pre-vertebral abscess

- **MRI feature of TB over neoplasia**
  - Paravertebral abscess
  - Bone fragments within abscess
  - Destruction to endplate and disk space Pyogenic infections start at end plate and rupture through into adjoining disk and into next vertebral body
- **CXR**
- **Treatment:** Quadruple therapy
  (Rifampicin, Isoniazid, Ethambutol and Pyrazinamide) for 6 months
- TB and arthroplasty - don’t do until no local recurrence for 10 years 3 months pre op and 6 months post op antitubercular medications

Chronic Relapsing Multifocal Osteomyelitis CRMO

- Relapsing, remitting inflammation of multiple skeletal sites
- Autoimmune or unknown organism
- Exclude malignancy
- **Complications:**
  - Persistence or extension of infection
  - Amputation
  - Sepsis
  - Malignant transformation (Marjolin's ulcer) - Most commonly SCC
- **Epidural abscess:**
  - Collection of pus between dura mater and surrounding adipose tissue
  - More common in C-spine
  - Preoperative degree of neurologic deficits is most important indicator of clinical outcome
- **Pott paraplegia:**
  - Spinal cord injury is caused by abscess/bony sequestra (better prognosis) or meningomyelitis.
  - Caused by TB
  - Vertebra magna: with resultant canal narrowing, permanent loss of disc height
  - Block vertebra: spontaneous disc space fusion
  - Causes of neurologic deficit
    - Direct infection of neural elements
    - Compression from abscess
    - Spinal instability
    - Anterior spinal artery syndrome
  - Kyphosis: Surgery to correct deformity

Sepsis Six:

- Bundle of medical therapies designed to reduce mortality of patients with sepsis
  - 3 diagnostic and 3 therapeutic steps, to be delivered within 1 hour of initial diagnosis of sepsis
- Diagnostic:
  - Blood cultures
  - Measure serum lactate and send full blood count
  - Commence urine output measurements
- Therapeutic:
  - Deliver high-flow oxygen
  - Administer empirical intravenous antibiotics
  - Start intravenous fluid resuscitation
- Associated with decreased mortality, decreased length of stay in hospital, and fewer intensive care days.

RHEUMATIC FEVER

- Group A (Beta haemolytic) Streptococcal URTI followed by migratory polyarthropathy, chorea and carditis
- Jones criteria
  - Major: carditis, polyarthralgia, chorea, erythema marginatum, subcutaneous nodules.
  - Minor: fever, arthralgia, prior rheumatic fever, ↑ESR, prolonged PR interval
- Laboratory test: Anti-Streptolysin O titres

FIBROMYALGIA (POLYMYALGIA RHEUMATICA)

- Anorexia
- American college of rheumatology criteria, 2010
  - Wide spread musculoskeletal pain index
  - Fatigue
  - Cognitive symptoms - Deficit in attention & memory
  - Sleep disorder (unrefreshing sleep)
  - Symptoms have been present for at least 3 months
  - 11 of 18 (9 paired) tender points – Occiput, trapezius, cervical, supraspinatus, 2nd rib, lateral humerus condyle , gluteal, GT, knee
- Treatment:
  - Steroids, anti-inflammatory
  - Immunosuppression: depress monocyte & lymphocyte function
  - Amitriptyline

HIV

- RNA retrovirus
- Spread by sexual transmission, infected blood products, or transplacental
- HIV antibody seroconversion, several months after infection and before antibodies detectable
- Diagnosis made using western blot and polymerise chain reaction (PCR)
- Higher risk of MRSA infections
- Risk of seroconversion following needle stick injury = 0.3%
- From bone allograft - 1 in 1 million
- From blood transfusion 1: 6.5 million
- **Precautions in theatre (universal precautions)**
    - Warn staff of risks
    - Minimal equipment
    - Double gloves
    - Careful handling of sharps
    - Use barrier protection

HEPATITIS B

- DNA virus
- Risk of transmission
    - From needle stick: 35 – 60 % eventually seroconvert (if unvaccinated) & 20 – 30 % develop clinical Hepatitis B infection
    - From blood transfusion: 1 in1 million
    - From allograft: 1 in 65 000

HEPATITIS C

- Risk of transmission
    - From needle stick: 0.5 to 2 %
    - From blood transfusion: 1 in 2 million
    - From allograft: 1 in 100 000

MANAGEMENT OF NEEDLE STICK INJURY

- Allow wound to bleed
- Wash wound with copious running water and soap
- Cover with waterproof dressing
- Take blood from healthcare worker and patient (need consent)
- Inform occupational health

HAEMOGLOBINOPATHIES AND COAGULOPATHIES

Sickle Cell Anemia

- Genetic disorder of haemoglobin synthesis - Autosomal recessive
- Sickle cell trait involves single copy of abnormal haemoglobin gene
- Under low O2 conditions affected blood cells become sickle shaped and unable to pass through vessels efficiently
- Haemolysis and microvascular occlusion lead to bone infarcts
- **Orthopaedic manifestations**
    - Sickle cell crisis:
        - Severe bone pain
        - Mimics infection
        - Decreased uptake on bone scan
        - Treated with hydroxyurea
    - Osteomyelitis
    - Septic arthritis (S Aureus is the most common pathogen; however, Salmonella is pathognomonic with sickle cell anaemic patients)
    - Osteonecrosis of femoral and humeral heads
    - Biconcave fish tail vertebrae due to bone infarct causing spinal collapse
    - Growth retardation/skeletal immaturity
    - Dactylitis
- MRI and bone scan differentiate infarction from infection
- Treat exertional sickling with rest, hydration and oxygen
    - Pre-operative transfusion in planned surgery

Primary hypercoagulopathies (inherited)

- Cause thrombophilia:
    - Factor V Leiden mutation (mutation renders it resistant to activated protein C)
    - Antithrombin III deficiency
    - Protein C deficiency or resistance
    - Protein S deficiency
    - Activated protein C resistance

Factor V acts as co-factor for activation of factor Xa
Activated Protein C is an anti-coagulant that degrades factor V)

- Splenectomy is associated with
    - Howell-Jolly bodies
    - Thrombocytosis
    - Macrocytosis (persistence of larger red blood cells)
    - Acanthocytes
    - Leucocytosis

Haemophilia

- Most common hereditary bleeding disorder (X-linked recessive)
- Excessive bleeding into joints and muscle - Synovitis & cartilage destruction - joint deformity
- Intramuscular hematoma can cause compartment syndrome
- Iliacus hematoma may compress femoral nerve
- Leg length discrepancy due to epiphyseal overgrowth
- Fractures due to generalized osteopaenia
- Repetitive haemarthrosis most commonly affects knee

- **Types:**
  - Haemophilia A (factor VIII)
  - Haemophilia B (Christmas disease)
    - Factor IX deficiency
    - Factor levels < 1 – 2 % are severe
    - Factors VIII and IX required for generation of thrombin in intrinsic coagulation pathway
    - APTT prolonged, but PT normal
  - Von Willebrand's disease
    - Autosomal dominant
    - Protein that carries factor VIII
    - Abnormal Von Willebrand factor leads to platelet binding dysfunction
    - Menorrhagia

- **Radiographs**:
  Ballooning of distal femur and widening of intercondylar notch and squaring of femoral condyles

- **Treatment:**
  - MDT (Haematologist) approach to pre-operative planning
  - Factor VIII or IX administration
  - Desmopressin (DDAVP)
  - Synovectomy
  - Synoviorthesis: destruction of synovial tissue with Intra-articular injection of radioactive agent

ARTHRITIS

Septic arthritis

- Release of proteolytic enzymes from inflammatory cells (PMNs) cause irreversible articular cartilage destruction
- Irreversible cartilage injury can occur by 8 hours
- **Pathogens**:
    - Staphylococcus species - most common in all groups of patients
    - Neisseria gonorrhoea - healthy sexually active adolescent & young adult
    - Streptococcus A & B
    - Salmonella - associated with sickle cell disease
    - Pseudomonas aeruginosa – associated with IV drug abuse
    - Lyme disease - Borrelia following bite of deer tick, erythema migrans
    - Kingella - in children – PCR for diagnosis
    - Extremity tends to be in position of maximum joint volume
    - ESR -
        - Often elevated but may be normal early
        - Rises within 2 days of infection and returns to normal 3-4 weeks
    - CRP -
        - Best to judge efficacy of treatment
        - Rises within few hours of infection
        - Normalize within 1 week of treatment
    - Joint fluid aspirate - gold standard
- **Treatment**: Emergency joint washout & Synovectomy

Degenerative arthritis

- Loss of articular cartilage of synovial joints
- Disruption of collage network allow hyperhydration - softening and decreased Young modulus of elasticity
- Reduced proteoglycans and increased water contents
- Increased inflammatory cytokines - IL1, IL6, TNF alpha
- **Risk factors**: obesity, manual labourers
- **Classification**
    - Grade 0: Normal appearances
    - Grade 1: Osteophytes with normal joint space
    - Grade 2: Less than 50% joint space reduction
    - Grade 3: More than 50% joint space reduction
    - Grade 4: Bone-on-bone contact
- **X-Rays:** Sub-chondral sclerosis, cyst, joint space narrowing, osteophyte
- **Why do osteophytes form?**
    - Wolff's law - bone responds to increased stress by laying more bone degenerate articular cartilage increases stress on bone
- **Why do cysts form?**
    - Stress fractures in sub-chondral bone don't heal because of continued pressure

Inflammatory Seropositive

- **Rheumatoid arthritis**
  See below
- **Juvenile Idiopathic Arthritis**
  - Arthritis for > 6 weeks in < 16 years
  - Rash
  - Most common joint affected is knee
  - Polyarticular (>4 joints)
  - Pauciarticular (<4 joints)
  - Atlanto-axial instability: flexion - extension radiographs
  - Ocular involvement: slit lamp twice yearly, Progressive iridocyclitis – blindness.
  - Treatment: DMARD (Disease Modifying Anti Rheumatic Drugs)

  Stills disease JRA with splenomegaly & fever & rash
  Treatment: Aspirin
- **SLE**
  - Butterfly facial rash
  - Joint pain
  - Reynaud phenomenon
  - Pancytopenia
  - Nephritis
  - Pericarditis
  - Positive - ANA & HLA-DR3

BSR & BHPR, BOA, RCGP and BSAC guidelines for management of the hot swollen joint in adults

Inflammatory sero-negative arthritis (RF and ANA negative)

- **Gout**
  - Tophi - ear, olecranon, Achilles tendon
  - Podagra: arthritis attacks of 1st MTPJ
  - Monosodium urate crystals, needle shaped, negatively bifringent, yellow
  - Crystals lead to inflammatory response
  - 80% of people with elevated uric acid will never have gout attack
  - Types:
    - Primary
    - Secondary: haemolytic anaemia, leukaemia, chemotherapy
  - X-Rays:
    - Punched out peri-articular erosion
    - Soft tissue crystal deposition or swelling
    - No osteopenia
  - White toothpaste-like appearance of tophus aspirate
- **Pseudogout**
  - Calcium pyrophosphate crystals, rhomboid shaped, positively bifringent, blueaa1
  - Can be very destructive
  - Chondrocalcinosis - Radiologic calcification in cartilage Knee & TFCC
  - Affect patients older than gout (> 60 years) and knee most often

- Treatment:
    - NSAIDs (Indomethacin 50mg TDS)
    - Colchicine (in patients with history of peptic ulcers)
    - Glucocorticoids
    - Prophylactic (Allopurinol (Xanthine Oxidase inhibitor)S

➢ **Reiter (Reactive arthritis)**

- Triggered by bacterial or viral GI or GU infection
- Components: Arthritis, urethritis, conjunctivitis, sacroiliitis. (Can't see, pee or bend the knee)
- Young male <40
- HLA-B27 positive in 75% of cases.
- Associated infections: Mycoplasma, Yesinia, Salmonella, Shigella, Chlamydia, Campylobacter
- Treatment: Antibiotics, NSAIDS

➢ **Psoriatic arthritis**

- HLA B27 positive in 50%
- Asymmetrical (different from RA)
- Bone density normal unlike RA
- Affects hand DIPJs
- Unlike OA does not have sclerotic margin.
- Onychodystrophy: Nail pitting.
- Dactylitis: sausage digits
- Arthritis Mutilans: severe form with gross instability.
- X-rays - Pencil-in-cup deformities
- Red scaly rash over extensor surfaces
- Entheses - Tendoachilles, Tib Post.
- Similar treatment to RA

TEST	+ve in
Rheumatoid factor	-RA -Sjogren's syndrome -Sarcoidosis -SLE
HLA-B27	-AS -Reiter's syndrome -Psoriasis -Enteropathic
Antinuclear antibody	-SLE -Sjogren's syndrome -Scleroderma

➢ **Enteropathic arthritis**

- inflammatory condition affecting the spine and other joints that commonly occurs in the inflammatory bowel diseases.

➢ **Neuropathic** -

- Charcot, common in Foot& ankle
- Syringomyelia - in upper limb

➢ **Haemochromatosis**

- Inappropriate high level of iron in blood and tissue
- Multi-system disease:
    - Hypogonadism
    - Diabetes
    - Liver cirrhosis
    - Cardiomyopathy
    - Arthritis
    - Skin pigmentation
- Serum Ferritin level elevated

- Liver Biopsy (gold standard)
- Should be suspected when symmetrical ankle arthropathy occurs in young men
- Treatment: reduce consumption of red meat
  - Avoid raw shellfish
  - Limit supplemental vitamin C
  - Avoid excessive alcohol (secondary liver damage)
  - Weekly blood letting

➢ **Scleroderma** - affects connective tissue in skin, joints, blood vessels
- Reynaud phenomenon

Rheumatoid Arthritis

➢ Chronic, systemic, autoimmune, polyarthropathy
➢ Bilateral symmetrical joint involvement
➢ T Cell-mediated immune response inciting synovial hypertrophy and mononuclear destruction of cartilage
➢ Pannus
- Characteristic histological feature
- Inflamed proliferative layer of synovium containing fibroblasts, plasma cells and lymphoid follicles

➢ **Aetiology**
- Unknown
- Genetic predisposition - (Human Leukocyte Antigen) HLA DR4 & DW4
- Rheumatoid factor is autoantibody IgM against IgG –
- IgM attaches to IgG forming immune complexes which are deposited in tissues causing damage

➢ **Felty Syndrome:** RA with splenomegaly & leukocytopenia
➢ **Sjogren's syndrome:** RA with decreased salivary and lacrimal secretions
➢ **American Rheumatism Association criteria:**
- Five out of following must be present for longer than 6 weeks
  1. Morning stiffness
  2. Arthritis of 3 or more joints
  3. Arthritis of hand joints
  4. Symmetrical arthritis
  5. Rheumatoid nodules
  6. RF positive
  7. Radiographic changes

➢ **X-Rays**
- Periarticular erosion from synovitis
- Generalized osteopenia
- Soft tissue swelling
- Deformities

➢ **Bloods**
- CRP
- ESR
- RF (in 70%)
  - 4% false positive
  - May be positive in chronic infections (TB, syphilis)

- ANA (Anti-Nuclear Antibodies)
- Anti CCP Ab (most sensitive & specific test)
- Anaemia

➢ **Manifestations**
- Temporomandibular joint involvement
- Spine - Atlantoaxial subluxation
- Hand deformities
- Knee valgus
- Foot - Pes planus
- Extra-articular Pulmonary fibrosis, Scleritis
- Rheumatoid nodules commonest extra-articular manifestation (Subcutaneous over elbow and hand)
- If painful or ulcerated - inject with steroid or excise

➢ **Treatment**
- **MDT**
- **Aim:** control synovitis, maintain joint function, prevent deformity, and relieve pain
    - Whenever patient present with RA – think of other manifestations
    - Rocker bottom (custom made) shoes to decrease pressure under MT head
- **Medical**
    - 1st line: Low dose corticosteroid
    - 2nd line: (DMARDs)
        - Methotrexate 7.5 – 25 mg/week
        - Sulfasalazine 2-3g/day
        - Hydrochloroquine
        - Leflunomide
        - Azathioprine
    - 3rd line: TNF antagonists
        - Adalimumab (Humira)
        - Etanercept
        - Infliximab
    - 4th line (IL1 antagonists)
        - Anakinra: Block biologic effects of pro-inflammatory cytokine
    - Consider bone protection therapy for osteopenia
- **Surgical**
    - Address proximal joints 1st
    - Synovectomy
    - Fusion
    - Replacement
- **NICE guidelines 2009**
    - Indication for surgery in RA:
        - Persistent pain because of joint damage
        - Worsening joint function
        - Progressive deformity
        - Persistent localised synovitis
        - Imminent or actual tendon rupture
        - Nerve compression

- Cervical myelopathy
- Stress fracture

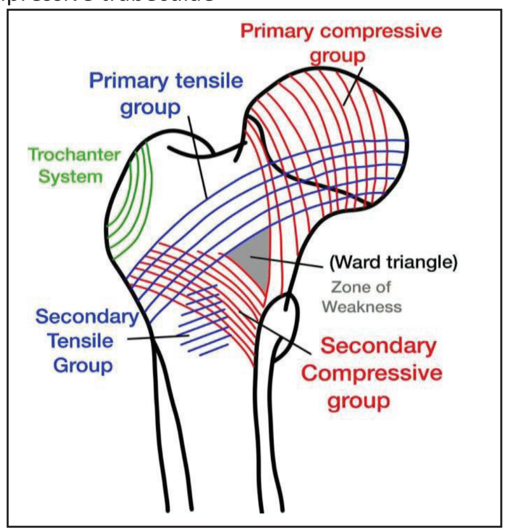
- **Perioperative management of RA medications**
  - **Steroids:** Low dose (≤7.5 mg/day) or any dose for <3 weeks – continue
  - **Methotrexate:** Continue - Doesn't impair wound healing or increase infection risk
  - **DMARDs:** Hold off postoperatively until bowel & renal function restored
  - **TNF antagonists:** Stop 1 dose cycle preoperatively and restart when wound healed

METABOLIC BONE DISORDERS

Osteoporosis

- **WHO definition**
    - Systemic skeletal disease characterised by low bone mass & micro-architectural deterioration of bone tissue, with consequent increase in bone fragility and susceptibility to fracture
    - BMD of > 2.5 below mean bone mass of average young healthy adult as measured by DEXA
    - Coupling: bone resorption followed by bone formation
    - Quantitative defect of bone: overall reduction in bone mass
- **DEXA scan**
    - Osteopenia: T score -1 to -2.5 SD
    - Osteoporosis: T score more than 2.5 SD below the mean
- **Blood tests:** Normal Ca, ALP, Vit-D and PTH
- Most individuals attain peak level of bone mass between ages of 16 and 25 years
- Bone mass decreases 2-3% per year for untreated women after menopause
- Fragility fracture - fracture following a fall from a standing height in patient > 50 years
- **Types**
    - Primary I: Postmenopausal
    - Primary II: senile > 75
    - Secondary: Steroid induced osteoporosis
- **T-score**
    - BMD against average young of same sex and race
    - Low is osteoporosis
- **Z-score**
    - BMD against *age matched* population of same sex and race
    - Low suggest pathology other than osteoporosis – such as juvenile idiopathic osteoporosis
- **NICE - osteoporosis guidelines 2012**
    - Fragility fractures result from mechanical forces that would not ordinarily result in fracture
    - Consider treatment for women >65 years & men > 75 years and presence of risk factors:
        - Previous fragility fracture
        - Use of glucocorticoids
        - History of falls
        - Family history of hip fracture
        - Smoking
        - Alcohol intake > 14 units/week for women & > 21 units/week for men
        - BMI < 19
        - Younger patients with risk factor - FRAX score

- **Singh index for osteoporosis**
  - Changes in trabecular pattern of upper end of femur as index of osteoporosis
  - These patterns are formed to resist tensile and compressive forces
  - **Bundles of trabeculae in proximal femur are**
    1. Primary compressive
    2. Primary tensile
    3. Secondary compressive
    4. Secondary tensile
    5. Greater trochanter
  - **Ward triangle**
    - Weak area of femoral neck formed by intersection of 3 bundles of trabeculae
    - Primary compressive, primary tensile and secondary compressive trabeculae



Femoral Trabecular-Pattern for Evaluation of Osteoporosis

- **Treatment** (National osteoporosis Guideline Group NOGG)
  - Replacement Ca 1500 mg & Vit. D 400 IU
    Elderly need more Vit-D to absorb Ca
  - Anti-resorptive
    - Bisphosphonates
    - Alendronate 70 mg once a week
    - Monthly Ibandronate helpful in patients who cannot tolerate weekly Alendronate or Risedronate, but does not have proven anti fracture efficacy in hip fracture
    - Inhibit osteoclasts by inhibiting attachment of ruffled border to bone surface & suppressing formation of ruffled border & inducing apoptosis
    - Types:
      - Nitrogen: Pamidronate Alendronate, Ibandronate, Zoledronate (IV)
      - Non-nitrogen: Induce osteoclast to undergo premature death & apoptosis
        Fracture intervention trial (Alendronate) –JAMA 1998
        50% ↓fracture risk
        Significant ↑ BMD
        Vertebral efficacy in Risedronate trial (VERT) –JAMA 1999
        41 – 49% ↓ vertebral #
        05 – 06% ↑ L-spine BMD
    - Side effects
      - Gastritis & oesophagitis take after food (Stay upright for 30 min)
      - Jaw osteonecrosis (treat with Teriparatide)
      - MHRA warned of atypical sub-trochanteric fractures in patients exposed to > 5 years of therapy
      - Routine contralateral imaging to rule out stress #

    - Prophylactic intramedullary fixation
  - Other uses:
    - Paget, CRPS, GCT, OI, Charcot's joint, Polyostotic fibrous dysplasia, multiple myeloma, Metastatic bone cancer, AVN
  - Contraindication**:** Renal disease, Spinal fusion
- **Raloxifen** (Evista) - 60 mg OD
  SERM – Selective Oestrogen receptor modulator
- **HRT** - Increase risk of breast Ca and IHD and VTE
- **Calcitonin:** For osteoporosis, malignant hypocalcaemia, Paget disease (Inhibits osteoclasts)
- **Denosumab** (Prolia)
  - Inhibits osteoclast-mediated bone resorption
  - Inhibits binding of RANKL to RANK
  - Given twice-yearly by subcutaneous injection
- **Anabolic** (Strontium Ranelate 2 mg OD): Stimulate proliferation of osteoblasts & inhibit osteoclasts
- **Teriparatide** (Forteo): PTH
  - Stimulate bone
  - Daily s/c injections or Infusion
  - Contraindicated in Paget disease due to potential osteosarcoma risk
  - NICE recommend changed to Teriparatide if another fracture and bone density reduces while on Bisphosphonate

Osteomalacia

- Metabolic bone disorder leading to unmineralised osteoid (qualitative bone defect)
- Painful
- **Causes**
  - Renal osteodystrophy
  - Vit-D deficiency
  - Alcoholism
  - Mal-absorption
  - Tumour induced
  - Drugs: anticonvulsants, steroids, Aluminium containing anti-acids
- **Diagnosis**
  - Blood tests: Hypocalcaemia, increased ALP, Low Vit-D
  - X-Rays:
    - Looser zones, radio lucencies perpendicular to cortex (pseudo fractures)
    - Located on compression side of bone
  - Bone biopsy
- **Treatment** Vit. D 1000 IU/day

MELORHEOSTOSIS

- Benign painful dysplasia of extremities characterized by formation of periosteal new bone
- **Presentation:** Pain, reduced ROM
- **Radiographs:**

Dripping candle-wax appearance with dense hyperostosis that flows along cortex of bone

- **Treatment:**

Hyperostotic bone resection with contracture release for contractures and pain.

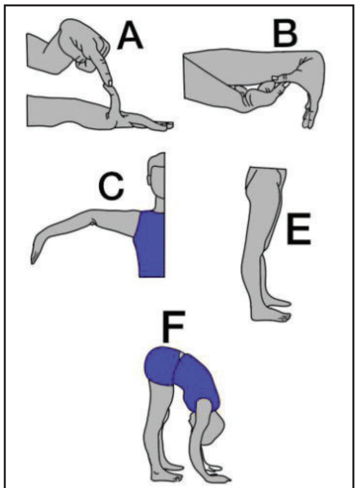
SCURVY

- Vit. C deficiency
- Leads to decrease in Chondroitin Sulphate and collagen synthesis and repair
- Also, causes abnormal collagen in blood vessels
- Affects primary spongiosa zone
- **Presentation:**
  - Bone pain
  - Bleeding gum
  - Haematuria
  - Joint effusions
  - Sub-periosteal bleeding
- **Radiographs:**
  - White line of Frankel: Widened zone of provisional calcification.
  - Trummerfeld zone: Transverse radiolucent band in metaphysis adjacent to Frankel line.
  - Wimberger ring: Ring of increased density surrounding epiphysis.
  - Pelkin spur & fracture: Metaphyseal spurs and fractures.
  - Corner sign of Park: Metaphyseal clefts

Ehlers - Danlos Syndrome

- Connective tissue disorder resulting from mutation of gene for type V collagen
- Hyper-elastic fragile skin with joint hypermobility & dislocation
- Mitral & aortic valve abnormalities
- Poor wound healing (hypertrophic scars)
- Bone fragility
- **Beighton-Horan scale defines joint hypermobility**

(1 point for each category in each limb, 5 or more suggests hypermobility)
  - Passive hyperextension of each index finger >90°(parallel to forearm)
  - Passive abduction of each thumb to forearm
  - Hyperextension of each knee >- 10°
  - Hyperextension of each elbow > -10°
  - Forward flexion of trunk with palms on floor and knees fully extended
- Diagnosed by collagen typing of skin biopsy



Beighton score

MARFAN SYNDROME

- Autosomal dominant
- Fibrillin gene defect found on chromosome 15
- Physeal hyperplasia
- Connective tissue disorder **associated with:**
  - **Skeletal**
    - Long limbs (dolichostenomelia): arm span greater than height
    - Arachnodactyly: long, thin toes and fingers
    - Steinberg sign: thumb extends beyond ulnar border of palm when held in fist
    - Ligamentous hyperlaxity
    - Scoliosis: bracing ineffective
    - Dural ectasia
    - Protrusio acetabulum
    - Pes planovalgus
    - Tall patient (try to differentiate from Homocysteinuria – see table below)
  - **Cardiovascular**
    - Mitral valve prolapsed
    - Aortic dilatation (risk of aortic dissection)
    - Pectus excavatum
  - **Ocular**
    - Superior lens dislocation

Marfan's Syndrome	Homocystinuria
AD-structure Fibrillin	AR-Enzyme Cystathionine synthase
Superior lens ectopia	Inferior lens ectopia
Joints loose	Joints stiff
Die by rupture aortic aneurysm	Die by pulmonary embolism\clots

GAUCHER DISEASE

- Enzyme deficiency of glucocerebrosidase leads to disturbances in cell metabolism with accumulation of sphingolipids in the liver, spleen and bone marrow
- More common in Ashkenazi Jewish origin
- Affects the Reserve zone of the physis

- **Systemic Manifestations**
  - Fatigue (anaemia)
  - Prolonged bleeding (thrombocytopenia)
  - Fever, chills, sweats (infection)
  - Seizure, developmental delay (CNS involvement)

- **Orthopaedic Manifestations**
  - Osteonecrosis in proximal and distal femur, proximal tibia and proximal humerus
  - Bone pain (fracture, osteomyelitis)
  - Bone crisis
- Erlenmeyer flask deformity: radiographic appearance typically in the femur showing relative constriction of the diaphysis and flaring of the metaphysis.
- **Diagnosis** confirmed by elevated plasma levels of glucocerebrosides

- **Treatment**
  - Supportive
  - Enzyme replacement
  - Bone marrow transplant

- **Preoperative considerations**
  - Preoperative optimization with enzyme therapy
  - Availability of blood, clotting factors and platelets
  - Maintain oxygenation to avoid precipitating bone crisis
  - Increased risk of infection

Paediatric Orthopaedics

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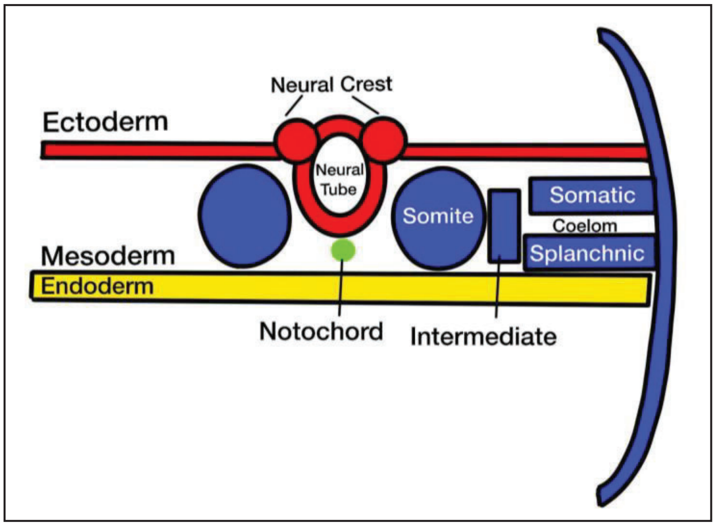
CONTENTS

GROWTH AND DEVELOPMENT

Embryo layers

- **Ectoderm:** Neural plate forms neural tube (brain and spinal cord) and neural crest cells (peripheral nervous system)
- **Mesoderm:**
  - Notochord is mesoderm-derived (persists as nucleus pulposus)
  - Para-axial - forms somites
    - Dermatome: dorsal aspect, forms skin
    - Myotome: forms skeletal muscles
    - Sclerotome: forms axial skeleton, annulus and ribs
    - Intermediate - skeleton
    - Lateral plate - bone and cartilage
- **Endoderm**: GI & respiratory



(Limb development)

Limb development

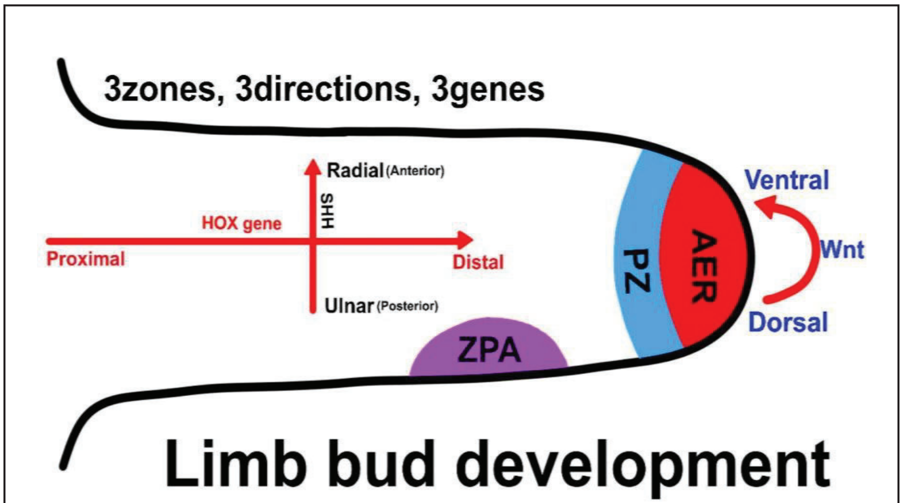
- Upper & lower limb buds start to form by 4 weeks from ventro-lateral aspect of embryo
  - Upper Limb day 24: C5 – T1
  - Lower Limb day 28: L2 – S3
  - Digits: 8 weeks, by cell death (apoptosis) along AER (Apical Ectodermal Ridge)
- Limb Bud mesenchymal core with thick ectodermal cap (Apical Ectodermal Ridge)
- Controlled by:
  - HOX genes: guide formation of correct structures in the limb at correct places of the body and help in segment development
  - Sonic Hedgehog protein (SHH) – secreted at ZPA (Zone of Polarizing Activity) at posterior part of limb bud
- Primary ossification centers from 8 weeks
  - Skeleton forms as a complete cartilage anlage with cleavage at each joint
  - Anlage: mid-shaft chondrocytes hypertrophy, vascular invasion to form Primary ossification centres
  - Osteoprogenitor cells migrate through vascular buds and differentiate into Osteoblasts

Three axes of development

- **Proximal – distal**
  - Proliferation of lateral mesodermal plate
  - Guided by Apical Ectodermal Ridge (AER) - Condensation of ectoderm
  - Fibroblast growth factor (FGF8) from AER critical to direct longitudinal growth of limb
  - Positive feedback loop between FGF 8, FGF 10 and Wnt 3a
  - Interaction of *Retinoic Acid and FGF8*
  - Affected by HOX (Homeobox) genes - Tbx 5 for upper limb and Tbx 4 for lower limb
  - Defect in AER – Proximal limb truncation (Cleft hand, radial club hand)

- **Radial - ulnar**
  - ZPA - Zone of Polarizing activity
  - Plays role in digit formation – Posterior elements > Anterior elements
  - Controlled by *Sonic HedgeHog SHH gene*
    - High concentration SHH posterior (ulnar) side – little finger development
    - Abnormally high – duplication – polydactyly on ulnar side
    - Abnormally low – loss of ulnar digits
    - Low concentration anterior (radial) side for thumb development
    - Abnormally high – loss of thumb

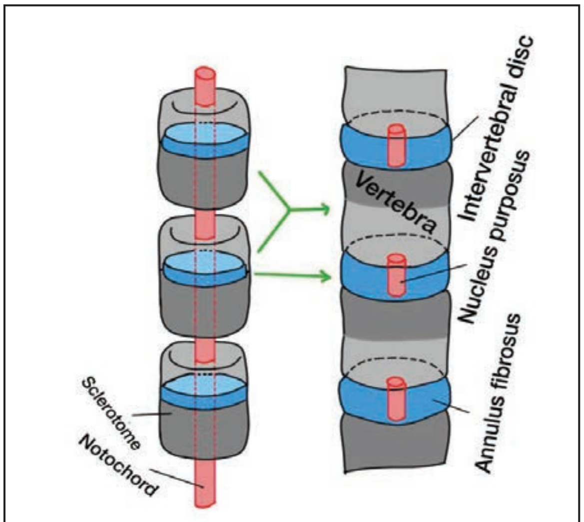
- **Dorsal – ventral**
  - Controlled by Dorsal Ectodermal Zone (non-AER) – Progress Zone
  - Directed by *Wnt(Wingless type) gene* which is responsible for all dorsal features
  - Engrailed-1 protein antagonistic to Wnt7a to allow ventral development.



(Idea courtesy of R Dhir)

Spinal column development

- **Somites** develop in cranial to caudal direction on either side of notochord & neural tube
    - Dorso-ventral patterning
        - SHH (ventral)
        - Canonical Wnt/B-catenin (dorsal)
    - Failure to close leads to...
        - Anencephaly when it fails to close cranially
        - Spinal bifida when it fails to close distally
- **Neural Tube:** Forms spinal cord
- **Neural crest**
    - Dorsal to neural tube
    - Becomes PNS, pia-mater, sympathetic trunk, basal ganglia, skin
- **Notochord**
    - Ventral to neural tube
    - Forms anterior vertebral bodies and nucleus pulposus
- **IV Disc**
    - Nucleus pulposus from Notochord
    - Annulus fibrosis from Sclerotome
- **Ossification** (3 centres):
    - Centrum: anterior vertebral body
    - Neural arch: posterior elements, pedicles, small part of anterior vertebrae
    - Costal elements: rib transverse processes, anterior part of lateral mass



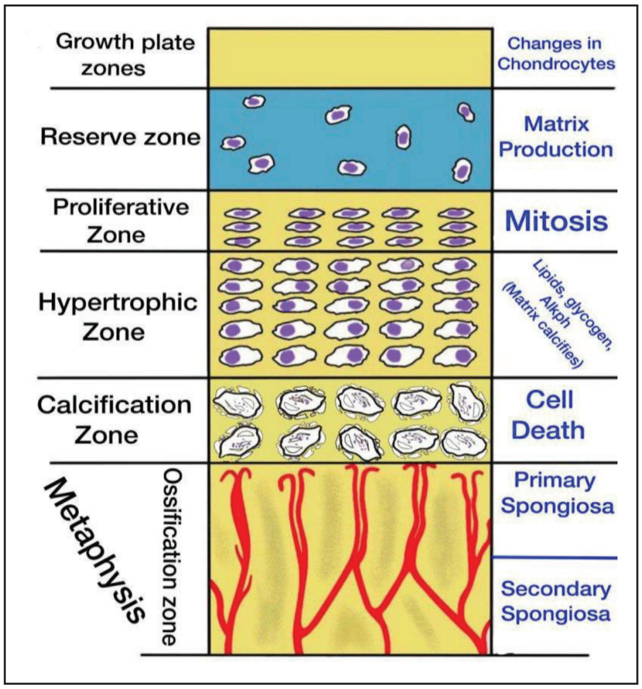
Spinal cord development

Cervical Spine Development

- **Atlas** (3 ossification centres):
  - Anterior arch: fuses to posterior arch age 7 years at the neurocentral synchondrosis.
  - 2 neural arches: fuse posteriorly age 3-4 years.
- **Axis** (4 ossification centres) –
  - Odontoid process & Body (centrum) & 2 neural arches.
  - Odontoid process: forms at 7th month of gestation
  - 2 separate ossification centres either side of midline: fuse at 3 months to form chondrum terminale,
  - 2 neural arches fuse at 2-3 years and fuse to the body at 3-6 years.
  - Body separated from odontoid process by dentocentral synchondrosis. This may persist until age 11 years and be mistaken for a fracture.
- **Sub-axial** (3 ossification centres):
  - 2 neural arches and a body.
  - Neural arches fuse 2-3 years and to the body at 8 years.
  - 95% canal diameter by 5 years.
  - Secondary ossification centres may be mistaken for a fracture – tip of transverse process, tip of spinous process, sup/inf aspects of vertebral bodies.
- **Packaging disorder**
  - Limbs moulded into abnormal positions in third trimester
  - Congenital Torticollis, DDH, metatarsus adductus
- **Thalidomide**
  - Inhibit angiogenesis – phocomelia
  - Associated with hydrocephalus and genitourinary malformations

GROWTH PLATE (PHYSIS)

- **Hueter-Volkman law**Compressive forces on the growth plate, above physiological limit inhibits bone growth whereas tension stimulates it
- Blood supply
  - Perichondrial artery is the major source of nutrition of growth plate
  - Epiphyseal artery supplies reserve and upper proliferative zone (main blood supply)
  - Nutrient and metaphyseal arteries supply calcification zone
- Decreased 02 tension as you go deeper in the layers



Reserve/Resting Zone

- Germinal cells of stem cell origin
- Small Chondrocytes surrounded by dense extracellular matrix in low O2 environment
- High ratio of ECM to cells
- Not aligned in columns
- Respond to circulating hormones
- Cells store lipids, glycogen and proteoglycan for later growth and matrix production

Proliferative Zone

- Chondrocytes proliferate and divide
- Increase in O2 tension – inhibits calcification
- Highest rate of ECM production
- Longitudinal growth – Type II collagen
- Columns of flattened chondrocytes
- Increased PG

Hypertrophic Zone

- Maturation Zone – Chondrocyte proliferation decreases and chondrocyte grow (5 times)
- Degenerative Zone – chondrocyte death (apoptosis)
- Provisional Calcification Zone – Chondrocyte death releases calcium for matrix calcification
- Type X Collagen – produced by hypertrophic chondrocytes
- Regulated by PTHrP, Indian hedgehog gene

Primary Spongiosa

- Vascular invasion from metaphysis brings osteoblasts and osteoclasts
- Matrix ossification
- Remodelling as primary bone is replaced
- Corner fractures

Secondary spongiosa

Closest to metaphysis

- **Groove of Ranvier**
    - Wedge of cells (Chondrocytes)
    - Adds width to the physis
    - Responsible for appositional bone growths by producing chondrocytes
    - Supplies chondrocytes to periphery
    - No periosteum in physis
    - Don't put K wire through it
    - Osteochondroma, Dysplasia Epiphysealis Hemimelica (Trevor's Disease)
- **Perichondrial ring of La Croix**
    - Dense fibrous circumferential ring bridging and anchors epiphysis to metaphysis
    - Provides mechanical strength to resist compression, tension and shear
    - Merges with periosteum of metaphysis
- **Apophysis**
    - Extra-articular
    - Insertion for tendons

Disorders of the Growth Plate

Epiphyseal Dysplasia	-Spondyloepiphyseal Dysplasia (SED) -Chondrodysplasia punctata -Multiple Epiphyseal Dysplasia (MED)
Reserve Zone	-Pseudoachondroplasia -Kniest dysplasia -Diastrophic dysplasia -Gaucher’s / Niemann-Pick
Proliferative Zone	-Achondroplasia -Gigantism -Hypochondroplasia
Hypertrophic Zone	-Mucopolysaccharidoses
Zone of provisional calcification	-Rickets -SCFE (not renal failure SCFE which is at spongiosa) -Physeal fracture -Enchondroma
Primary Spongiosa	-Metaphyseal Chondrodysplasia (Jansen, Schmid) -Osteomyelitis
Secondary Spongiosa	-Osteopetrosis -Osteogenesis imperfecta -Scurvy

DYSPLASIA

- **Dysplasia** abnormality of development, shape or structure of skeleton
- **Dystrophy** weakening, degeneration, or abnormal development of muscle
- **Short stature:** Height below 4' 10" at skeletal maturity (or 3SD below average)
  - Proportionate - metabolic and hormonal disorders
  - Disproportionate (normal trunk with short limb)
    - Rhizomelic: proximal short limb (achondroplasia)
    - Mesomelic: middle of limb (short forearm/legs)
    - Acromelic: distal short limb (short hands/feet)
- **<u>Type</u>**
  - Epiphyseal:
    - Hypo:
      - ✓ SED
      - ✓ MED
    - Hyper: Dysplasia Epiphysealis hemimelia (Trevor's disease)
  - Physeal
    - Hypo
      - ✓ Achondroplasia
      - ✓ Pseudoachondroplasia
    - Hyper
      - ✓ Marfan
      - ✓ Enchondromatosis
      - ✓ MHE
  - Metaphyseal
    - Hypo
      - ✓ Hypophosphatasia
      - ✓ Osteopetrosis
      - ✓ Metaphyseal chondrodysplasia
    - Hyper: Multiple exostosis
  - Diaphyseal
    - Hypo
      - ✓ OI
      - ✓ Osteoporosis
      - ✓ Hyperphosphataemia
    - Hyper

Spondyloepiphyseal Dysplasia (SED)

- Congenita: AD
- Tarda: X-linked
- Mutation in **COL2A1 gene** – defect in Type II collagen
- **Proportionate dwarfism** – short trunk and short limbs
- Congenita more severe than tarda
- Flat face
- Delayed epiphyseal appearance at hips
- Genu valgum
- Clubfeet

- Check for retinal detachment / myopia
- Primarily affects vertebrae and epiphysis of bone
- Cervical myelopathy due to atlantoaxial instability, odontoid hypoplasia or Os Odontoideum
- Instability from odontoid hypoplasia
- Thoracolumbar scoliosis
- Respiratory difficulty - secondary to thoracic dysplasia
- Hip pain due to coxa vara
- Flattened vertebral bodies / vertebral beaking

Chondrodysplasia Punctata

- 2 inheritance forms – AD and AR
- Perioxisomal enzymatic defect
- AD form (Conradi-Hunermann) less severe than AR form
- Rhizomelic dwarfism
- Multiple punctuate calcifications, flat face, stippled epiphyses

Multiple Epiphyseal Dysplasia (MED)

- AD
- Abnormality in **Cartilage Oligomeric Matrix Protein (COMP)** or Collagen IX (and Type II)
- Short-limbed, **disproportionate dwarfism**
- Irregular epiphyseal ossification in multiple long bones. Affects epiphyseal growth plate rather than horizontal growth plate. Therefore, epiphyses are abnormal but overall length of long bone is normal. 33% patients have short stature
- Waddling gait
- Severe form – Fairbanks
- Coxa Vara – Usually same stage bilaterally unlike Perthes. Early acetabular changes and no metaphyseal cysts.
- Flat femoral condyles
- Double-layer patella
- Genu valgum
- Joint deformity
- Short Metacarpals and Metatarsals
- Treatment – corrective osteotomy or hemiepiphysiodesis

Trevor's Disease

- Osteochondroma in the Groove of Ranvier – Asymmetric limb development
- Incidence 1:1,000,000
- Male > Female
- Usually knee or ankle
- Joint deformity with early OA
- Treatment – excision of overgrowth or corrective osteotomy
- Recurrence is common.

Disorders of the Reserve Zone

Pseudoachondroplasia

- AD
- Clinically like achondroplasia
- COMP protein mutation
- Differs from achondroplasia by normal face
- Cervical instability due to odontoid hypoplasia
- Absence of spinal stenosis
- Flexion contractures and OA of joints
- Metaphyseal flaring
- Delayed epiphyseal ossification

Kniest Dysplasia

- AD
- Defect in Type II collagen
- Disproportionate dwarfism – short trunk
- Joint contractures, enlarged and stiff joints
- Dumbbell-shaped femur
- Retinal detachment
- Cleft palate
- Scoliosis & kyphosis
- Round face with central depression and prominent eyes
- Bell-shaped chest

Diastrophic Dysplasia

- AR
- Defect in Phosphate transport protein
- Very short stature - Rhizomelic shortening - disproportionate dwarfism
- Stiff joints
- Cleft palate
- Cauliflower ears - early treatment with compressive bandages
- Hitchhiker's thumb
- Thoracolumbar scoliosis
- Severe cervical kyphosis and atlantoaxial instability
- Hip and knee contractures
- Genu valgum
- Dysplastic hips
- Bilateral skew foot and rigid clubfoot

Gaucher

- AR
- Lysosomal storage disease with accumulation of cerebroside
- Ashkenazi Jewish population at risk
- Femoral head necrosis
- Erlenmeyer-flask shaped distal femur
- Hepatosplenomegaly
- Bone pain indicates Gaucher crisis – involved bone appears 'moth-eaten'

Neimann-Pick

- AR
- Accumulation of Sphingomyelin
- Expanded marrow space and cortical thinning

Disorders of the Proliferative Zone

Achondroplasia

- **Commonest** skeletal dysplasia
- AD
- Mutation of **FGFR3** on Chromosome 4. Defect causes FGFr3 to be continually active leading to abnormal production of chondroblasts in proliferative zone during endochondral bone formation.
- **Disproportionate short-limbed dwarfism**
- **Rhizomelic** (proximal involvement) - short humerus and femur. May be seen as short femur on antenatal USS
- Large head with frontal bossing and mid-face hypoplasia
- Trident hand
- Ligamentous laxity
- Spine
    - Lumbar and cervical stenosis (short pedicles, decreased inter-pedicular distance),
    - Foramen magnum stenosis, kyphosis (resolves spontaneously, can brace in extension until 2 years old)
- Champagne glass pelvis - wider than it is deep
- Genu varum and inverted V distal femoral physis
- Advanced parental age is a risk factor
- Wide metaphysis
- Normal intelligence and normal life expectancy
- Delayed motor milestones
- **Treatment**
    - Lengthening (if requested by patient)
    - Growth hormone to augment height
    - Distraction osteogenesis - takes long time
    - Kyphosis - brace fusion if progressive
    - Stenosis - laminectomy
    - Genu varum - tibia osteotomy or hemi-epiphysiodesis

PAEDIATRIC TRAUMA

General Rules

- Children < 8 years are more susceptible to cervical spine injury due to larger head size relative to the trunk. Increased physiologic motion due to horizontally oriented facet joints, ligamentous laxity and weaker muscles
- Children > 8 years are more susceptible to thoracolumbar spine injuries
- All spinal injuries need to be followed to maturity due to risk of spinal column deformities
- Intraosseous infusion (antero-medial area of the upper part of the tibia) is most appropriate method of venous access in paediatric trauma patient when unable to obtain peripheral IV line
- Broselow paediatric emergency tape for estimating child's weight
- CNS and spinal injury are the predominant cause of paediatric traumatic death
- Paediatric bone has lower modulus of elasticity and absorbs more energy (more plasticity)
- Plastic deformation difficult to treat as deformity can recoil later - might have to break bone
- Periosteum thicker and stronger and can be used to assist and maintain reduction.

Physeal (growth plate) injuries

- General rules:
  - Prognosis worse with advanced types of SH classification
  - Growth plate weaker than ligaments
- **Salter Harris Classification (JBJS, Am 1963)**
  - Type I — slipped growth plate (Reserve layer not damaged)
  - Type II — through hypertrophic layer, occurs during period of rapid growth
  - Type III & IV — more significant as they go through germinal layer of physis. These are intra-articular and require anatomical reduction
  - Type V — Compression

Salter–Harris classification of epiphyseal injury

Injuries involving the piphyseal plate (Salter &Harris)

  - S – Type I: **S**eparation of physis
  - A – Type II: **A**bove the physis
  - L – Type III: **L**ower (below the physis)
  - T– Type IV: **T**hrough everything injury (involves all 3 – metaphysis, physis, and epiphysis)
  - E – Type V: **E**rasure of growth plate or Compression/crushing injury
  - R – **R**ang's modification, 1969: peri-chondral ring injury
- Angulated fractures in children remodel by 10 degrees per year
- Factors enhancing remodelling
  - Better if plane of deformity in plane of adjacent joint movement
  - Better in younger children
  - Better if fracture closer to physis

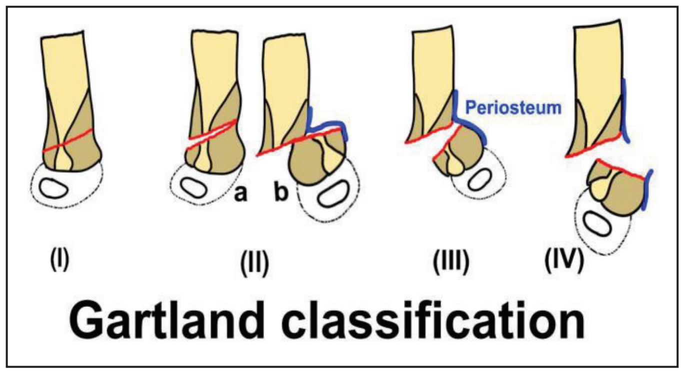
- Children's bone is more plastic which leads to unique fracture patterns
  - Buckle (torus) fractures: buckled cortex under compression
  - Greenstick fractures: incomplete fracture due to failure of cortex on tension side and plastic deformation on concave side
  - Thurston-Holland fragment: small metaphyseal triangular bone in type II and IV Named after Liverpool Radiologist, Charles Thurston-Holland (1863–1941)
- **Complications**
  - Physeal growth arrest, other causes of which are congenital or infection (Incidence reduced with anatomical reduction and fixation)
- **Treatment**
  - Closed reduction and percutaneous k-wire
  - Intra-articular fractures must be reduced anatomically with open reduction
  - Physeal growth arrest:
    - Bar resection with interposition (<50% physeal involvement, >2 years or 2cm growth remaining)
    - Contralateral epiphysiodesis and/or ipsilateral lengthening (>50% physeal involvement)

Upper limb trauma

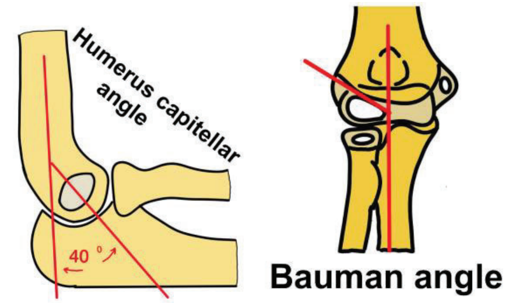
Humerus supracondylar fracture

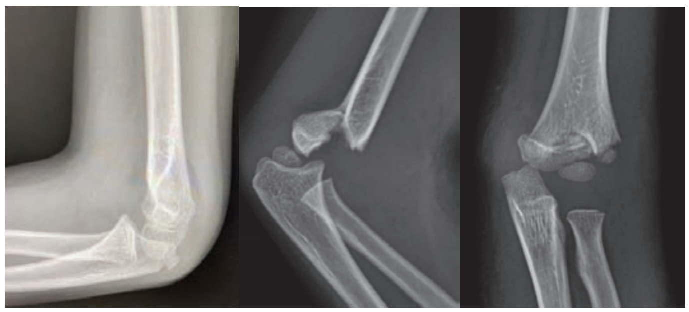
- 80% of Humerus growth comes from proximal physis
- Associated injuries
  1. Nerve Injury:
     - Anterior interosseous nerve (AIN) .most common nerve palsy
     - Radial nerve palsy second most common
     - Ulnar nerve palsy flexion-type injury patterns
  2. Vascular compromise rich collateral circulation can maintain circulation
  3. Ipsilateral distal radius fractures
- **Examination:**
  - AIN (OK sign) & ulnar nerves (fingers abduction)
  - Assess vascularity at regular intervals (radial pulse, capillary refill < 2 seconds)
  - Brachialis pucker sign: bruising & puckering from subcutaneous proximal fragment that buttonholed brachialis muscle. (Try to milk it out)

Pucker sign



- **Types:**
  - Flexion 5%
  - Extension 95%
    - ✓ **Gartland Classification:** for extension injuries
      - I: Non-displaced
      - II: posterior cortex intact
        - A: partially displaced with intact posterior cortex
        - B: partially displaced & rotated
      - III: completely displaced but posterior periosteum intact
      - IV:periosteum disrupted leading to instability in flexion and extension - diagnosed intra-operative
- **Radiographs**
  - Baumann angle (shaft-physeal angle): Between axis of humerus & physis of lateral condyle, Normal is 75-80°, 90^0 suggests cubitus varus
  - Anterior humeral line: Line along anterior aspect of humerus should intersect middle of capitellum
  - Humerus-capitellar angle: the normal is 40°, decreases in hyperextension.





Type I (Fat Pad) (Type IIB)

(Courtesy of M Yousef)

- **Treatment**
  - Document – status of radial pulse, distal capillary refill time and assessment of radial, median, and ulnar nerves
    - Type I: Back slab in comfortable position
    - Type II: Percutaneous pinning reduces the re-displacement risk and reduces the need to over flex the elbow which can increase forearm compartment pressure.
    - Type III: MUA and percutaneous pinning.
  - Night-time operating is not necessary unless there are indications for urgent surgery.
- **Paediatric Supracondylar Humerus Fracture (BOAST guidelines)**
  - Document radial pulse, digital cap refill, and individual nerves: median, AIN, ulnar & radial.
  - Same-day or next-day surgery – not overnight routinely.
  - Overnight indications: absent radial pulse, impaired perfusion, threatened skin.
  - Medial wires should be inserted using a technique to avoid ulnar nerve.
  - 2mm K-wires to be used.
  - Reduction to correct Baumann's angle and avoid cubitus varus
  - Nerve injuries are usually transient neurapraxia – if post-op consider exploration!
  - A perfused limb does not require exploration of the brachial artery, regardless of presence/absence of the radial pulse.
  - An ischaemic limb, however, needs discussion with the vascular team before reduction. If remains ischaemic after reduction, then needs exploration by a surgeon trained in small vessel repair.
  - Post-operative documentation of nursing compartment observations (BOAST 10).
  - Post-op x-ray between day 4-10 to ensure reduction maintained
  - Wire removal at 3-4 weeks.

- **Reduction technique**
  - Traction for 5 min to correct the longitudinal alignment.
  - Side pressure to correct the medio-lateral (coronal) displacement.
  - In posteromedial displacement: forearm pronated with hyperflexion, in posterolateral displacement: forearm supinated with hyper flexion (Rule of thumb).
  - Thumb is toward direction of injury in posteromedial you put hand in pronation o depend on intact periosteal hinge and opposite with posterolateral
  - AP view is with elbow flexed (shoot through) – rotate the arm and forearm together for lateral view
  - Open reduction if position after closed reduction is unacceptable.
  - Puckering sign indicates need for open reduction.
  - Surgical stabilization should be with bicortical 2 mm K wire fixation, crossed wires are associated with lower risk of loss of fracture reduction.
  - Divergent lateral wires reduce risk of injury to ulnar nerve.
  - Perfused limb does not require brachial artery exploration
  - Crossed K-wires are biomechanically stronger to torsional stress than 2 lateral wires, but it has risk of ulnar nerve injury - should be done under vision and put your thumb to protect the nerve with the elbow in extension to relax the nerve
  - Don't cross wires at fracture site.
  - Check X rays in 1 week and remove wires in 4 weeks in clinic. It will take 6 months for 95% of normal elbow range of motion to return.

Scannell – JBJS 2013 *After 20 months of follow-up, children with perfused, pulseless supracondylar humeral fracture treated with closed reduction, percutaneous pinning, and observation demonstrated palpable distal radial pulse, normal growth of arm, and good/excellent functional outcomes.*

- **BOAST guidelines – management of arterial injuries associated with fractures or dislocations - 2014**
  - Risk of compartment syndrome is high following reperfusion - low threshold for performing fasciotomies
  - Risks of delayed revascularisation include myoglobinuria and may be associated with increased mortality
  - Vascular perfusion should be restored using temporary shunts
  - Skeletal stabilisation should then be performed, followed by reconstruction with autologous vein grafts.
- **Lateral K wires: Skaggs, JBJS (2004) – prospective study**
  - Lateral entry pins were effective for even most unstable supracondylar humeral fracture
  - There were no iatrogenic ulnar nerve injuries, and no reduction was lost
  - Important technical points for fixation with lateral-entry pins are
    1. Maximize separation of pins at fracture site
    2. Engage medial and lateral columns proximal to fracture
    3. Engage enough bone in both proximal and the distal fragments
    4. Maintain low threshold for use of 3rd lateral entry pin

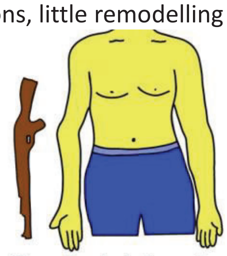
Zhao – meta-analysis, CORR (2013)

Iatrogenic ulnar nerve injury was higher with the crossed pinning technique than with the lateral entry technique, no statistical differences in radiographic outcomes, function, and other surgical complications.

- **Approach for open reduction:**
  - Anterior approach (if requires vascular exploration),
  - lateral approach (if closed reduction fails)
  - posterior (triceps splitting/triceps sparing – least favoured) (it will affect posterior blood supply to distal humerus)

- Open exploration of antecubital fossa is indicated in patients with under-perfused hand after reduction and pinning of displaced paediatric supracondylar humerus fractures (in presence of vascular surgeons).
- In case you find brachial artery is in spasm you can use local anaesthesia or Papaverine or stellate ganglion sympathetic block to produce arterial vaso dilatation
- If these failed so it is intimal tear need excision of injured segment and reversed venous graft With prophylactic fasciotomy

- **Complications**
  - Acute
    - AIN injury : is the most common associated nerve injury as the fracture presses on posterior part of median nerve where AIN comes from ,or due to traction affecting the more fixed AIN , the patient unable to flex the inter-phalangeal joint of the thumb and the distal inter-phalangeal joint of the index finger (can't make OK sign).
    - Ulnar nerve injury seen with flexion-type injury
    - Compartment syndrome
    - Brachial artery injury: Intimal damage due to stretching
  - Chronic (Gunstock deformity)
    - Due to varus mal-union with hyperextension and internal rotation (triplane deformity), usually cosmetic issue with little functional limitations, little remodelling as the elbow has little growth potential.



Gunstock deformity

    - **Management**:
      - ✓ Bilateral: due to chromosomal anomalies so no need for surgical intervention
      - ✓ Unilateral: if severe valgus - supracondylar closed wedge (French) osteotomy is recommended. Delay until skeletal maturity is recommended to avoid deformity progression due to growth plate damage.
    - **Principles of osteotomy**
      - ✓ Are to be as close as possible to the deformity, avoid having excessive lateral prominence (Chicane deformity)
      - ✓ Cubitus valgus can also be produced by step-cut osteotomy without creating a lateral prominence

Distal humerus epiphyseal separation

- Seen in children under 3 years old
- High association with child abuse (non-accidental injury)
- May be posteromedial displacement of radial and ulnar shafts relative to distal humerus as both radius and ulna translate together without alteration of their relationship.
- Could be confused with dislocation
- Radiocapitellar line is intact unlike dislocation
- elbow arthrogram can be done to confirm diagnosis
- **Treatment**
  - Closed/open reduction and percutaneous K wires

- Complications:
  - Cubitus varus (like supracondylar fracture)
  - Medial condyle AVN.


(Courtesy of Sbah Chenow)

Medial epicondylar fracture

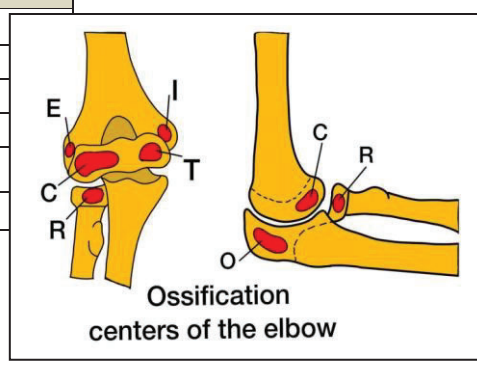
- The most common fracture pattern associated with elbow dislocation in child
- Flexor pronator muscle mass attachment to the fracture fragment
- **Treatment**
  - Roberts technique –valgus stress with forearm supination and fingers and wrist extension – Closed reduction manoeuvre to extricate incarcerated fragment
- **Indications for ORIF**
  - Apophysis entrapment in joint (elbow arthrogram)
  - Displacement > 5 mm
  - Valgus instability and ulnar nerve dysfunction
- Approach: Medial approach to the elbow, fix with K wire or cancellous screw.
- Complications: Non-union can lead to instability.


(Courtesy of H Hermina)

Traumatic subluxation of radial head (Nursemaid elbow)

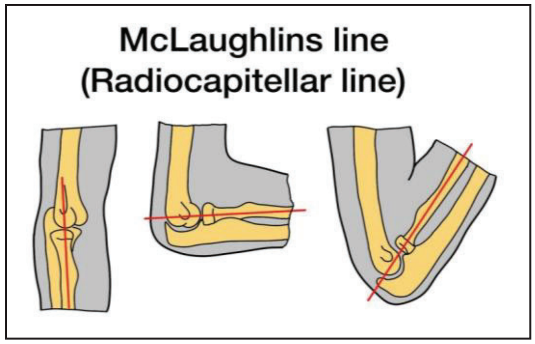
- Reduction technique: Supinate forearm and flex elbow past 90^0 then apply pressure over the radial head
- Alternative technique: hyper pronation of forearm while in flexed position.

Ossification center	Appearance on X-rays	Year of fusion
Capitellum	1	12-14
Radius	3	12-16
Internal(medial)epicondyle	5	16-18
Trochlea	7	12-14
Olecranon	9	15-17
External(lateral)epicondyle	11	12-14



McLaughlins line drawn down the neck of the radius
Not along the shaft because of angulation of the neck of the radius.
Should intersect the capitellum

(CRITOE)



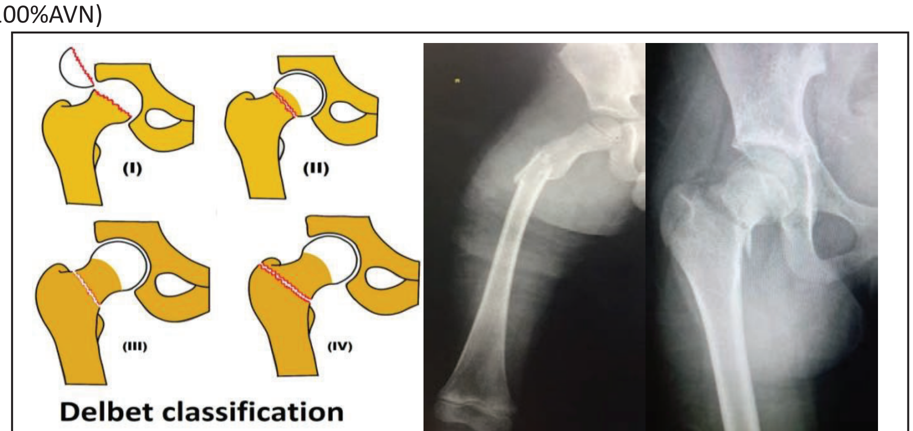
Forearm fractures

- Outcome and acceptable reduction depends on :
  - Age of patient
  - Residual angulation after closed reduction
  - Level of fracture – proximal, mid-diaphysis or distal
- Acceptable alignment of forearm fractures in children
- Forearm fractures can be splinted in children younger than 8 years, if within
  - $<15^0$ mid and distal shaft
  - $<10^0$ proximal shaft
  - $<30^0$ mal-rotation
  - <100% displacement (bayonet apposition with <1cm shortening might be acceptable
- In older children, acceptable alignment is $<10^0$ of angulation
- If outside this range, closed reduction should be attempted to correct deformity
- **Cast width index**: Cast AP/lateral ratio (ideally <0.7-0.8) for successful treatment of forearm fractures in cast (Kamat et al, Journal of Paediatric Orthop, 2012)

Lower limb trauma

Proximal femoral fractures

- Proximal femoral epiphysis grows about 3 mm/year.
- 30% of femur length 15% of lower limb length
- Trochanteric apophysis contributes to femoral neck growth so shortening is associated with coxa valga and overgrowth leads to coxa vara.
- Associated with other injuries
  - head or facial trauma
  - Splenic lacerations
  - Retroperitoneal haemorrhage
  - perineal injury
  - Pelvic ring or acetabular fractures
  - Hip dislocation
  - Femur fractures
- Associated complications
  - AVN
  - Premature physeal closure
- **Blood supply**
  - Medial femoral circumflex artery (MFCA)
    - Via the posterosuperior and posteroinferior retinacular branches
    - At 4 years , becomes the main blood supply
  - Lateral femoral circumflex artery (LFCA)
    - At birth, contributes to the blood supply to the head
    - Regresses in late childhood
  - Artery of the ligamentum teres
    - At birth, contributes to the blood supply to the head
    - Diminishes after 4 years' old
  - metaphyseal vessels
    - Contribute to blood supply to the head < 3 years old and after 14-17 years
    - Between 3 to 14years, the physis blocks metaphyseal supply
    - After 14years, anastomoses between metaphyseal-epiphyseal vessels develop
- **Delbet classification** of fractures of the head and neck of femur in children:
  - Type I: Transphyseal (38-100%AVN)
  - Type II: Transcervical
  - Type II: Basicervical
  - Type IV: Intertrochanteric



(Courtesy of M Elgendy)

- **Treatment**
  - Early reduction (< 24hr) reduces risk of AVN by restoring blood flow from kinked vessels
  - **< 4 years** (Hip spica cast)
    - Contraindications
      - ✓ Unacceptable shortening or angulation
      - ✓ Open fracture
      - ✓ Thoracic or intra-abdominal trauma
      - ✓ Very large or obese children
  - **> 4 years** (Closed/open reduction and internal fixation with screws (length stable device)
    - Short screw: 4.5-6.5 mm
    - Transphyseal: 6.5-7.3 mm, if crossing physis necessary to achieve stable fixation as it is easier to treat LLD from premature physeal closure than non-union
    - Paediatric hip screw - for type III & IV
- **Complication**
  - AVN: Most common complication, decreased from type I to type IV
  - Coxa vara 2nd most common complication
  - LLD from physeal arrest
  - Chondrolysis
  - Non-union
  - Coxa valga especially in type IV fractures from premature closure of the GT apophysis
  - Compartment syndrome with hip spica (very rare). Try to apply smooth contours around popliteal fossa and limit the knee flexion to < 90°.

Femoral shaft fracture

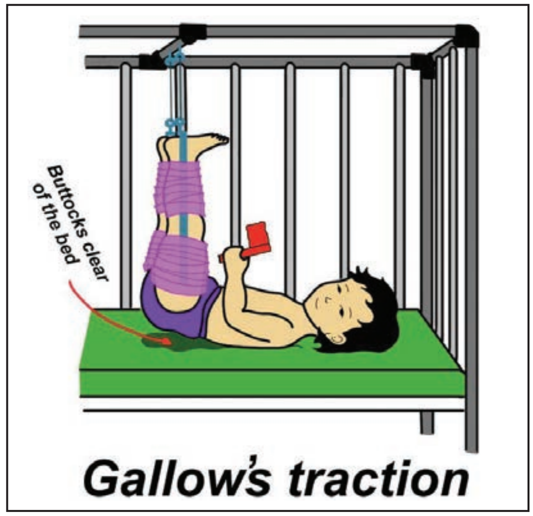
- 1st 6 months (Pavlik harness)
- Up to 18 months, < 15 Kg in weight: Gallows traction (for 2 weeks then spica) as it is easier to care for nappies
- 1-6 years (but not >25kgs):
  - Traction (if displaced) then spica cast when fracture stable
  - Acceptable position is < 10^0 rotation and < 2 cm shortening with valgus mould, as we can't accept more than 10^0 varus.
  - The spica cast should be in 90^0 flexion (for seating), 50^0 abduction and 15^0 external rotation for 4 – 6 weeks with broomstick to prevent child from moving and damaging the spica.
- 4-12 years (but weight < 50 kg): flexible nailing (length stable but rotationally unstable) or plate (if unstable), takes longer time to heal
- >11 years (or weight >50 kg): rigid trochanteric entry nails (Adolescent lateral femoral nail) or sub-muscular plate.

Tisherman et al, Journal of Paediatric Orthop. 2018:
Systematic review of spica casting for the treatment of paediatric diaphyseal femur fractures
Acceptable limits of deformity for applying spica cast:

$8\text{-}16^0$ varus-valgus angulation
$10\text{-}22^0$ pro/re-curvatum
and <12-18mm shortening (more deformity acceptable in younger children)

- **Gallows traction** for children < 15 Kg
  - As with bigger child, the risk of skin damage, vascular compromise and peroneal nerve injury is increased.
  - traction should be enough to just lift the buttocks off the bed
  -

(Paediatric femoral fractures for



- **Skin traction**
  - Non-adhesive strap above the knee (adhesive strap damages the skin) with bandage in crossed fashion (circular can cause vascular compromise). Hamilton Russell traction can be used, followed by hip spica casting
- **Flexible nails** (maximum weight is 50 kg)
  - Rotationally unstable so restricted weight bearing for 2-3 weeks
  - Insertion points on femur is 1 to 2 cm proximal to the distal physis
  - Nail size determined by multiplying the width of the isthmus of femoral canal by 0.4
  - The goal is 80% canal fill
  - The most common complication is pain at insertion site near the knee
  - Insert simultaneously to better control displacement
  - Avoid twisting more than 180 deg to prevent corkscrew phenomenon
  - Use F tool to help the reduction
  - Use of end caps in unstable fractures as it increases the stability of the nail, prevent soft tissue irritation and facilitate extraction of nail.
  - Remove when fracture healed and remodelled (2 -4 months)
- **Complications**
  - ✓ Mal union (most common)
  - ✓ AVN, piriformis fossa entry contraindicated due to injury to ascending cervical artery from MCFA
  - ✓ Trochanteric entry nail can damage trochanteric physis
  - ✓ Overgrow by 1-1.5 cm due to regional hyperaemia
  - ✓ Non-union: 4 times higher in titanium compared to stainless steel flexible nail

MacNeil et al, Journal of Paediatric Orthop. 2011

Systematic review of rigid, locked IM nail insertion sites and avascular necrosis of the femoral head in skeletally immature AVN rate for tip of greater trochanter entry site nails is 1.4% with no reported cases of AVN with lateral entry nails

Distal femoral fractures

High incidence of physeal arrest (follow up closely)
Most commonly Salter-Harris II fracture

- **Complications**
  - Complete growth arrest leads to LLD
  - Incomplete arrest leads to progressive deformity
- **Treatment**
  - Closed reduction and fixation with percutaneous K wires, single pass not through articular cartilage. Reduction could be blocked by periosteum infolding into fracture site.
  - ORIF

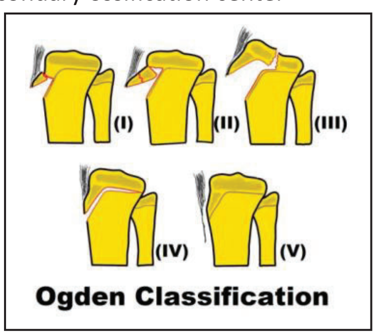
Patella sleeve fracture

- Avulsion of the distal pole of patella with large portion of articular cartilage sleeve
- In 8-12 years' age when the patellar ossification nearly completed
- Presents with palpable gap at lower end of patella
- Most important blood supply to the patella is located at the inferior pole
- **X ray:** flakes of bone adjacent to the inferior pole
- **MRI**: when diagnoses not clear from plain radiographic findings.
- **Treatment:**
  - Cylinder cast for non-displaced fracture.
  - Tension band wire: for displaced fracture with suture repair through tunnels then cast for 3 weeks in mild flexion.
- **Complication:** extensor lag

Tibial tuberosity fractures

Proximal tibial physis started to close from posterior to anterior

- **Ogden classification**
  - Type I fracture of secondary ossification center
  - Type II fracture extends from secondary to junction with primary ossification centres
  - Type III fracture through both secondary and primary ossification centres
  - Type IV fracture through entire proximal tibial physis
  - Type V periosteal avulsion of extensor mechanism from secondary ossification center
  - They are subdivided into A (un displaced) and B (displaced)

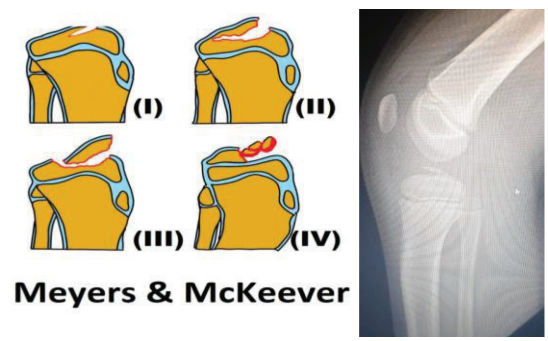


- **Treatment:**
  - Undisplaced: above knee plaster NWB for 6 weeks followed by progressive extensor mechanism strengthening
  - Displaced: ORIF with 4 mm partially threaded screws and patellar tendon reattachment with suture anchors, Consider removal of screw at 10 weeks.

- **Complications**
  - Recurvatum deformity is the most common due to decrease in the tibial slope
  - Compartment syndrome due to injury of the anterior tibial recurrent artery
  - Stiffness
  - Bursitis: most common complication following surgical repair. Due to prominence of screws and hardware about the knee
  - Vascular Injury

Tibial eminence fracture

- Skeletally immature bone fails under tension before ACL
- **Meyers and McKeever classification**
  - I: undisplaced
  - II: anteriorly displaced (elevation)
  - III: completely displaced (no contact)
  - IV: comminuted



(Courtesy of M

Treatment:

- I and reducible II: Immobilization in full extension
- Irreducible II & III:
  - Open/arthroscopic fixation
  - Block to reduction (need to be disengaged) from fat pad, inter-meniscal ligament or anterior horn of meniscus (medial meniscus entrapment most common)
  - Fix with suture anchor and try to avoid physis injury (technically demanding)
  - Cannulated screw over K wire without washer
- **Complications:**
  - ACL laxity
  - Arthrofibrosis: is most common with surgical reconstruction
  - Growth arrest

Proximal tibia fractures

- Reducible - above knee cast with varus mould
- Epiphyseal: Displaced treated by percutaneous or open internal fixation parallel to physis
- Metaphyseal: Cozen fracture

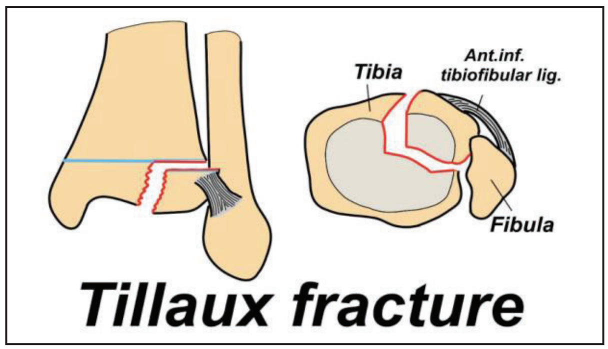
Can cause late valgus deformity despite anatomical reduction secondary to increase in metaphyseal growth medially from hyperaemia

Normally remodels and follow up for a year is required.

In refractory cases: medial hemi-epiphysiodesis in skeletally immature patient or corrective osteotomy in skeletally mature patient

Tillaux fracture

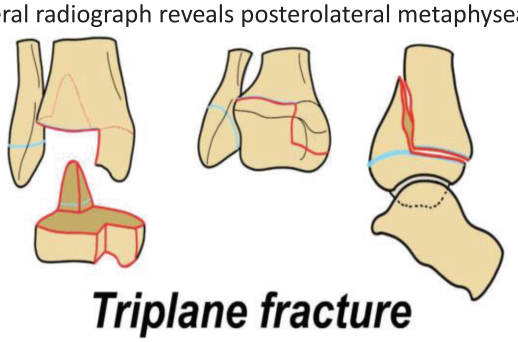
- Avulsion fracture of the anterior inferior tibio-fibular ligament
- **SH type III** fracture of anterolateral distal tibia epiphysis.
- results from supination-external rotation injury
- lack of coronal plane fracture in the posterior distal tibial metaphysis distinguishes this from a triplane fracture
- **Pathophysiology:**
  - In adolescent growth plate is weaker than bone. Also, ligaments are less stiff than bone in immature skeleton and absorb more energy before failure.
  - Occurs in children at end of the growth period when anterolateral physis is the only portion not fused
  - Distal tibia fusion progresses from Pattern of closure occurs in a predictable pattern: central > anteromedial > posteromedial > lateral
- CT to check for displacement



- **Treatment:**
  - Fixation if displaced by a cannulated screw parallel to physis
- **Complications**
  - Growth arrest
  - Arthritis: Residual displacement leads to articular surface incongruity; degenerative changes can be seen radiographically as early as 4 years after injury.

Triplane fracture

- It is **SH type IV** fracture - AP view shows SH III, lateral view shows SH II fracture pattern
- AP reveals intra-articular component
- Lateral radiograph reveals posterolateral metaphyseal fragment (Thurston-Holland)



- **Treatment:**
  - Undisplaced: POP cast NWB
  - Displaced: fix with cannulated partially threaded AP screw above physis and medial-to-lateral screw below physis, when irreducible requires ORIF to remove interposed periosteum.
- Most common complication is increased external rotation foot progression angle.

PEDIATIC UPPER LIMB DISORDERS

Obstetric Brachial Plexus palsy

- 1 in 1000 live births
- 25% permanent disability without treatment
- Abnormal deforming forces due to muscle weakness cause hypoplasia of glenoid
- Traction injury during delivery (head pulled away from the shoulder)
- **Risk factors:**
  - Large babies (> 4Kg)
  - Difficult or prolonged labour
  - Abnormal foetal presentation – breech / shoulder dystocia
  - Multiple pregnancies
  - Previous child with OBPI
- **Classification (Narakas)** – Grade 3 and 4 = worst prognosis

1	C5/6 roots, weakness of shoulder abduction and elbow flexion
2	C5/6/7, As above + wrist drop. Spontaneous recovery
3	Complete paralysis
4	As above + Horner's Syndrome

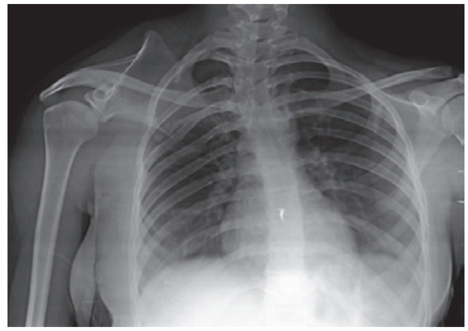
- **Erb's Palsy**
  - Upper roots : weakness of SS and IS muscles (Suprascapular nerve) and Rhomboids (Dorsal scapular nerve)
  - Unopposed subscapularis – IR contracture
  - Progressive flattening and retroversion of humeral head. Biconcave glenoid with false postero-inferior facet.
  - Secondary overgrowth of acromion and lateral clavicle
- **Total Plexus Injury**
  - Mainly hand weakness, but also deltoid, subscapularis and pectoralis muscles
  - Flail shoulder but less IR contracture
  - Differential diagnosis of a flail shoulder in the infant includes fracture and septic arthritis

Sprengel's deformity

- Congenital condition with a small and undescended scapula often associated with
  1. Scapular winging
  2. Omo-vertebrael connection


(Courtesy of S Chenow)

- If bilateral, shoulders start after the head
- Due to interruption to embryonic subclavian artery blood supply: Scapula remains hypoplastic and elevated
  Or persistent omo-vertebral connection between superior medial angle of scapula and cervical spine can be fibrous or bony
- May be associated with other abnormalities
  - Klippel-Feil Syndrome
  - Poland Syndrome
  - VACTERL Syndrome
  - Congenital scoliosis


(Courtesy of L Prakash)

- Shoulder abduction limited due to loss of normal scapulothoracic movement and glenoid malposition
- Can mimic scoliosis due to asymmetry
- **Management**
  - Physiotherapy to maintain ROM
  - < 8 years to improve cosmesis and shoulder abduction
  - Release of peri-scapular muscles – move scapula down – repair inferior muscles
  - Woodward procedure

Congenital pseudoarthrosis of the clavicle

- Failure of fusion possibly due to high subclavian artery
- Usually Right side – if on the Left may be associated with dextrocardia
- Painless, non-tender mass on clavicle (differentiate from fracture)
- Surgery if pain or limited shoulder function – ORIF + Bone graft
- Contraindicated if pseudoarthrosis associated with neurofibromatosis

(Congenital pseudoarthrosis of clavicle)

Facioscapulohumeral dystrophy

- Autosomal dominant muscular dystrophy
- Muscles of face and shoulder affected
- Bell's-type palsy of the face
- Unable to whistle
- Winging of the scapula
- Limited abduction of the arm due to inability to stabilise the scapula during abduction
- **Treatment** – scapulothoracic fusion
- **Differential diagnosis of scapular winging in children**
  - Nerve palsy – Long thoracic or Spinal accessory nerve
  - Scapular dyskinesia
  - Scoliosis

Torticollis

- From Latin torti (twisted) & collis (neck)
- Head tilt towards affected side with chin rotation away from affected side
- **Congenital**
  - Klippel-Feil
  - Down's
  - Vertebral anomalies:
    - Occipitalization of C1, congenital hemi-atlas
    - Contracture of SCM muscle: packaging disorder
    - Palpable neck mass
  - **Treatment**
    - Stretch (90% respond)
    - >1 year: surgical release of SCM, Z-plasty lengthening
- **Acquired**
  - Ocular: compensatory to achieve optimal vision in patient with nystagmus
  - Improved when eyes closed and asleep
  - Atlanto-axial rotatory displacement/instability, due to ligamentous laxity
  - Trauma – facet dislocation
  - Retropharyngeal abscess (Grisel's disease), resolves spontaneously with NSAIDs
  - RA: Odontoid not equidistant from the two lateral masses
- **Fielding classification of atlanto-axial rotatory subluxation**
  - Type I: Unilateral facet dislocation with intact transverse ligament
  - Type II: Unilateral facet dislocation with injured transverse ligament
  - Type III: Bilateral anterior facet dislocation
  - Type IV : Bilateral posterior facet dislocation
- Dynamic CT is gold standard in diagnosis.

Non-Traumatic Radial Head Dislocation

- Usually good function
- May be a lump or click
- Associated with Larsen Syndrome and Nail-Patella Syndrome
- **Differentiate congenital dislocation from post-traumatic:**
  - Hypoplastic capitellum
  - Convex radial head
  - Bilateral involvement
  - Inability to reduce
- **Radiographs:**
  - Radial head Shape (round in congenital) and direction of dislocation (posterior)
- **Treatment:**
  - Non-operative
  - Radial head Excision
  - Radiocapitellar joint reconstruction
  - Radial head excision not advised in young children due to proximal migration of the radius resulting in wrist pain and cubitus valgus

PAEDIATRIC HIP DISORDERS

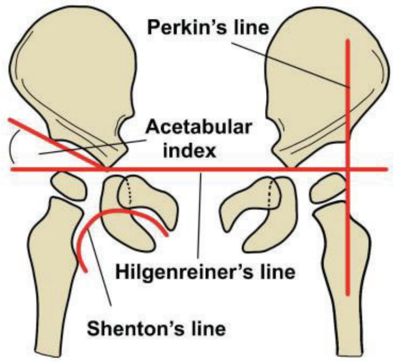
DDH (Developmental Dysplasia of Hip)

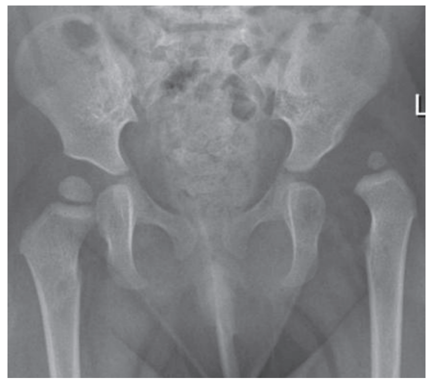
- Abnormal development of hip ranging from acetabular dysplasia to subluxation to dislocation
- **Aetiology:** is *multifactorial* including genetic and intra-uterine factors
- **Risk factors:** 6Fs
  - First born
  - Female (6:1 over males), hormonal effect causing laxity
  - Fetal presentation – breech (hips adducted)
  - Family history
  - Fluid in amniotic sac - Oligohydramnios
  - Associated with packaging deformities :congenital muscular torticollis, Metatarsus adducts, Congenital knee dislocation
- **Incidence:**
  - 4-6:1000 live births, but only 1or 2 in every 1000 babies have DDH that needs to be treated). Early instability is extremely common, but > 90 percentage of cases will resolve by the age of 6-8 weeks without intervention.
  - Left hip more affected than right (the left hip adducted against the mother's lumbosacral spine in the most common intrauterine position, left occiput anterior)
- **Screening:** NHS NIPE (Newborn and Infant Physical Examination) program
  - Recommends USG within 2 weeks if screening examination is positive
  - Recommends USG within 6 weeks if screening examination is negative, but risk factors are present:
    - 1st degree family history
    - Early hip problem or breech presentation after 36 weeks
    - Packaging disorders

(DDH for FRCS)

- **Look**
  - LLD – Galeazzi test
  - Asymmetrical gluteal and medial thigh creases
- **Move**
  - Reduced abduction in flexion (most sensitive)
  - Infants can abduct to > 60 degree normally
- **Tests**
  - Barlow's provocative manoeuvre: dislocates a dislocatable hip by adduction and depression of flexed femur
  - Ortolani's reduction manoeuvre: reduces a dislocated hip by elevation and abduction of flexed femur
  - The effectiveness of clinical examination is questionable, with the sensitivity being as low as 36% in inexperienced hands. Therefore, ultrasound screening for DDH has been established as the gold standard to assess hip morphology and stability.
- **Investigations**
  - <6 months: US as femoral head ossific nucleus is absent
  - Radiographs in > 6 months
  - **Hilgenreiner line (German orthopaedist)**
    - Horizontal line through right and left tri-radiate cartilage (femoral head ossification should be inferior)
  - **Perkin line (Orthopaedist from Oxford)**
    - Perpendicular line to Hilgenreiner line at the lateral margin of acetabulum (femoral head ossification should be medial)

- **Shenton line (Radiologist - London)**
  - Arc along inferior border of femoral neck & superior margin of obturator foramen, the arc line should be continuous.
- **Acetabular index**
  - Line from tri-radiate cartilage to lateral margin of acetabulum and Hilgenreiner line should be less than 25° in patients older than 6 months.



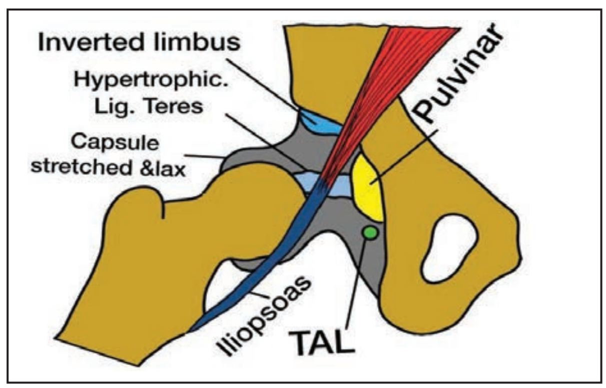


(Courtesy of M Meda)

NB: If hip is subluxed but well-formed in > 6 months age, think of other causes for subluxation such as effusion.

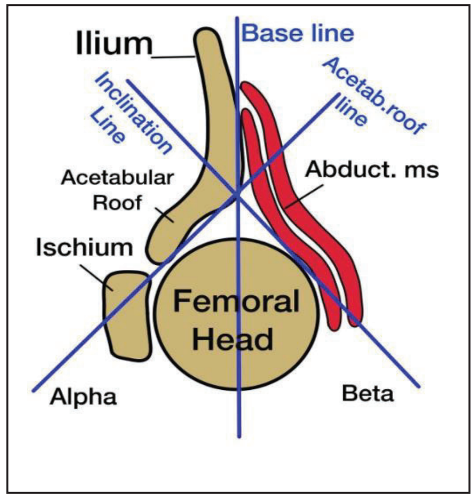
➢ **Arthrogram:**

- To confirm reduction and identify blocks to reduction which are:
  - Extracapsular:Tight adductors & hamstrings & rectus femoris
  - Hip capsule constricted by iliopsoas tendon causing hour-glass deformity
  - Pulvinar proliferation of fibrofatty tissue in acetabulum
  - Intracapsular
  - Inverted labrum (limbus)
  - Inverted capsule
  - Thickened transverse acetabular ligament
  - Elongated ligamentum teres

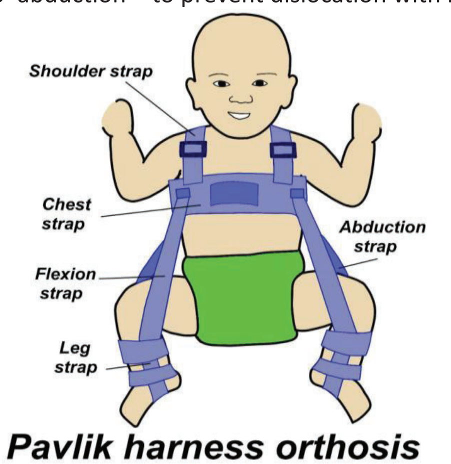


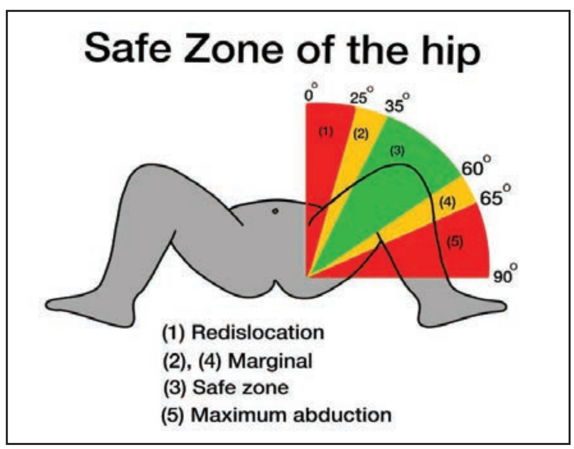
- Medial dye pooling > 5mm indicate subluxation
- Medial approach (in abducted hip, put the needle underneath the adductor tendon close to its origin in the direction of the ipsilateral shoulder), so that extravasation of dye does not block images.

- **USS:**
  - Useful to evaluate reduction - static (Graf) or dynamic (Harcke)
  - Graf method:
    - Alpha angle: measurement of acetabular concavity between ilium (baseline) and bony acetabulum (sourcil) Normal >60^0, opposite to acetabular index as it is referenced to ilium.
    - Beta angle: between labrum and base line Increased angle indicated lateral subluxation, normal < 55^0



- **Management**
  1. **<u><6 weeks</u>:** no treatment, 90 % stabilise within 6 weeks
  2. **<u>< 6 months</u>:** Pavlik harness (Dynamic flexion abduction orthosis)
     - **Techniques of applying harness:** (Harness position (safe zone of Ramsey):
       - Anterior strap - 90-100^0 flexion
       - Posterior strap adjusted to prevent adduction beyond neutral and achieve abduction by gravity (not by forced abduction)
       - <60^0 abduction – as more abduction causes impingement of MCFA leading to AVN
       - >30^0 abduction – to prevent dislocation with hip adduction





- Measurement by using size of chest circumference (5 sizes)

- Leg/anterior strap for flexion
- Back/posterior strap for abduction
- Colour coded for matching sides
- Shoulder straps at nipples
- Allows some movements within safe zone of Ramsey (20-30 degrees from maximum abduction)
- Worn for 23 hours/day for 3 months or until hip is stable, then night-time for 6 weeks
- USG every week for first 3 weeks to check position
- Check femoral nerve with knee extension every week
- Other splints - Von Rosen Splint (static)

• **Complications**
  - Femoral Nerve injury with excessive flexion
  - AVN (2 %) with excessive abduction
  - Pavlik harness disease: Erosion of posterolateral acetabulum associated with prolonged use in persistently dislocated hip

3. <u>6 – 18 months</u>:

• EUA and arthrogram, then spica cast . Also used if Pavlik harness fails

• Spica cast technique
  - Spica table
  - Stockinette on legs and abdomen
  - Allow space for breathing
  - 1 inch of padding
  - Figure of 8 around the hips
  - Use fibreglass cast to make a bar
  - Place in safe zone of Ramsey

• 3 months to cure the dysplasia, change it in theatre at 6 weeks

• Confirm reduction with CT

• Complications
  - AVN: 5 - 10%
  - Re-dislocation 5%, Closed reduction might need to be supplemented with percutaneous adductor/iliopsoas tenotomise.

• If harness failed, an attempt of closed reduction +/- adductor tenotomise

• If hip will reduce but needs to be held in an extreme position to maintain reduction or the hip is irreducible due to obstructions, the procedure should be abandoned to prevent development of AVN and plans made for open reduction when the proximal femoral ossific nucleus appears as this is felt to be protective against AVN.

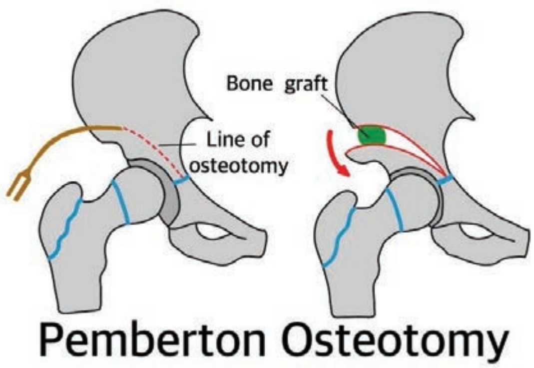
4. <u>> 18 months</u>:

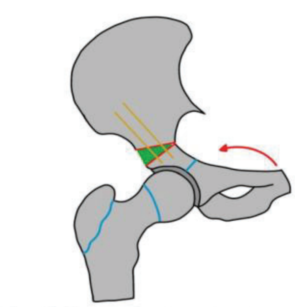
• EUA and arthrogram, then open reduction & spica cast

• Also for failed closed reduction, spica for 6 weeks

• Anterior approach
  - Decrease the risk of injury to the medial femoral circumflex artery
  - Easier to get to obstructing structures
  - Higher risk of AVN with medial approach.
  - Remove obstructions
  - Adductor release
  - Tighten the capsule

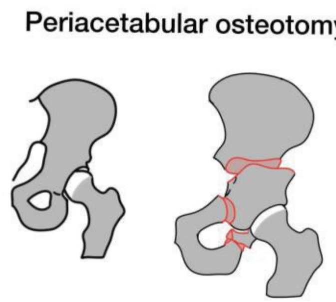
5. **<u>>2 years:</u>**
   - EUA and arthrogram
     - Femoral osteotomy: for changes on femoral side (Proximal femoral varus and de-rotational osteotomy) to correct excessive femoral anteversion and/or valgus.
     - Pelvic osteotomy: for changes on acetabular side
       1. Re-directional: where the acetabulum is deficient in one area
       2. Volume-reducing: where the acetabulum is shallow, being deficient superiorly
       3. Salvage: where the femoral head is not contained or the joint incongruent
6. **<u>18 months to 6 years of age</u>:**
   - Salter osteotomy - Re-directional
     - Cut above acetabulum through ilium to sciatic notch
     - Hinged on symphysis
     - The bone graft is typically secured using two wires.





Salter's innominate osteotomy

   - Pemberton osteotomy - Volume-reducing
     - Is like Salter's osteotomy but a small arc of the posterior column at the tri-radiate cartilage is left uncut
     - Acetabular roof is hinged on this arc to allow anterior or anterolateral coverage.
     - More stable than a Salter osteotomy, does not require metal fixation
     - Rotation rather than translation, changes direction more than volume.
7. **<u>6 years to teenage:</u>** Triple pelvic osteotomy (Tonnis).
   - After the age of 6 the pubic symphysis loses its elasticity.
   - The ischium and pubis must be cut to allow the rotation to occur.
   - Once position has been achieved, the fragment is secured using screws.
8. **<u>Teenage to adulthood</u>:** Periacetabular (Ganz) osteotomy (PAO).
   - Once the triradiate cartilage has fused
   - Keeps the posterior wall intact
   - Keeps the point of rotation close to the acetabulum allowing greater correction
   - Once position has been achieved, the fragment is secured using screws.



- **Salvage osteotomies (>6 years of age)**
  - Shelf osteotomy:
    - Apply cortical bone to anterolateral ilium & lateral aspect of acetabulum to cover femoral head
    - Redistributes WB through larger area
    - Salvage for hips which cannot be concentrically reduced
  - Chiari osteotomy:
    - Iliac osteotomy & medial displacement of acetabulum
- Once treated, all patients should be followed up until skeletal maturity. Sarkissian et al (from Philadelphia), J Paediatric Orthop 2015 – 17% patients showed secondary dysplasia after successful treatment in Pavlik harness.
- **Prognosis:**
  - Depends on age at presentation
  - Pavlik harness success almost 90% with low complication rates – 1-3% rates of AVN (Risk of requiring THR is same as normal population if treated early in Pavlik Harness)
  - Hips requiring open reduction have a poorer prognosis – 12 - 60% complication rates (50% of patients in their 50's require THR if they required open reduction)
  - Residual dysplastic hips carry worse prognosis (more symptomatic) than high-riding complete dislocation

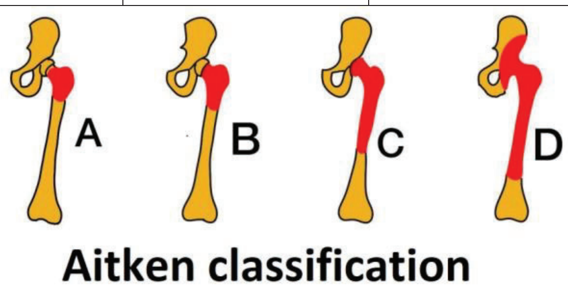
PFFD (Proximal focal femoral deficiency)

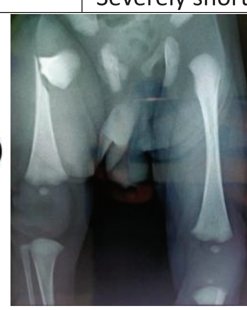
- Congenital syndrome characterized by poor hip joint development and femoral shortening due to defect in primary ossification center (diaphysis), associated with Sonic Hedgehog gene and severe shortening of one or both legs.
- **Associated with**
  - Hypoplasia of lateral femoral condyle
  - ACL deficiency
  - Femoral retroversion
  - Fibular hemimelia (50%)
  - Coxa vara


(Courtesy of M Elgendy)

- **Aitken classification**

Class	Femoral Head	Acetabulum	
A	Present	Normal	Shortened femur, coxa vara
B	Present	Mildly dysplastic	Femoral neck pseudoarthrosis
C	Absent	Severely dysplastic	Very short femur
D	Absent	Absent	Severely short femur




(Type A)


(Type C)

(Courtesy of L Prakash)

- **Treatment**
  - Challenging and should be undertaken in specialized center (NICE guidelines) Based on
    - LLD
    - Hip and knee joint stability
    - Proximal musculature
    - Presence or absence of foot deformities
    - Availability of expertise
    - Patient and family motivation
  - Bilateral: observe
  - Unilateral:
    - ✓ Femoral length > 50% of normal side: Limb lengthening +/- contralateral epiphysiodesis
    - ✓ Femoral length < 50% of the normal femur: Amputate through joint to avoid overgrowth which can lead to difficult prosthesis fitting
    - ✓ If the ipsilateral foot is at the level of contralateral knee: Van Nes Rotationplasty (limb rotated 180^0, knee fusion, ankle used as knee joint and foot act as residual tibia).

SUFE (Slipped Upper Femoral Epiphysis)

- It is slippage of the femoral neck metaphysis anteriorly and externally rotates through hypertrophic zone of physis.
- **Risk factors**
  - Male to female ratio is 3:2
  - African Americans
  - Obese (greatest)
  - Period of rapid growth
- **Incidence:** 1:1000
- **Age:** 10 – 14 years

(SUFE for FRCS)

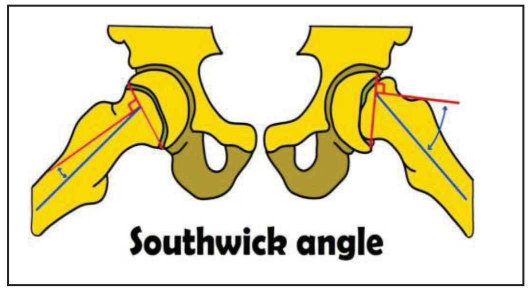
(SUFE for FRCS)

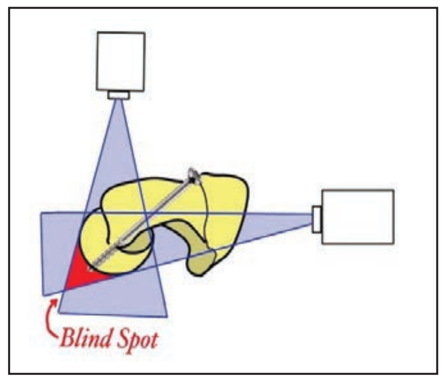
- **Aetiology**
  - Idiopathic
  - Mechanical/Anatomical: (Thinning of perichondrial ring, increased slope of physis)
  - Endocrine: Hypothyroidism (2.5 %), hypogonadism (in < 10 years)
- **Presentation**
  - Knee pain – knee pain in a child is from the hip until proven otherwise
  - Out toeing gait
  - Loss of hip internal rotation, abduction, and flexion
- **X rays:** AP and frog lateral (80% sensitivity)
  - Hip joints and femoral necks are better visualized in the frog leg lateral view and can be easily compared, (do not do in unstable hip).
  - Increased external rotation compared to contralateral hip (prominent lesser troch)
  - **Klein line (Trethowan sign):** on AP view, drawn along superior border femoral neck will not intersect femoral head in a child with SCFE
  - Epiphysiolysis: growth plate widening
  - Decrease epiphyseal height
  - **Capener sign:** entire metaphysis is lateral to posterior acetabular margin

(Courtesy of M Shashoo)

  - **Metaphyseal blanch sign of Steel:** crescent-shaped area of increased density overlies metaphysis adjacent to physis on AP radiograph duo to superimposition of femoral neck and posteriorly displaced capital epiphysis
- USG: 95 % sensitivity
- MRI: gold standard
- CT: scan to help plan surgery in severe cases

- **Classification**
  - Loder (JBJS Am, 1993)
    - Stable: able to weight bear with/without crutches (AVN<10%, 96% good results with pinning in situ)
    - Unstable: unable to weight bear at all (AVN 40-50 %)
  - Wilson grades of slippage
    - I: < 33% of metaphysis uncovered
    - II: 33 – 50 %
    - III: > 50%
  - Southwick angle classification (JBJS Am 1967)
    - Used to grade severity of slip in frog lateral view by subtracting the normal side from the slipped side (between shaft and epiphysis) (in AP normal angle is 145 degree in lateral 10 degree)
    - Mild: < 30 Deg
    - Moderate: 30 – 50 Deg
    - Severe: > 50 Deg





- **Management**
  - Aim to prevent progression with further growth
  - Depends on stability and severity
  - Percutaneous in situ fixation (forceful reduction increase risk of AVN)
    - Trajectory of screw marked in two planes (triangulation)
    - 1 screw, 6.5 mm fully threaded (easier to remove)
    - Start on anterior surface of neck
    - Perpendicular to physis and not parallel to neck
    - >5mm from subchondral bone (5 threads into the epiphysis)
    - Screen under live fluoroscopy to confirm that pin is not penetrating the hip joint (risk of chondrolysis) or inject radioactive dye through the cannulated screw.
  - Toe-touch weight bearing for 6 weeks, remove screw when physis closed (not necessary) and follow up until physis fuses
  - Enabling growth of physis can be facilitated by using smooth wires, or with proximally threaded screws or a growing screw by allowing growth and remodelling, the impingement lesion between metaphysis and acetabulum may improve. Likewise, the neck length and abductor function will be maximised.
  - Contralateral prophylactic pinning: Risk-benefit analysis **(Stasikelis, JBJS (1996) – retrospective review**
    - Slip > 50^0 on Southwick
    - Obese males
    - Endocrine disorders (e.g. hypothyroidism, GH deficiency)
    - Age < 10 years
    - Chronic renal insufficiency
    - Poor patient compliance (delay between onset of symptoms and presentation)

- **Severe acute slip:**
  - Work from **Southampton (Phillips et al, JBJS Br 2001)** suggested the risk of AVN increases after 24 hours of presentation. So safer to convert the situation to a chronic severe slip and then manage after a period of traction (trial of closed reduction is contraindicated).
  - This has obvious implications for the timing of tertiary referrals.
  - The technique for open reduction is very similar to that for the chronic slip.

- Work from **Alder Hey (Bone and Joint J 2015)** for unstable SUFE suggested
  - Open reduction has better outcome than closed reduction, which has higher incidence of AVN (80% AVN with pinning in situ after complete reduction as compared to 33% AVN with incomplete reduction)
  - No AVN in cases who underwent osteotomy after 13 days
- **NICE guidelines 2015:**
  - Adequate evidence of efficiency of open reduction for severe SCFE, but at risk of AVN
  - Surgeon taking up such a case should be adequately trained and details of the case should be entered in BSCOS register to review clinical outcome
- **Complications**
  - Chondrolysis: Rapid loss of articular cartilage associated with implant penetration of articular surface, presented with restricted hip motion and pain with radiographic joint space narrowing, diagnosed by MRI less than 3mm absolute joint space narrowing or more than50 % loss of joint space in comparison to other side
  - AVN
  - LLD
  - Coxa magna

- **Proximal femoral osteotomies**
  - Acute slip: Neck shortening osteotomy (Dunn)
  - Chronic slip: Cervicotrochanteric corrective osteotomy (Southwick/Imhauser)

Legg – Calve - Perthes disease (coxa plana)

- Idiopathic AVN of proximal femoral epiphysis, which is possibly due to anatomically smaller arteries (lateral epiphyseal artery) that leads to recurrent ischaemic episodes causing resorption and remodelling via creeping substitution. It was described in 1910 by Legg (US), Calve (France), Perthes (Germany).

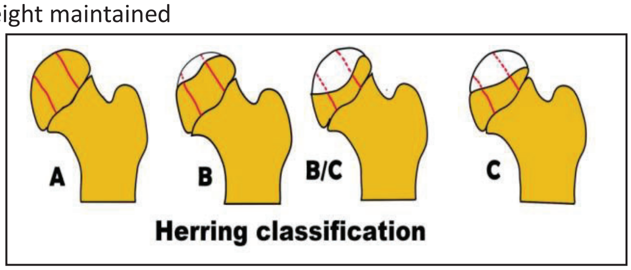
- **Incidence**
  - 1: 1000
  - 3-7 years
  - Boys 6:1 Girls
  - Bilateral in 15 % (consider epiphyseal dysplasia if synchronous or symmetrical)

- **Risk factors**
  - Family history
  - Social deprivation
  - White children being most commonly affected
- Approximately 1/2 of patients develop premature osteoarthritis secondary to a spherical femoral head

- **History**
  - Pain , age , sex (girls do worse)
  - Look - overweight, short for their age
  - Trendelenburg gait
  - Move - restricted abduction and internal rotation

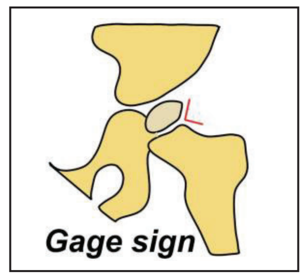
- **Waldenstrom radiological staging (simplified by the Elizabethtown classification in to four stages):**
  - I: Sclerosis: ischemia flattening, coxa plana
  - II: Fragmentation: at 6 months from onset of symptoms, Subchondral fracture – crescent Sign
  - III: Re-ossification: radio-dense areas replace radiolucent areas, can deform if not concentrically contained. No re-ossification in adult AVN. Last part to ossify is the middle as blood supply comes from periphery
  - IV Remodelling: continue until maturity

- **Herring classification (Journal of Paediatric Orthop 1992, modified in 2004)**
  - Based on height of lateral pillar (highest point lateral to fovea) on AP radiograph
  - Lateral pillar prevents subluxation and weight bearing part
  - Used in fragmentation phase
    - A: Normal lateral pillar
    - B: > 50% height maintained
    - B/C: 50%, poorly ossified lateral pillar and tall/narrow <3cm width
    - C: < 50% height maintained



- **Herring, RCT (JBJS, 2004)**
  - Herring A - any age: good results with any treatment
  - Herring B and < 6: do same regardless of treatment
  - Herring B and > 6: do better with surgery
  - Herring C and < 6: do better with surgery
  - Herring C and > 6: poor results with any treatment
- Reimer index: describe extrusion
- Catterall classification: low interobserver reliability
- Stulberg classification describes end stage at maturity

- **Catterall head at risk signs**: Indicate more severe disease (radiological all lateral)
  - Gage sign: V-shaped radiolucency in the lateral portion of epiphysis & adjacent metaphysis
  - Calcification lateral to epiphysis
  - Lateral subluxation of femoral head (containment surgery if > 20%)
  - Horizontal proximal femoral physis - adduction contracture
  - Metaphyseal cyst (lateral)



- **Clinical head at risk signs:** (FOOBS) female, obesity, older age, bilateral, stiffness, flexion with abduction, adduction contracture in extension

- **Radiographs**
  - Describe staging - Herring, Catterall
  - Medial joint space widening (earliest)
  - Irregularity of femoral head ossification
  - Bilateral Perthes - asymmetrical (MED if symmetrical)
  - Bone scan & MRI for early diagnosis
  - Arthrogram: to assess containment if there is loss of abduction

The natural history of Legg-Calve-Perthes disease

- **Management principles**
  - symptomatic relief
  - containment of head
  - maintain ROM
  - prevent secondary OA

- **Non-operatively** (Indications):
  - Under 6 do well (most important prognostic factor) and Group A
  - Activity modification until re-ossification (bearing in mind that this process spans years in highly active small children, even if you advise off-loading or restricted sports it is extremely unlikely that this will be achieved)

- **Operative:** Indications: For group B aged > 6 years and group C < 6 years
  - Used for subluxation
  - Provide containment to allow acetabulum to serve as mould during healing phase (like cone ice cream, the only way to prevent it from melting away is to cover or contain it)
  - Containment minimizes loss of sphericity and lessens subsequent degenerative changes
  - Proximal femoral osteotomy: Re-directional varus open wedge proximal femoral osteotomy if head can be reduced (Up to $10\text{-}15^{0}$ varus producing)
  - Pelvic osteotomies have better radiological outcome than femoral osteotomies in patients aged < 6 years
  - Salvage options: Shelf or Chiari osteotomy in Catterall stage III or IV in patients > 8 years (controversial prognosis)
  - Salvage valgus femoral osteotomy for hinge abduction in late disease to lengthen neck
  - Arthrodiastasis: minimally invasive, does not affect leg length or anatomy of hip; however it is an external fixation with risk of pin site infections, stiffness and psychological issues.

- **Challenges with THR**
  - Anteverted neck
  - Previous femoral osteotomy

(Perthe's for FRCS)

- **Complications of Perthes**
  - FAI
  - OA
  - Coxa breva
- Prognosis depends on Stulberg classification **(JBJS 1981)** Related to congruency of hip joint and sphericity of femoral head, worse in girls
- Lifetime risk of arthritis

I and II	III	IV and V
Spherical congruity	Aspherical congruity	Aspherical incongruity
0-16%	55-60%	75-80%
(No early arthritis)	(THR 10 years earlier than normal)	(Severe arthritis by age of 50)

Septic arthritis of hip

- More common in immunocompromised patients with peak following chickenpox infections
- **Clinical presentation:**
  - Child looks miserable
  - Pain at night (red flag)
  - Refuse to walk or move hip
  - Pseudoparalysis indicates pain
  - In neonates, systemic features of infection often absent
  - Stops walking and start crawling in discitis
  - Odd gait
  - Odd posture – flexion abduction external rotation leg position) - Hip capsular volume increases with this position
- Always think of spine, iliopsoas abscess, or osteomyelitis
- Most common organism
  - < 2 years (group B Strep)
  - >2 years (Staph Aureus)
  - Adolescent Neisseria Gonorrhea
- Kocher criteria, JBJS (1999): fever > 38.5 deg, non-weight bearing, ESR >40, WBC > 12
  - No criteria fulfilled - 0.2%
  - 1 criteria - 3 %
  - 2 criteria - 40%
  - 3 criteria - 93%
  - 4 criteria - 99.5%
- **Luchmann's, JBJS (2004)**
  - The presence of all four criteria was only 59% predictive of septic arthritis, the strongest predictors are
    - WBC >12
    - Fever
    - History of a previous healthcare visit.
- **Singhal, JBJS Br (2011):**
  - CRP > 20 mg/l was the strongest independent risk factor for septic arthritis
  - Weight-bearing status and CRP > 20 mg/l, Individuals with neither predictor had < 1% those with both had 74% probability.
- Radiographs: Widening of joint space
- Blood culture
- Hip aspiration: cell count, gram stain, glucose, protein & lactate (high)
- Bone scan to look for multifocal osteomyelitis, but high radiation dose
- MRI can take 14 days to see changes, need sedation or GA if < 6 years
- US to look for effusion, if normal – think pyomyositis (primary muscle infection)
- Approach for incision and drainage is anterior approach (groin skin crease - bikini incision)
  - Main blood supply to femoral head is posterior (MCFA) not lateral
  - Aspirate joint before arthrotomy to get good sample
  - Washout with warmed normal saline through giving set
  - Adequate washout of posterior portion behind femoral neck
  - Don't close capsule as increased pressure risks AVN
- Empirical antibiotics until culture results available
- Observe symptoms and haematological parameters to assess need for further washout

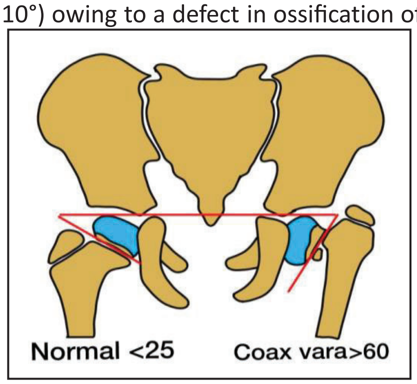
- **Complications**
  - Femoral head destruction due to release of proteolytic enzymes from inflammatory & synovial cells & bacteria causing articular damage within 8 hours
  - AVN: Intra-articular pressure exceeds perfusion pressure
  - Growth disturbance (long-term outpatient follow up)
  - Osteomyelitis

Transient synovitis of hip

- Hip pain due to inflammation of synovium, it is the most common cause of hip pain in children
- **Symptom**: Pain worse on awakening
- **Investigation:**
  - US
    - Detects intracapsular effusion, may show synovial membrane thickening .difficult to distinguish transient synovitis from septic arthritis (Bilateral to compare)
    - Do pelvic and abdominal US also to rule out other intra-abdominal pathologies causing groin pain
  - MRI
    - Can differentiate transient synovitis from septic arthritis
    - If symptoms improved with NSAIDS, more likely to be transient synovitis
    - Symptoms resolve in less than 1 week from date of presentation

Coxa vara

- Localized bone dysplasia characterized by decreased neck-shaft angle (<110°) owing to a defect in ossification of the infero-medial femoral neck (Fairbank's triangle).

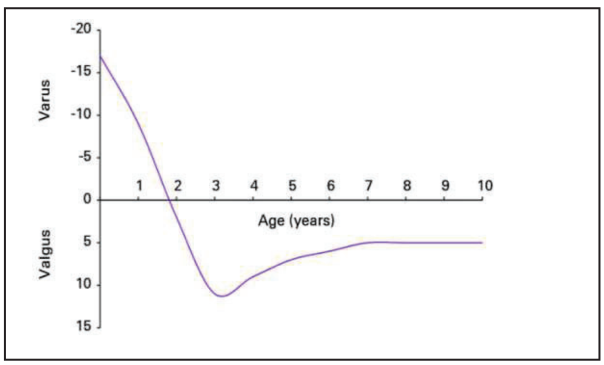


- **Aetiologies**
  - Congenital: PFFD, congenital short femeur
  - Acquired: trauma, SCFE, Perthes disease, infection, fibrous dysplasia
  - Dysplasia: MED
  - Developmental
  - Metabolic: rickets, Cretinism (congenital hypothyroidism)
- **Clinical features**
  - Painless progressive limp
  - Prominent greater trochanter on the affected side
  - Weakness of hip abductors (positive Trendelenburg's test and gait)
  - Decreased internal rotation of the hip owing to decreased femoral anteversion or true retroversion
  - In unilateral cases LLD (2-3cm)
- **Radiographic assessment**
  - Hilgenreiner's epiphyseal angle (HEA).
  - The angle between Hilgenreiner's line and a line drawn along the femoral capital physis.
  - The normal angle is <25°.
  - Physis is vertical (increased incidence of fracture neck femeur)
- **Treatment**
  - <45°, deformity corrects spontaneously
  - 45–60°, outcome uncertain – Observe
  - >60°, all patients will progress, therefore, require corrective surgery

PAEDIATRIC KNEE DISORDERS

Genu varum

- **History**
  - Onset, progression, age of walking
  - Medical history: Trauma, infection
  - Symptoms Painful – pathological
    Painless - physiological
- **Clinical examination**
  - Asymmetry: heel together and patellae pointing forwards (normal intercondylar distance < 6cm)
  - Cover up test:
    - Patient supine and lower extremities fully extended with patellae pointing straight up
    - One hand cover ankle and other perpendicular to long axis of tibia to cover-up middle
    - Blount's disease patient will have neutral or varus proximal tibia
  - Angular deformity – associated with internal tibial torsion
  - Tibio-femoral alignment
    - At birth: 15^0 of varus
    - 2 years: neutral
    - 3-4 years: 10^0 of valgus (peak valgus)
  - 6-7 years: 7^0 of valgus (stabilisation of valgus)
  - Unilateral, asymmetrical, progressive or accompanied by short stature is pathological
- **Salenius & Vankka curve**



- **Aetiology**
  - Physiological: before 2 years: can be associated with internal tibial torsion, usually bilateral with Drennan's angle $<11^0$ (Drennan's metaphyseal–diaphyseal angle is formed by intersection of a line through the transverse plane of the proximal tibial metaphysis with a line perpendicular to long axis of diaphysis. Normal is <11°, abnormal is $>16^0$)
  - Blount disease
  - Rickets
  - Skeletal dysplasia: Achondroplasia, MED, enchondromatosis, Osteogenesis imperfecta
  - Trauma
  - Infection
  - Polio
  - Spina bifida

- Focal Fibro-cartilaginous Dysplasia: benign, unilateral
  spontaneously corrects
  curettage/corrective osteotomy if persistent or progressive deformity

➢ Persisting genu varum in more than 3-4 years of age is a cause for concern

Tibia vara (Blount's disease)

➢ Progressive idiopathic tibia vara, could be unilateral or bilateral

➢ History - familial

(Courtesy of M Elgendy)

➢ **Examination:**

- Look:
  - Height of patient (rickets are short)
  - Inter-malleolar distance should be < 8mm after age of 7
  - Examine PFJ
  - Beighton score

➢ **Types of tibia vara**

- Infantile
  - < 4 years, 50% correct by 2 years of age, bilateral
- Adolescent
  - >10 years, unilateral, usually progress, causes early OA
- Juvenile
  - 4-10 years (Blount's disease)

➢ **Aetiology**

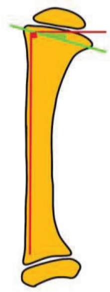
- Growth disorder of endochondral ossification of proximal posteromedial physis (dyschondrosis)
- Secondary to combination of hereditary and developmental factors
- Repetitive trauma to knee in overweight child may lead to overloading of growth plate

➢ **Risk factors**

- Obese
- Early walker
- Afro-Caribbean

➢ **X rays**

- Standing long-cassette AP of both lower extremities with x-ray beam centered at anteriorly facing patellae
- Varus focused at proximal tibia (physiologic varus at distal femur and proximal tibia)
- Metaphyseal peaking
- Drennan's metaphyseal diaphyseal angle.
- Narrowing of medial epiphysis



DRENNAN'S ANGLE

(Courtesy of M Elgendy)

- **Langenskiöld's classification of tibia vara**
  - Type I: Medial metaphyseal peaking
  - Type II: Cartilage-filled depression
  - Type III: Ossification at the inferomedial corner epiphysis
  - Type IV: Epiphyseal ossification filling the metaphyseal depression
  - Type V: Double epiphyseal plate
- Type VI: Medial physeal closed
- **Treatment**
  - Nonsurgical
    - KAFO for < 3 years old
  - Surgical
    - Proximal tibia & fibula valgus osteotomy with epiphysioloysis (bar resection)
      - Risk of recurrence significantly lessened if performed before 4 years of age
      - Overcorrect to 10-15° of valgus because medial physeal growth abnormalities persist
    - Osteotomy with external fixation and gradual correction
      - Taylor Spatial Frame or Ilizarov ring external fixator
      - 12-18 weeks of treatment needed
      - Gradual correction limits NV compromise and risk for compartment syn
      - Allows for correction of deformity in all planes and correction of LLD
    - Lateral tibial hemiepiphysiodesis (8-plate)
      - Done alone or implemented as an adjunct to tibial osteotomy, in patients younger than 10 years.

Genu valgum

- **Aetiology**
  - Unilateral
    - Trauma: Physeal injury, proximal metaphyseal tibial (Cozen fracture)
    - Infection
    - Tumours: Fibrous dysplasia, osteochondroma
  - Bilateral
    - Physiologic: After age 7, valgus should not be more than 120
    - Renal osteodystrophy
    - Skeletal dysplasia: SED
    - Familial hypophosphataemic rickets (usually short)
- **Treatment**
  - Genu valgum in < 2 years child and progressive deformity > 8 years of age

- Normal inter-malleolar distance < 8 cm
- Non-operative: Bracing (ineffective), wait if < 10^0 valgus angle
- **Operative**:
  - Hemiepiphysiodesis of medial side of distal femur (transient by 8 plate or staples or permanent)
  - (8 plate) for < 10 years age (do not delay referral to paediatric orthopaedic surgeon) staples and plates function by increasing compression forces across the physis which slows longitudinal growth (Heuter-Volkmann principle)
  - Distal femoral varus osteotomy for > 10 years age

Fibular deficiency (hemimelia)

- The most common congenital long bone deficiency
- Linked to *sonic hedge-hog gene*
- Three types of tibial bowing exist in children
  - anteromedial bowing (fibular hemimelia)
  - anterolateral bowing (neurofibromatosis)(pseudoarthrosis)
  - posteromedial bowing (physiologic)
- **Look:**
  - Anteromedial leg bowing (describe the apex of deformity
  - Shortening or absence of fibula
  - Often missing lateral toes & equinovalgus
  - LLD
- **Gait** : Short leg gait
- **Move**: Assess knee and ankle stability and extensor mechanism
- **Associated with (from proximal to distal)**
  - Coxa vara
  - PFFD
  - ACL laxity
  - Genu valgum
  - Knee and ankle instability
  - Ball and socket ankle joint
  - Tarsal coalition
  - Absent lateral rays

- Most common congenital long bone deficiency, linked to sonic hedgehog gene
- **Coventry & Johnson classification**
  - I: Partial & unilateral
  - II: Complete & unilateral
  - III: I or II & bilateral or presence of other congenital abnormalities
- **Treatment**
  - Aim to equalize limb length and achieve adequate alignment and stability
  - Non-operative: Brace, shoe lift
  - Operative: (Reconstruction Vs amputation)
    - Contralateral epiphysiodesis if LLD < 5cm
    - Limb lengthening: requires functioning & stable foot & ankle and discrepancy < 15 cm
    - Syme’s amputation in severe cases like non-functional foot

Tibia deficiency (hemimelia)

- Associated with anterolateral bowing of leg , other cause is tibia pseudoarthrosis
- **Treatment**
  - Knee disarticulation and prosthesis in complete absence of tibia
  - Tibiofibular synostosis with modified Syme's amputation if
    - The proximal tibia presents
    - Intact extensor mechanism
    - Minimal flexion contracture

Nail patella syndrome

- Present in late childhood
- **Features**
  - Fingernails dysplasia
  - Absent or hypoplastic patellae
  - Iliac horns (exostosis)
  - Radial head hypoplasia and instability
  - Ligamentous laxity

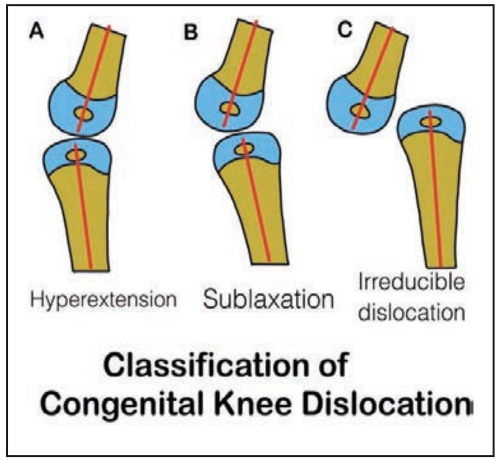
Congenital patella dislocation

- Ossification: Males at 4-5 years, females at 3 years
- **Pathoanatomy**
  - Osseous - hypoplastic patella or trochlea, external tibial torsion
  - Soft tissue - tight lateral retinaculum or quadriceps
  - Genu valgum - patella subluxed posteriorly causing quadriceps to act as knee flexor
- **Treatment**
  - Impairs long term function if left untreated (fixed flexion deformity from quadriceps tightness)
  - Surgery before 1 year old
    - Release lateral structures
    - Reef medial structures
    - VMO advancement
    - Lengthen quadriceps tendon & shorten patellar tendon to correct patella alta

Congenital knee dislocation

- Presents with hyperextended knee at birth
- **Types**
  - I: Hyperextended knee (Resolves spontaneously)
  - II: Anterior subluxation of tibia
  - III: Anterior dislocation of tibia
- Associated conditions
  - Myelomeningocele
  - Arthrogryposis
  - Larsen's syndrome
  - Developmental dysplasia of hip (screen for it)
  - Clubfoot
  - Metatarsus adductus


(Courtesy of M Elgendy)



- **Treatment**
  - MUA and long leg cast
  - Stretching (physiotherapy)
  - Indication of surgical soft tissue release: failure to gain 30^0 of flexion after 3 months of casting
    - Quadriceps tendon lengthening (V-Y or Z quadricepsplasty)
    - Anterior joint capsule release
    - Posterior capsulorrhaphy
    - Hamstring tendon posterior transposition
    - Collateral ligaments mobilization
  - If both knee & hip dislocated, treat knee 1st - cannot get Pavlik on hip if knee dislocated

Larsen syndrome

- Ligamentous hyperlaxity and multiple joint dislocations (hips, knees, shoulders, radial head), closed reduction rarely successful
- **Clinical features**
  - Abnormal facial features:
    - Flattened nasal bridge, prominent forehead
    - Hypertelorism (increased distance between eyes)
    - Cervical kyphosis - Progressive kyphosis may require cervical fusion
    - Potentially lethal
    - Long fingers
    - Club feet

PAEDIATRIC FOOT AND ANKLE DISORDERS

Calcaneovalgus


(Courtesy of S Chenow)

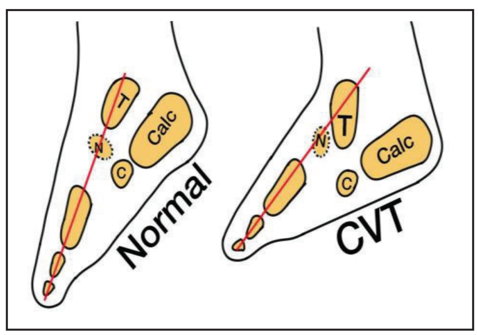
- In any foot deformity describe
  - Hindfoot: equines/calcaneus, varus/valgus
  - Midfoot: supination/pronation
  - Forefoot: adduction/abduction
- Soft tissue deformity with muscle imbalance:
  - Spasticity of dorsiflexors / evertors
  - Weakness of plantarflexors / inverters
- Result of intrauterine positioning
- Associated with posteromedial tibial bowing
- Passively correctable - flexible
- Clinically like vertical talus but
  - Can differentiate on physical exam (Vertical talus has rigid hindfoot equinus/valgus and rigid dorsiflexion)
  - Plantar flexion radiographs (before ossification of navicular at age of 3 years old
  - 1st MT used as proxy for navicular bone)
  - Calcaneovalgus foot: first metatarsal will line up with talus
  - Vertical talus: axis of talus plantar to 1^{st} MT
- **Treatment:**
  - Gentle stretching and splintage
  - Correct in 18 months
  - Tibial bowing deformity spontaneously corrects over 5-7 years
- **Complications:** LLD

(Calcaneo-valgus deformity)

Congenital vertical talus

- Fixed dislocation of talonavicular joint producing rigid flatfoot deformity (rocker-bottom / convex deformity)
- **Associated with neuromuscular disorders**
- Can be idiopathic
- Clinically looks like calcaneovalgus but deformity is at midfoot
- Components
  - Fixed hindfoot equinovalgus
  - Rigid midfoot dorsiflexion
  - Forefoot abducted and dorsiflexed
- **Pathoanatomy:**
  - Talus plantar flexed and the navicular articulates with dorsum of talus (in difference to oblique talus where talonavicular joint reduces on foot plantarflexion)
- **X-rays:**
  - Meary's angle — angle between talus and 1st MT longitudinal axis normally 0-4 degree
  - Forced plantar flexion lateral view shows persistent dorsal dislocation of talonavicular joint with talus parallel to tibia

(Vetical Talus)



- **Treatment:**
  - Preoperative serial manipulation and casting for 3 months to stretch contracted dorsal & lateral soft tissue
  - Reverse Ponsetti
  - TA, EHL, EDL and peroneals surgical release and talonavicular reduction and pinning

CTEV (club foot)

- A deformity in which the forefoot is in adduction and supination, and the hindfoot is in equinus and varus **(NOT A PACKAGING DISORDER)**
- **Epidemiology:**
  - The most common birth defect
    - 1/1000 Caucasians, 3/1000 Polynesians
    - Female: Male = 2: 1
    - Bilateral in 50%
- Underlying bone problem are
  - deformed talus, which it is flexed and medially deviated
  - calcaneus is in varus and rotated medially around talus
  - navicular and cuboid are displaced medially
- **Aetiology: *multifactorial***
  - **Neurogenic theory**: Histochemical abnormalities secondary to denervation changes in various muscle groups of the leg/ foot
  - **Neurogenic imbalance deformity**: Defect in nerve supply (the incidence of varus and equinovarus deformity in spina bifida is approximately 35%)
  - **Myogenic theory**: Primary muscle defect. Predominance in type I muscle fibres and fibre type IIB deficiency
  - Congenital constriction bands/rings
  - Retracting fibrosis: Increased fibrous tissue in muscles and ligaments
- **Clinical examination:**
  - Examine the whole child to exclude **associated abnormalities**: Myelomeningocele, intraspinal tumour, diastematomyelia, polio, CP
  - Look for any associated **developmental syndrome**: Arthrogryposis, diastrophic dysplasia .
  - Examine the **spine** (neurological cause)
  - Pulses: Usually present but vascular dysgenesis is possible (absent dorsalis pedis artery)
  - Examine foot creases: Medial, plantar, posterior
  - Affected limb may be shortened, calf muscle is atrophic, and foot is short compared to opposite side
- Deformities - **CAVE**
  - Midfoot Cavus (tight intrinsic, FHL, FDL)
  - Forefoot Adductus (tight tibialis posterior), forefoot supinated in relation to hindfoot but relative pronation due to 1st MT drop)
  - Hindfoot Varus (tight tendoachilles, tibialis posterior)
  - Hindfoot Equinus (tight tendoachilles)
- **Pirani score (maximum score = 6)**
  - Score severity of hindfoot & midfoot contracture and likelihood of success of treatment 0 – 1 for each,
    - normal (0),
    - moderately abnormal (0.5) or
    - severely abnormal (1)

- Hindfoot
  - Posterior crease
  - Rigidity of equinus
  - Degree of emptiness of heal
- Midfoot
  - Severity of medial crease
  - Coverage of lateral head of talus
  - Curvature of lateral foot

(Courtesy of M Yousef)

➢ **Investigation**

- Radiographs not routinely taken in a newly diagnosed presenting infant but may be of value if the case is resistant to therapy or other pathologies (e.g. congenital vertical talus) is suspected
- Dorsiflexion lateral (Turco view): shows hindfoot parallelism between talus and calcaneus
- Lateral:
  - Talo-calcaneal angle < 25^0
  - Tibio-calcaneal angle > 90^0
- AP:
  - Talo-calneal (Kite) angle < 20^0

➢ **Treatment**

- Aim of treatment: painless functional plantigrade foot without need of orthotic shoe in the 1^{st} year
- **Ponseti** – Spanish physician worked in Iowa in 1950s
  - 90 % success
  - Start at 7 days - can be used in children up to 10 years
  - Lasts for 6-8 weeks
  - Serial weekly above knee casting with knee in 90^0 flexion
- Cast manipulation using **head of talus as fulcrum**
  - Cavus corrected first by dorsi-flexing first ray, increase supination – foot looks worse
  - Forefoot abducted
  - Adduction and varus corrected simultaneously (varus corrected with hindfoot abduction)
  - Finally, equinus corrected – once anterior calcaneum is abducted from under talus)
- **Kite error** (Fulcrum at calcaneo-cuboid joint, which prevented correction of hindfoot)
- **Post-reduction abduction splinting** is required to maintain the position for 23 hours per day (full-time splinting) for 3 months and then 12 hours per day (night-time splinting) until age 5 (or as close to this as can realistically be achieved).
- Traditionally, this involved Denis Browne boots and bar; however, Mitchell boots are gaining popularity as they are well tolerated by infants (and therefore, their parents)
- Residual equinus requires tendoachilles release in 90 %
  - ➢ Aim for at least 150 dorsiflexion
  - ➢ Done under LA (full division)
  - ➢ Cast for further 3 weeks while tenotomise heals
- **Cochrane:** Ponseti technique produce better short-term outcomes compared to Kite's
- **Posteromedial soft tissue release and Achilles tendon lengthening**

- **Indication:**
  - Resistant feet in young children
  - Rocker bottom feet that develop as result of serial casting
  - Syndrome-associated clubfoot
- **Technique:**
  - Capsulotomies: Ankle posteriorly, subtalar joint, calcaneocuboid joint
  - Divide and lengthen tibialis posterior, flexor hallucis longus (FHL) and flexor digitorum longus (FDL)
  - Release plantar ligament, abductor hallucis, flexor digitorum brevis (FDB)
  - Repair of tendons and insert K-wires into talus and calcaneus to hold reduction
- **Delayed presentation >1-2 years of age and recurrence**
  - Posteromedial release
  - Calcaneal slide osteotomy to correct varus
  - Medial opening or lateral column (cuboid)-shortening osteotomy

- **Residual deformity:** Consider spinal cord MRI to rule out spinal lesion. Must exclude a neurological cause. Residual deformity may be either:
  - Dynamic (Foot supination only during walking)
    - SPLATT (split anterior tibialis transfer) or, indeed, whole tibialis anterior tendon transfer considered if the patient is unable to evert their foot actively.
    - A three-incision technique allows harvesting, proximal pull-through and distal re-implantation (classically into the ossified intermediate or lateral cuneiform).
    - The foot typically held in cast for 6 weeks postoperatively.
  - When the deformity is fixed
    - Consider a repeat release if there is not too much scarring and the patient is <5 years old. This is difficult, and in general, poor results reported.
    - Patients are older than 5 years, may need bony procedures to straighten the lateral border of the foot.
- The envelope for successful treatment with Ponseti casting has been extending, and it can be attempted even in late presenting or relapsing cases before surgery (for relapse before 30 months of age and for first relapse in children older than 30 months).
- **Complications**
  - Rigid pes planus from over-correction
  - Rocker-bottom
  - Occurs when attempted correction of equinous contracture occurs before fully correction hindfoot varus deformity. Dorsiflexion occurs through midfoot instead of through hindfoot.
    - Residual cavus
    - AVN of talus
    - Relapse
    - Hypotrophic limb: affected foot and calf will be smaller in size
    - Short leg gait
    - In-toeing gait
    - Pressure damage from casting

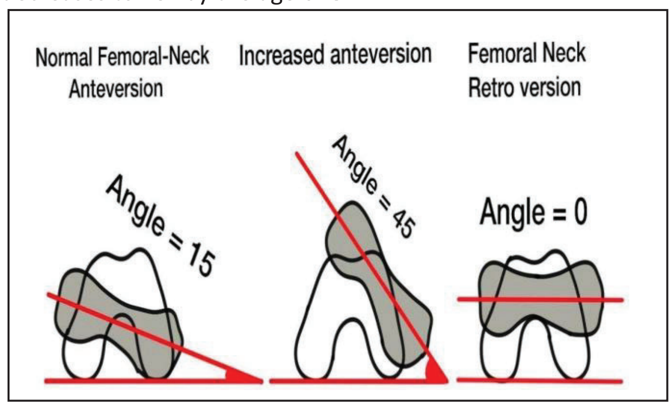
(CTEV for FRCS)

In toeing: (Pigeon toe)

- **Aetiology**
  - Femoral anteversion
  - Metatarsus adductus (infants)
  - Internal tibial torsion (toddlers)

Increased femoral neck anteversion

- Femoral anteversion is the angle between femoral neck and posterior femoral condylar axis
  - Seen in early childhood (3-6 years), resolve by age of 10 years
  - Twice as frequent in girls than boys ,often bilateral
  - At birth the femoral anteversion angle is 30-40° decreases to 15° by the age of 8



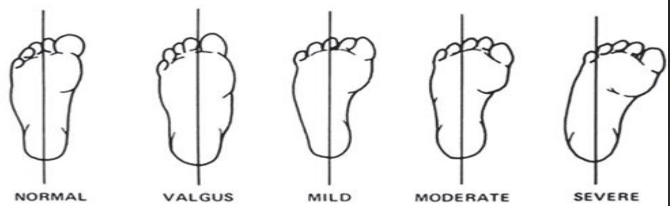
- **Symptoms**
  - Patellae and toes point in same direction
  - Child classically sits in the W position
- **Physical exam**
  - Range of hip rotation:
    - Prone - Knees flexed at 90 deg
    - (normal IR 20 – 60deg)
    - Increased IR and decreased ER, stabilize pelvis for external rotation
  - Craig test to measure femoral anteversion angle
    - Femoral neck horizontal when GT at maximum prominence
- **Treatment**
  - Resolves in more than 80% of affected children by late childhood
  - Bracing and orthotics don't change natural history
  - De-rotational femoral osteotomy for deformities that persist after age of 10 Sub-trochanteric or supracondylar (more visible scar)

Internal tibial torsion

- The most common cause in toddlers (1-3 years)
- Thigh-foot angle: prone position - Knee flexed to 900
- Normal is -5 to 20^0
- -10^0 is considered internal tibial torsion
- Between thigh axis and sole of foot in resting position
- Trans-malleolar axis
  - If foot shape abnormal
  - Between transcondylar axis of proximal tibia and bimalleolar axis
  - Normal 0 – 45^0
- **Treatment**
  - Self-limiting, resolves by 4-6 years
  - In children > 10 years with functional disability such as frequent trips and falls, de-rotational tibia osteotomy: proximal (distal to tibial tuberosity) or supra-malleolar
  - Prophylactic decompression of anterior compartment

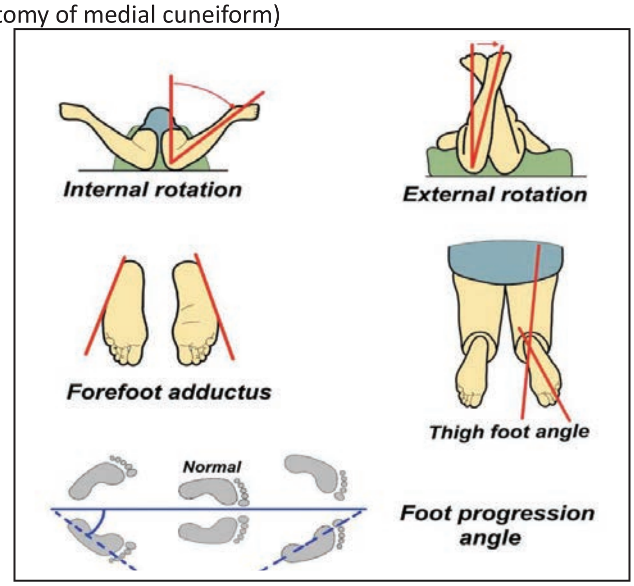
Metatarsus adductus (varus)

- Infants, noticed with 1st year of life
- Associated with DDH – hip screening US
- Internal rotation of forefoot with normal hindfoot
- Look at lateral border of foot, normally lateral border on foot is straight line
- Difference from club foot is that heel is not affected
- Heel bisector test (Bleck grades), normally line passes between 2nd & 3rd toes



(Courtesy of M Elgendy)

- **Treatment:**
  - Non-operative
    - Flexible stretching (manipulation) – for rigid deformity that do not resolve by 6-9 months of age
    - Straight shoe casting (above knee)
  - Operative: > 4 years
    - Release of abductor hallucis and medial capsule
    - Lateral column shortening (closing wedge osteotomy of cuboid or calcaneus)
    - Medial column lengthening (opening wedge osteotomy of medial cuneiform)
- **Staheli rotational profile**
  - To assess location and severity
  - Foot progression angle for overall alignment
  - Direction in which foot points during gait with respect to line of progression -5 to + 20
  - Patellae and feet should be pointing in same direction
  - And the following 3 tests



(In-toeing)

- **Investigations**
  - CT scanogram horizontal cuts through hips, knees and ankles
- **Indications for intervention**
  - Tripping over
  - Bullying
  - Asymmetry

Out-toeing

- **Aetiology**
    - Femoral neck retroversion
    - External tibial torsion
    - Perthes' or SUFE should be suspected, especially if unilateral
- Thigh foot angle >30^0
- Trans-malleolar axis measurement at infancy is 5^0 internal rotation
- At adulthood, range 0-40^0 external
- Increased external rotation of hip (normal 30 – 60^0)
- Difficulty with gait, worsens with growth
- Increased risk of OCD
- **Treatment**
    - Observe, worsens during late childhood and early adolescence
    - More likely to require surgery than internal tibial torsion
    - Supra-malleolar rotational osteotomy for children older than 8 years of age with >40 degrees
    - Oblique osteotomy for fibula to increase contact area and decrease non-union
    - Transverse for tibia then crossed wires and plaster

Toe-walking

- **Aetiology**
        - Common when toddlers start to walk (< 2 years old), reassess in 6 months
    - Idiopathic
    - Habitual
    - Achilles tendon tightness
    - CP (Stretching, Botox)
    - LLD (unilateral)
    - Duchenne muscular dystrophy
    - Neuromuscular
- **History**
    - Painless
    - Birth history
    - Development milestones
    - Family history
- **Physical exam**
    - Look for contractures
    - Neurological including abdominal reflexes
    - Creatine Kinase (CK)
- **Treatment**
    - Most likely resolves at 7 years
    - Insoles
    - Serial casting

CEREBRAL PALSY

- Non -progressive upper motor neuron disease (Static encephalopathy) due to injury to immature brain
- Caused by lack of oxygen damaging the developing brain
- Encephalopathy is static while affected musculoskeletal system changes with growth.
- The disorder affects posture and movements,
- Onset within 1^{st} two years of life
- Most reliable predictor for ability to walk is independent sitting by age 2
- **History**
  - Talk to child and ask name
  - Birth History
  - Pain (hip)
  - Walking (delayed motor development due to spasticity)
  - Developmental milestones: sit at 8 months, stand at 10 months, walk at 16 months, hop on 1 foot at 4 years, bowel and bladder control to rule out spinal problems
  - Cognitive level
  - ADL (sitting hygiene)
  - Previous treatment
  - Current problems
- **Examination**
  - Look:
    - Ambulant or chair-bound
    - Joint deformity (contractures)
  - Standing (how they stand)
    - Scoliosis
    - Inspection, spinal movements and gait
    - Head control
    - Involuntary movements
    - Splints and orthotics
  - Sitting:
    - Spine
    - Hand under buttock for pelvic obliquity, ability to control trunk
  - Gait
    - Toe walking (equinus) spasticity of Gastrocnemius
    - Crouch gait: increased hip & knee flexion in stance phase, spasticity of hamstrings, can be associated with apparent equinus
    - Scissoring: spasticity of adductors
    - Stiff knee: spasticity of rectus, decreased knee flexion during swing, knee kept in extension
    - Spastic gait: legs held together and move in stiff manner, toes drag and catch on floor, windswept
  - Move
    - Tone
    - ROM (shoulders, elbows, hips - Thomas test for FFD, leg over edge due to knee
    - FFD
    - Duncan Ely test for tight rectus
    - Knee: popliteal angle test, flex hip to 900 and extend knee

- Foot: equines (Silfverskiold test)
- Staheli rotational profile
- Neurological (sensation, predictive of ability to use limb, spasticity)

➢ **Aetiology**

- Prenatal
  - Infections: TORCH (Toxoplasmosis, Rubella, CMV, Herpes simplex)
  - Placenta insufficiency- Smoking, alcohol
  - Obstetric complications, pre-eclampsia
- Perinatal
  - Hypoxia
  - Prematurity (most common)
- Postnatal
  - Infections
  - Trauma

➢ **Incidence:** 2: 1000 live births

➢ **Physiologic classification**

- Spastic
  - Most common (80%) due to cerebral damage of motor cortex causing increased muscle tone
  - Spasticity is velocity dependent increased tone
  - Rigidity is velocity independent increased tone
  - Most common form to develop scoliosis
  - Hyper-reflexia: secondary to simultaneous contracture of agonists and antagonists
- Ataxic (cerebellum damage)
  - Inability to coordinate muscle voluntary movements
  - Unbalanced wide based gait
- Dyskinetic: damage to basal ganglia & thalamus
- Athetosis: slow writhing involuntary, uncontrolled movements
- Dystonia: involuntary muscle contraction that results in abnormal posture
- Chorea: random movements that increase at rest & improve with movement
- Hypotonic

➢ **Anatomical classification**

(Plegia= complete loss of power, Paresis=some power preserved)

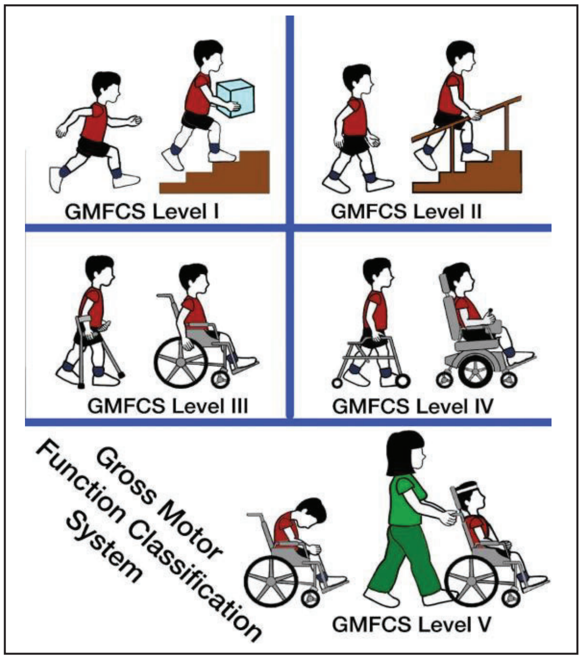
- Monoplegia: single limb
- Hemiplegia: affect both limbs on one sidearm usually worse than leg
- Diplegia: affect right and left side equally
- Minimal spasticity may be present in upper limbs, but lower limb spasticity predominates. IQ near normal
- Paraplegia: impairment of function in trunk, legs, and pelvic organs depending on level of injury
- Arm function is preserved
- Quadriplegia (tetra), both legs and both arms (non-ambulatory), associated with low IQ and higher mortality

➢ **Functional classification**

- **Gross Motor Function Classification System GMFCS (Royal Children's Hospital)**
  - Walk without limitations
  - Walk with limitations (stairs)
  - Walk with assistance device - crutch or wheelchair

- Use powered mobility
- Transported in wheelchair, head unstable

➢ **Assessment**
- MRI brain-periventricular-leukomalacia (PVL)
- Gait analysis
- Hearing
- Dentitions



Hip

➢ FFD

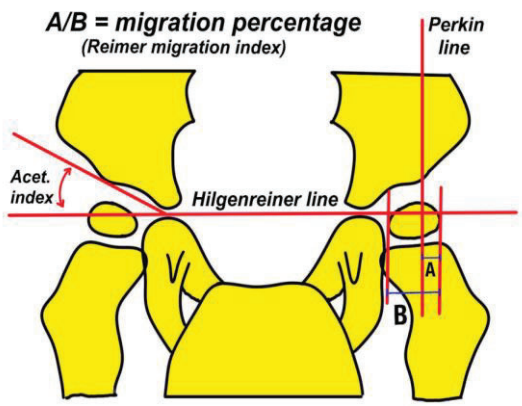
➢ Strong tone in hip adductors & flexors lead to scissoring & predisposes to posterior hip subluxation and dislocation

➢ Resulting difficulties in seating, hygiene, personal care, and hip pain (monitor)

➢ **Treatment**
- At risk or Subluxed: adductor & psoas tenotomise, abduction bracing to prevent progression
- Dislocated:
  - VDRO proximal femoral varus de-rotation osteotomy
  - De-rotational pelvic osteotomy (mature patients with incongruent joint)

➢ Salvage procedure Girdlestone
Valgus osteotomy

➢ **Reimer migration index:**
- Percentage of femoral head with no acetabular coverage (ratio of femoral head lateral to Perkin line)



- Most accurate method to identify and monitor hip stability
- Normal is < 30 %
- < 50% more stable and can be improved with soft tissue procedure
- >50% requires bony procedure as it will progress and dislocate

➢ NICE guidelines for hip screening in CP
- Hip x-rays at 2 years in patients with clinical risk factors – difficulty posturing or pain, limb length discrepancy, increased hip tone, or reduced ROM (restricted abduction)
- If migration index > 30% - hip X-rays 6 monthly
- GMFCS $\geq$ 3 – hip X-rays annually

(Hips in CP)

Spine

➢ Scoliosis if progress or long C curve
➢ Sitting imbalance – become hand dependent sitters – limits upper limb function
➢ Custom seat and bracing help to improve sitting balance but don't affect natural history
➢ With level pelvis, treat hip 1^{st}
➢ With pelvic obliquity on sitting position (sit on one buttock and other lifted off)
- Do spine 1^{st} to level pelvis, otherwise hip will re-dislocate
- Then must do hip as straightening spine will make seating more difficult

Knee

➢ FFD, from hamstrings tightness or extensor lag

Foot

➢ Equinus is most common deformity in CP (Silfverskiold test)
➢ Serial manipulation (AFO)
➢ TA lengthening: lead to progressive flexion at hips & knees, worsening crouched gait
➢ Equinovarus
➢ Hallux valgus
➢ Planovalgus

Shoulder

➢ Internal rotation: de-rotational osteotomy
➢ Subscapularis and pectoralis lengthening
➢ Capsulotomy

Elbow & forearm

➢ Pronation: pronator teres release
➢ Flexion: biceps and brachialis lengthening, brachioradialis origin release

Wrist

➢ Flexion & ulnar deviation: FCU or FCR lengthening

Hand

➢ Thumb in palm deformity: release of adductor pollicis and stabilization of MCPJ

Treatment:

Multidisciplinary approach

- Management principles
  - Maintain and improve function ,posture and mobility
  - Consider the limb as a whole
  - Reduce pain

- Dynamic contractures
  - Physiotherapy
  - Serial manipulation and casting
  - AFO

- Botox
  - Botulinum A toxin injections - Injected locally
  - Inhibit release of acetylcholine at neuromuscular junction
  - Effective for 3-6 months

- Baclofen
  - GABA agonist
  - Act centrally & peripherally to decrease spasticity

- Diazepam

- Rhizotomy
  - Resection of nerve root, surgical/chemical/RF
  - Interrupts reflex arc in spastic CP
  - For ambulatory bilateral spastic

- Principles of surgery
  - Preventative surgery
  - Correctable contractures, early if functional (thumb in palm or wrist flexion)
  - Fixed contractures or patients with low function (arthrodesis)
  - Muscle lengthening after age of 7 to reduce recurrence
  - SEMLS – Single episode multiple level surgery to avoid ‘’Birthday syndrome’’

GENETIC DISORDERS

Spinal Muscular Dystrophy

- Autosomal recessive disease caused by progressive loss of alpha-motor neurons in anterior horn of spinal cord due to Survival Motor Neuron (SMN) gene mutation
  - Sensory function preserved
  - Symmetric progressive motor weakness
  - Areflexia
  - More profound in lower extremity than upper extremity
  - More profound proximally than distally
- **Diagnosis based on**
  - DNA analysis
  - Muscle biopsy
  - EMG normal
  - Absent deep tendon reflexes: distinguish from Duchenne's muscular dystrophy where they are present
- **Associated disorders**
  - Hip dislocation: painless and high recurrence rate if open reduction attempted
  - Scoliosis: bracing devices may delay but not prevent surgery in children younger than ten years
  - Operative PSF to pelvis for progressive curve
    - < 9 years growing rods anchored to pelvis
    - > 9years posterior fusion with pedicle screws
- Lower extremity contractures - Surgical release controversial as function in non-walkers is rarely improved and recurrence is common

Duchene muscular dystrophy

- Recessive X (sex) linked, affects males only
- This means that if women are carriers (XX), then their sons (XY) have 50% chance of inheriting disease
- Mutation for dystrophin gene - causes poor muscle fibre regeneration
- Progressive replacement of muscle tissue with fibrous and fatty tissue
- Called Becker muscular dystrophy if dystrophin is decreased
- Progressive muscle weakness affecting proximal voluntary muscles first
  - Delayed walking
  - Tibialis posterior retains strength until later: equinovarus, toe walking
  - Calf pseudohypertrophy
- Scoliosis: progresses rapidly
- **Gower test:** (Neurologist from London)
  - Use arms to stand from squatting position due to weakness of proximal muscles
  - Climb up on one-self

(courtesy of L Prakash)

- Deep tendon reflexes present (unlike spinal muscular atrophy)
- **Investigation**
  - Raised CPK
  - Muscle biopsy
  - DNA testing shows absent dystrophin protein
  - EMG
- **Treatment**
  - No cure
  - Bracing
  - Mild activities, swimming
  - Corticosteroid improves strength, slows progressive weakening, prevents scoliosis formation and delays deterioration of pulmonary function
  - Soft tissue releases of contractures to prolong ambulation
  - Treat scoliosis early with fusion to avoid pulmonary and cardiac compromise
- **Prognosis**
  - Unable to ambulate independently by age 10
  - Die of cardiomyopathy and respiratory problems by age 20

Down syndrome

- Most common chromosomal abnormality (trisomy 21)
- Hip dislocation
- Patello-femoral instability
- Cervical instability
- Occipital condyle hypoplasia: avoid contact sports
- Atlantoaxial instability: fusion if ADI >10mm
- SUFE
- Pes planus
- Metatarsus adductus
- Systemic: Mental retardation & Hypothyroidism
- Premature aging
- Heart disease

Turner syndrome
- 45XO - affects only females
- Amenorrhea, sexual infantilism, monitor for osteoporosis
- Short stature, short 4th MC
- Webbed neck (low hairline)

Chiari malformation
- Structural defect in cerebellum due to herniation through foramen magnum
- Puts pressure on brainstem, spinal cord and obstruct CSF flow

Prader-Willi Syndrome
- Hip dysplasia
- Juvenile onset scoliosis
- Hypotonic
- Obese
- Intellectually impaired
- Insatiable appetite
- Hypoplastic genitalia

Rett Syndrome
- Progressive impairment and developmental delays seen in girls 6-18 months
- Affects grey matter of brain (spasticity and joint contractures)
- Ataxia
- Hypotonia
- Bruxism (grinding of teeth)
- Chorea (abnormal hand movement)

Fetal alcohol syndrome
- Physical and mental developmental delays secondary to alcohol consumption during pregnancy
- CNS dysfunction
- **Orthopaedic manifestations**
    - Joint contractures
    - Hip dislocation
    - Congenital fusions of cervical spine and upper extremity
    - Congenital scoliosis
    - Pectus excavatum
    - Myelodysplasia

Apert syndrome (Acrocephalosyndactyly)
- Premature fusion of cranial sutures (craniosynostosis) results in flattened skull and broad forehead (acrocephaly)
    - Defect of FGFR-2 gene
    - Bilateral complex syndactyly of hands and feet
    - Radio-ulnar synostosis
    - Symphalangism

Poland Syndrome

- Chest wall (absent pectoralis major) and hand and forearm hypoplasia
- Brachydactyly - shortening of middle fingers
- Humerus absent/abnormal
- Microcephaly
- Preaxial polydactyly
- Ureteric anomalies
- Vertebral segmentation anomaly
- Soft tissue procedures produce better functional results than bone lengthening

Arthrogryposis

- Non-progressive congenital disorder with multiple rigid joints and severe limitations in movements
- **Pathology** Defect of anterior horn cells or motor unit
- **Causes**
    - Extrinsic: decreased mobility in uterus, Oligohydramnios
    - Intrinsic: inflammatory or infective
- Can present as single deformity (Vertical talus & club foot)
- **Treatment**
    - Non-operative

      Like RA, important thing is function of whole limb to allow walking and transfer
        - Passive manipulation
        - Serial casting
    - Operative

      Corrective surgery within 18 months
        - Soft tissue release
        - Corrective osteotomy to assist with personal hygiene
        - Talectomy for failed CTEV and vertical talus

Friedreich ataxia

- Neuropathy in dorsal root ganglia with loss of peripheral sensory nerve
- Degeneration of posterior columns of spinal cord
- Problem with Frataxin gene
- Babinski upgoing
- Ataxia
- Pes cavovarus
- Scoliosis
- Cardiomyopathy
- Usually wheelchair bound by age 30
- Usually die by age 50 from cardiomyopathy

Myasthenia Gravis

- Autoimmune disease
- Antibodies bind to acetylcholine receptors

Mucopolysaccharidoses

- Inability to metabolize proteoglycans (Lysosomal storage disease)
- Incomplete glycosaminoglycan breakdown products accumulate and cause dysfunction in various organs
- Proportionate dwarfism

- **Main forms include**
  - Morquio syndrome: atlantoaxial instability due to hypoplasia of odontoid, Normal IQ
  - Hurler syndrome: mental retardation
  - Sanfilippo syndrome most common form with mental retardation
  - Hunter syndrome: low IQ
- Bone marrow transplant and intravenous enzyme replacement therapy improve life expectancy but does not alter orthopaedic manifestations.

Cleidocranial dysplasia

- Skeletal dysplasia affecting bones formed by intra-membranous ossification (facial bones, cranium, and clavicles), RUNX2/CBFA1 gene mutation
  - Proportionate dwarfism
  - Widened cranium due to delayed fontanels ossification
  - Cleft palate
  - Clavicle dysplasia leading to hypermobility of shoulders
  - Scoliosis
  - Coxa vara
  - Failure of pubis to ossify
- **Treatment:**
  - Excision of clavicular fragments to decompress irritated brachial plexus
  - Scapulothoracic arthrodesis

METABOLIC DISORDERS

Rickets

- Defect in mineralization of osteoid matrix caused by inadequate calcium and phosphate with failure of calcification in zone of provisional calcification
- (Childhood form of Osteomalacia)
- **Types**
  - Familial Hypophosphataemic Vit D resistant
    - Most common
    - X linked dominant , mutation in PHEX gene – increases FGF23
    - Renal phosphate wasting (inability to reabsorb Phosphate)
    - Normal PTH
    - Treat with phosphate replacement & high doses Vit D
  - Vit D dependent: rare & severe
    - Low levels of 1,25 (OH)2 D3 due to defect of 1 alpha hydroxylase in kidney (type I)
    - End-organ resistance to 1,25 (OH)2 D3 (type II VDDR)
    - Treat with high doses of Vit D
  - Vit D deficient
    - Nutritional
    - Vit D/Ca/Phosphate deficiency
    - Lack of sunlight exposure
    - >90% of vitamin D supply is derived from exposure to UV-B light)
    - DOH recommends Vit D supplements for children from 6 months – 5 years
    - Common in Afro-Caribbean
    - Malabsorption
    - Low Ca, low Vit D, low phosphate, high PTH
    - Treat with Vit D (5000 IU/day) and education
  - Renal osteodystrophy
    - Glomerular damage causes phosphate retention that leads to secondary hyperparathyroidism
    - Tubular damage causes reduction in 1,25 (OH)2 D3 synthesis
- **Symptoms:** Night pain, muscle weakness
- **Signs** Kyphosis
  Rachitic rosary (Enlargement of costochondral junction)
- **X-rays**
  - Coxa vara, genu valgum
  - Physeal widening and metaphyseal cupping causing wrist swelling
  - Looser lines, pseudo-fractures on compression side
  - Cod-fish vertebrae
  - Raised ALP in all types
- **How to investigate a traumatic fracture in the young?**
  - History - exposure to sun light, no Vit D in breast milk
  - Ca, Phosphate, PTH, ALP, Vit D
  - Albumin for nutritional status
  - Skeletal survey

Hypophosphatasia

- Same features as Rickets but with low serum ALP
- Failure of mineralization of osteoid, zone of provisional calcification never forms
- Can cause subtrochanteric or metatarsal fractures and frequent bones fractures

Condition	genetic	Ca	Po4	ALP	PTH	VIT D
Vit D resistant rickets	XD	-	↓	↑	-	
Vit D deficiency rickets	nutritional	-↓	↓	↑	↑	↓
Type I Vit D Dependent	AR	↓	↓	↑	↑	↓↓
Type II Vit D Dependent	AR	↓	↓	↑		↑↑
Hypophosphatasia	AR	↑	↑	↓↓	-	
Renal Osteodystrophy	Renal disease	↓	↑	↑	↑	
Hyperparathyroidism	90% adenoma	↑	↓	↑	↑	

OSTEOPETROSIS (MARBLE BONE DISEASE)

- Failure of osteoclastic resorption due to Carbonic Anhydrase gene deficiency and abnormal ruffled border formation & function
- **Leads to**
  - Dense bone and generalized bone sclerosis
  - Loss of bone marrow (anaemia, osteomyelitis due to lack of marrow vascularity)
  - Blindness from overgrowth of skull foramina
  - Macrocephaly
  - Fractures due to reduced bone elasticity
- **X-rays**
  - Marble bone
  - Rugger jersey spine
  - Erlenmeyer flask femur
  - Bone within bone
- **Treatment**
  - Vit D: stimulates dormant osteoclasts
  - Bone marrow transplantation
  - Erythropoietin
  - Corticosteroids to reduce calcium in bone
  - Interferon beta

(Courtesy of M Imam)

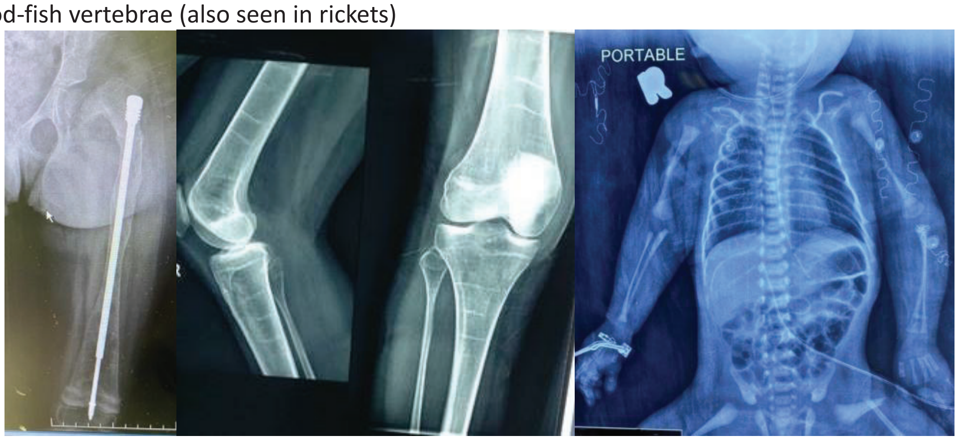
OSTEOGENESIS IMPERFECTA

- Defective type I collagen synthesis due to mutation of chromosome 7 or 17, leads to defective osteoid formation

- **Sillence types**
  - I: AD, mild blue sclera (A-normal teeth/B-abnormal teeth)
  - II: AR, fatal, blue sclera, intrauterine fractures
  - III: AR, severe, white sclera, short stature, scoliosis
  - IV: AD, moderate, white sclera, fragility fractures (A-normal teeth/B-abnormal teeth)

- **Clinical presentation**
  - Bone pain, easy bruising
  - Deafness
  - Bowing of long bones
  - Basilar invagination causing myelopathy

- **X-Rays**
  - Thin cortices, generalized osteopenia
  - Looser zones on tension side of bone as defect is in collagen (tensile strength)
  - Wormian bones, small intra-sutural bones that lie between cranial sutures (>10 are pathological)
  - Cod-fish vertebrae (also seen in rickets)



(Courtesy M Elgendy)

  - Harris lines (growth arrest lines)
    Parallel lines of increased bone density that represent position of growth plate at time of insult.
    Result of juvenile malnutrition, sickle cell disease, and trauma or due to growth spurts. Due to osteoblasts forming bone on abnormal collagen matrix
  - Zebra stripe sign
    Occurs where children with osteogenesis imperfecta have been treated with cyclical Bisphosphonate therapy, e.g. Pamidronate.
    When drug is delivered in cycles, dense bone formed while treatment is being given, dense stripes across the whole metaphysis of bones
  - Dentinogenesis imperfecta
    - Scoliosis develops early and progressive

- **Investigation**
  - Genetic profile
  - Biopsy: Increased Haversian canal diameter and cellularity, decreased trabeculae

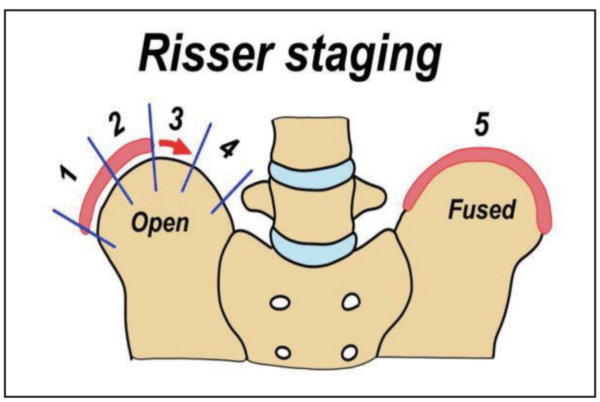
- **Management**
  - Treatment principle
    - Prevent fracture (brace, minimal handling, bisphosphonate)
    - Maximize function
    - Reduce Pain
    - Prevent deformity
    - Correct deformity
  - Deformity correction
    - IM nailing, Sheffield telescopic rods (Fassier-Duval Telescopic IM nailing system)
    - Realignment osteotomies
    - Posterior spinal fusion and bracing to prevent basilar invagination
    - ASF only indicated in very young children to prevent crankshaft
  - Poor bone quality leads to fractures, dislodgement of implants and loss of correction

CONSENT FOR CHILDREN

- Non Gillick competent Child
  - Parent
  - Mother automatically has parental responsibility
  - Father has parental responsibility if
    - Married to mother now or at time of birth
    - Agreement of court order
    - Named on birth certificate
- 14 – 16 Gillick competent can go against parent if they can make judgement and balance the risks and benefits
  - Can the child understand the nature, purpose, benefits and hazards of treatment?
- Child up to 18 years: May be over-ridden by parent if they refuse treatment
- The more serious the potential consequence, the more stringent the test of Gillick competence
- The unborn child
  - Only the pregnant mother can consent to any form of medical treatment of procedure for the unborn child
- If both parents refuse, courts can overrule their decision (but in an emergency when treatment is vital and waiting to obtain consent would place child at risk, treatment can proceed without parental consent)
- Legal guardian, appointed by court
  - Ward, someone placed under protection of legal guardian
- For assessing capacity, things to look out for
  - Able to understand
  - Retain the information
  - Use and weigh the information given
  - Able to provide consent
  - Ward someone placed under protection of legal guardian

RISSER STAGING

- Used to determine skeletal maturity by assessing iliac apophysis appearance and ossification
- Ossification starts anteriorly and proceeds posteriorly
  - <25 %
  - 25 – 50 %
  - 50 – 75 %
  - 75 – 100 %
  - Fusion, start from posterior



- Used as guide to skeletal maturity and likelihood of further deterioration of scoliosis
- Small curves and greater maturity predict smaller likelihood of curve progression.

NON-ACCIDENTAL INJURY (NAI)

- **Risk factors**
  - 1st child
  - Step-child
  - Single parent
  - Domestic violence
  - Substance abuse or mental health disorder in parent/carer
  - Low income
  - Demanding parenting roles
- 80% of cases occur in < 18 months
- 50 % of fractures < 1 year are due to abuse
- If unreported, 30-50% chance of repeat abuse and 5-10% chance of death from abuse
- **'Kids who don't cruise shouldn't bruise**

- **Signs**
  - Delayed presentation
  - Inconsistent/discrepancy in history
  - Mechanism does not explain injury
  - Multiple fractures in different stages of healing (callus formation)
  - Long bone fracture in non-ambulatory, most common cause of femur fractures in non-ambulatory infant
  - Metaphyseal corner or bucket handle (abnormal density between metaphysis and epiphysis) fracture
  - Rib fracture in infants (oblique views of ribs, look at costo-vertebral junctions, beware of normal sternum ossification centers) – strongest predictor of child abuse
  - Skull fractures - Head injury is most frequent cause of long-term physical morbidity
  - Multiple skin bruises of different ages
  - Burn or bite or finger marks
- Undress and do full examination

- **Management**
  - Duty of care to act on concerns
  - Priority to ensure child in safe environment
  - Admit to hospital
  - Follow local safeguarding procedure
  - Non-judgmental approach
    - Keep comfortable, manage the fracture
    - Examine from head to toe
    - Check register
    - Contact GP
    - Child protection team (child protection officer usually paediatrician consultant on call)

- NICE guidelines for child maltreatment (2009)
  - Listen and observe – history, behaviour, interaction between parent or carer and child
  - Seek an explanation in open non-judgmental manner
  - Record details
  - If considering maltreatment: Discuss with paediatrician, more experienced colleagues, safeguarding professional. Gather collateral information. Ensure follow up review at a date appropriate to the concern and look out for repeated alerting feature
  - If suspecting maltreatment, refer to social care following local safeguarding children procedures – fractures in children < 3 years is a red flag to suspect maltreatment
  - Maltreatment excluded if suitable explanation is found for alerting features.

- **Investigation:**
  - Skeletal survey (X-ray entire skeleton, 22-film radiographs in any child < 2 years when abuse is suspected). Repeat skeletal survey 11-14 days after.
  - Blood tests (bone profile, PTH, Vit D, clotting profile, FBC with platelet count)
  - Urinalysis for occult blood
  - LFTs and amylase to screen for occult abdominal injury
  - Bone scan for children > 5 years (metaphysis hot due to increased vascularity)
  - If in doubt – admit child and repeat skeletal survey in 2 weeks
  - Photo documentation of any external injuries

- **Differential diagnosis**
  - OI
  - Metabolic bone disease
  - Accidental trauma

LOWER LIMB RECONSTRUCTION

- **Causes of LLD**
  - Congenital (DDH, PFFD, fibula hemimelia, hemi-hypertrophy)
  - Neuromuscular (CP, Polio, family history)
  - Metabolic: rickets
  - Tumour: A-V malformations
  - Trauma: diaphyseal or physeal injury
  - Dysplasia (MHE)
  - Infection
  - AVN
  - Haematological: Haemophilia
  - Scoliosis

- **Predicting LLD**
  - Onset of menarche best determinant of skeletal maturity in females, skeletal maturity usually within 2 years
- **White-Menelaus method, arithmetic estimation**
  - General assumptions that growth continues until 16 years in boys and 14 years in girls
  - Growth primarily occur at knee in lower extremity & away from elbow in upper limbs
  - Leg grows 23 mm/year, mostly comes from knee (15 mm/year)
  - Proximal femur 3 mm / years
  - Distal femur 9 mm / years
  - Proximal tibia 6 mm / years
  - Distal tibia 5 mm / years

- **Paley Multiplier method**
  - Prediction based on multiplying current discrepancy by appropriate multiplier for sex and age
  - Most accurate for congenital LLD

- **Green –Anderson chart**
  - Predicts growth remaining in femur and tibia of both limbs relative to skeletal age
  - Wrist x-ray to determine skeletal age compare to Greulich and Pyle atlas
  - Dashed line 1 SD from mean and solid line 2 SD from mean

- **Moseley straight-line graph**
  - Special graph for each patient
  - Need length of normal and abnormal legs and skeletal age at 3 different occasions
  - Boys (3 – 16) at bottom and girls (4 – 14) at top

- **CORA - Centre of rotation of angulation**
  - Intersection of proximal mechanical or anatomical axis and distal mechanical or anatomical axis
  - Complex deformities can have multiple CORAs
  - Hinge (virtual) on convex side to correct and lengthen

	Coronal	Sagittal	Axial
Translation	Medial Lateral	Anterior Posterior	Shortened Lengthened
Angulation	Varus Valgus	Flexion (procurvatum) Extension (recurvatum)	Internal rotation External rotation

- CT scanography is the most accurate diagnostic test

- **Principles**
  - Acute for mild to moderate deformities < 30^0
    - Greater correction will carry risk of NV injury and compartment syndrome
  - Gradual
    - Hemi epiphysiodesis in open physis
    - Distraction osteogenesis if deformity at diaphysis

- **Treatment**
  - < 2cm - Shoe lift
  - 2-5 cm
    - Epiphysiodesis of long side
    - Shortening osteotomy if mature
  - > 5 cm - limb lengthening of short side
    - 15 cm lengthening and shortening
    - 25 cm prosthesis
- External fixator – TSF Distraction osteogenesis stimulates new bone formation
  - **Techniques**
    - Metaphyseal corticotomy with Gigli saw or drill and osteotomes
    - Low energy to preserve blood supply
    - ISKD Intramedullary Skeletal kinetic Distracter
    - Wait 5-7 days then begin distraction (1 mm/day)
    - 6 deformities - angulation and translation in AP, lateral and axial plans
- Partial growth arrest leads to angulation
  - < 2 cm growth remains - Ipsilateral completion of arrest
  - > 2cm growth remaining
    - Bar resection with interposition if < 50% physeal involvement
    - Epiphysiodesis then lengthening if >50 % bridge Drill (permanent) or 8-plate (reversible)
- Adjunctive osteotomy if deformity > 20^0

HEMI-HYPERTROPHY

- Asymmetry between right and left sides of body to greater degree than can be attributed to normal variation
- Skin thicker on involved side
- Limb circumference asymmetric
- Associated conditions compensatory scoliosis
- Wilms's tumour: needs serial kidney U/S and serum alpha - fetoprotein
- Polycystic kidney
- Adrenal carcinoma, needs abdominal US
- **Classification**
  - Congenital
  - Acquired: trauma or infection
  - Idiopathic: Non-syndromic
  - Syndromic:
    - Beckwith-Wiedemann syndrome - overgrowth syndrome
    - Klippel Trenaunay syndrome
    - Neurofibromatosis

- **<u>Klippel – Trenaunay - Weber syndrome</u>**
  - Elongated, enlarged bones can lead to LLD
  - Soft tissue swelling
  - Phleboliths within soft tissue
  - Port-wine stain, AV malformations
  - Varicose veins
- **Treatment:** Surgery if LLD > 2cm

(Courtesy of M Elgendy)

The Spine

AUTHORS

Siddhant Kapoor, Husam Elbana, Imran Ali and Firas Arnaout

CONTENTS

EXAMINATION OF THE SPINE

- **Common cases:**
  1. Myelopathy
  2. Stenosis
  3. Scoliosis
  4. Lumbar/Sacral nerve root impingement (Radiculopathy)
  5. Diastematomyelia / spinal dysraphism
  6. Girdlestone / excision arthroplasty / hip fusion with lumbar spondylosis

History

- Always ask about **red flag symptoms** -
  - Loss of power
  - Non-mechanical pain: unrelated to activity, night pain
  - Bladder/bowel disturbance: 'any problems controlling your bladder or bowels
  - Thoracic pain
  - Weight loss
  - Fever
  - History of malignancy or immunosuppression therapy
- Radiculopathy
  - Sharp radicular pain
  - Neurological claudication
  - Abnormal sensation:
    - Paraesthesia – tingling, burning or pricking sensation
    - Allodynia - Pain from stimulation that doesn't normally cause pain
- Myelopathy
  - Non-dermatomal paraesthesia (tingling) and numbness in bilateral extremities
  - Decreased manual dexterity like writing/dressing, dropping things
  - Think especially in RA patients
- **Examination**
  - Expose patient and ask the patient to stand

Look

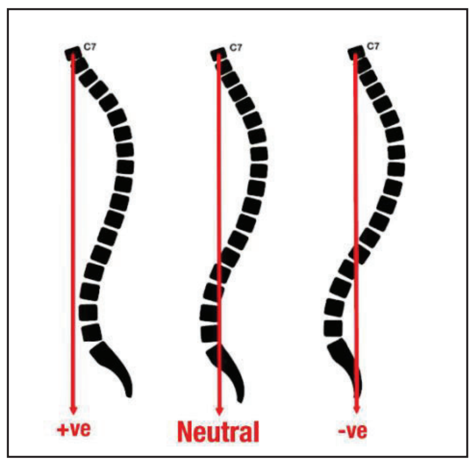
- Front:
  - Muscle wasting, hand wasting in myelopathy
  - Skin marks and freckles (NF)
  - Coronal balance
  - Symmetry of shoulder height and waist line (scoliosis)
  - Pelvic balance
- Side:
  - Normal curvature /cervical lordosis /thoracic kyphosis /lumbar lordosis
  - Sagittal balance
  - Kyphosis
  - Hyper-lordosis (excessive lordotic curvature of spine), Possible causes
    1. FFD hips
    2. Spondylolisthesis

(Lumbar spine examination)

- Lumbar flat back: decreased lumbar lordosis causing spine and head to displace forward, Possible causes
    - Anterior wedge fractures
    - Degenerative disc disease
    - AS
    - Scoliosis surgery (use of distraction instrumentation such as Harrington rod)
- Back:
    - Birthmarks, Café au lait
    - Spina bifida occulta - Hairy patch, dimple
    - Scoliosis
    - Sprengel's deformity - can look like scoliosis

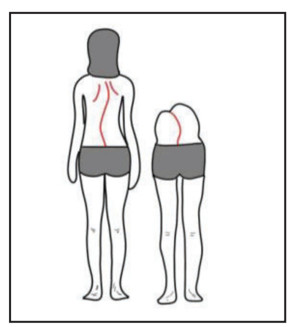
- Don't forget to look at hands and feet - for cavus & clawing
- Gait: Waddling widely spaced feet, unsteady, shuffling with increased stance. Can be due to proprioceptive neurological disorders (e.g. Myelopathy)
- Balance assessment
    1. Plumb line (coronal balance assessment)
        - Hang tape measure from C7 spinous process, should pass through centre of gluteal fold +/- 3cm of posterio-superior corner of S1

    Sagittal balance:
    - Positive - Anterior to sacrum, hip flexion contracture or flat-back
    - Negative - Posterior to sacrum, lumbar hyperlordosis



(Cervical spine examination)

2. Adam forwards bend test - forward bending reveals structural scoliosis with asymmetrical rib and scapula prominence - Bend down to level of patient when looking
    - In fixed rotational deformity - vertebral body rotates towards convexity
    - In Postural scoliosis (Due to other causes such as pelvic obliquity from LLD or nerve root pain) - will not demonstrate this prominence
    - Next sit the patient down - if scoliosis disappears → flexible deformity



Feel

- Spinous process – (any step) - Spondylolysthesis can have step off
- Para-spinal muscles
- SIJ tenderness in Ankylosing spondylitis

Move

- C-spine: Chin to chest (flexion), look at ceiling (Extension), touch ear to shoulder (lat flexion) Look at shoulder (rotation)
- L spine:
    - Flexion (Bend forward please)
    - Extension ('can you arch back' → Facet joints pain (Facet OA))
    - Lat bending (slide your hands down your thigh please)
- T spine: Rotation – Look for any restriction or pain
- Gross restriction of all movements in AS
- FABER test - for SIJ pain
- Prone
    - Ankle jerk (S1)
    - Femoral stretch test (L2, L3 nerve roots) - stabilize buttock, knee flexed to 90 deg
- Supine
    - Full sensory, motor ,tone and reflexes examination
    - SLR - most predictive physical finding for identifying appropriate candidate for surgery
    - Most sensitive test
    - It helps in drop foot to differentiate between central Vs Peroneal nerve pathology
    - Cross SLR - most specific test
    - Lasegue test
        - SLR until leg pain - lower leg to relieve discomfort - passively dorsiflex foot until pain reoccurs
        - If negative, pain induced by straight leg rising is probably due to hamstring tightness
- Mention that I would like to examine abdomen for AAA and test perianal sensation and anal tone and power

Cervical spine Examination

- Most common case in exam is Cervical Myelopathy. Other less common cases are Cervical Radiculopathy, Thoracic outlet Syndrome.
- Test – UMN: Tone, Reflexes, Clonus
- Tone
  - Muscle resistance to passive stretching
  - Helps to maintain posture
  - Make sure patient fully relaxed
- Clonus
  - Series of involuntary muscular contractions in response to passive stretching of muscle
  - Tested by rapid dorsiflexion of ankle resulting in rapid muscle contractures of
  - Gastrocnemius
  - >3 beats is pathological

(Clonus)

	UMN (myelopathy)	LMN (lumbar stenosis)
Tone	Increased	Decreased
Power	Decreased	Decreased
Reflexes	Increased	Decreased
Muscle bulk	Normal	Atrophy
Plantar Babinski reflex	Up going	Down going
Muscle fasciculation	Absent	Present
Clonus	Present	Absent

Cervical Myelopathy examination

- Look, feel, move and Special tests e.g. Spurling, Adson
- Waddling gait
- Special UMN tests
  1. Grip and release test - normally patient can make fist and release 20 times in 10 seconds - myelopathic patients may struggle to do this
  2. Hoffman reflex - reflex thumb and index flexion with sudden long finger distal phalanx flickering
  3. Romberg test - patient stands with arms held forward and eyes closed. Loss of balance consistent with posterior column dysfunction
  4. Finger to nose test for coordination
  5. Finger escape sign – ask patient to hold fingers extended and adducted. Small finger spontaneously abducts due to weakness of intrinsic muscle
  6. Inverted brachioradialis reflex
  7. Lhermitte sign - Neck flexion/extension produce burning electric shock in arms and legs – NOT ADVISED TO DO IN EXAM.

Neurological Assessment

- **Motor power(Myotomes)**
  - Palpate muscles when assessing power

Shoul. abduction	Deltoid	C5	
Elbow flexion	Biceps	C5	"bend your elbow and don't let me straighten it"
Wrist extension	ECRL	C6	"cock your wrist up"
W. rad.deviation	Brachioradialis	C6	
Elbow extension	Triceps	C7	"push me away"
Wrist flexion	FCR	C7	
Fingers flexion	FDS	C8	"hook my fingers and pull"
Fingers abduction	Interossei	T1	"keep your fingers apart"
Hip flexion	iliopsoas	L2	"lift your leg up"
Hip extension	Gl.Maximus	L2	
Hip adduction	adductors	L3	
Knee extension	quadriceps	L3	"don't let me bend your knee"
Foot dorsiflexion	Tib ant	L4	"lift your foot up towards you"
Foot inversion	Tib ant	L4	
Hip abduction	Gl. Medius	L5	
Big toe dorsiflexion	EHL	L5	"lift your toes up towards you"
Knee flexion	hamstrings	S1	
Foot plantar flexion	Gastro - soleus	S1	"push your foot against my hand"
Foot eversion	Peroneals	S1	
Big-toe plantarflexion	FHL	S2	
Bowel & bladder		S3 / S4	

  - **MRC grading of muscle power**

Grade 5	Muscle contracts normally against full resistance
Grade 4	Muscle strength is reduced but can move against some resistance
Grade 3	Muscle strength reduced and can be moved only against gravity
Grade 2	Muscle can move only if resistance of gravity is removed
Grade 1	Trace or flicker of movement or fasciculation but no joint movement
Grade 0	No movement observed, total paralysis

- **Sensation (Dermatomes):**
  - Close your eyes and tell me when you feel me touching you
  - Pain (paper clip), light touch of finger, vibration, two-point discrimination
    - Occiput (C2 / C3)
    - Back of neck (C4)
    - Deltoid region (C5)
    - Radial hand (volar distal phalanx of thumb) (C6)
    - Middle finger (C7)
    - Ulnar hand (C8)
    - Medial elbow (T1)
    - Axilla (T2)
    - Nipples (T4)
    - Xiphisternum (T8)

- Umbilicus (T10)
- Groin (L1)
- Anterior thigh (L2)
- Knee (L3)
- Medial malleolus (L4)
- Dorsum of foot & 1st web space (L5)
- Lateral foot & little toe (S1)
- Posterior medial thigh (S2)
- Ischia tuberosity (set on) (S3)
- Perianal (wipe of) (S4 / S5)

➢ **Reflexes**

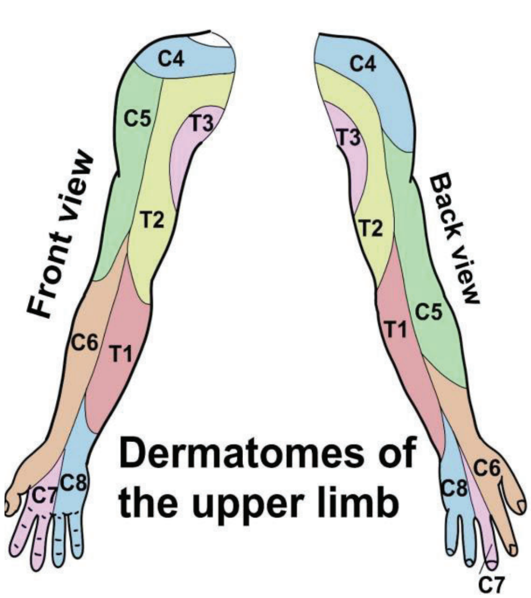
C5	Biceps	
C6	Brachioradialis	
C7	Triceps	
L1	Cremasteric	-Lightly stroke superior and medial part of thigh. -Normal response is contraction of cremaster muscle that pulls up testes on same side
L3	Patellar	
S1	Achilles	-Flex knee to elicit

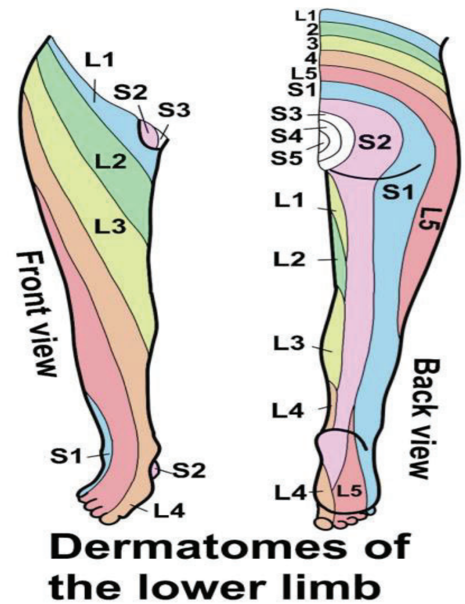
- Plantar (Babinski):
  - normal down
  - If extension of great toe on scraping sole of foot - UMNL
- Abdominal
  - Abnormal in spinal cord anomalies (syrinx)
  - Above umbilicus (T7 - T10)
  - Below umbilicus (T10- T12)

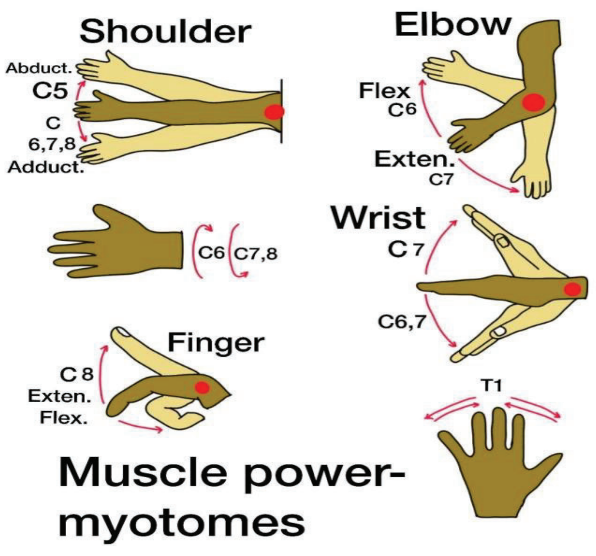
➢ **Position sense**

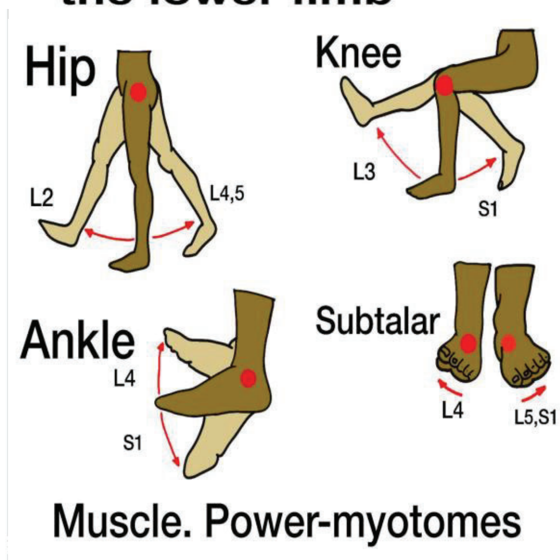
- Affected because of cord involvement
- Big toe flexion and extension at the IP
- Eyes open 1st to explain to patient

'I would like to do vascular examination'
'I would like to examine hips'- rotate the hips in extension


Front view
Back view
C4
C5
T3
T2
C6
T1
C7
C8
Dermatomes of the upper limb


L1
2
3
4
L5
S1
S2
S3
S4
S5
L2
L3
L4
L5
Front view
Back view
Dermatomes of the lower limb


Shoulder
Abduct.
C5
C
6,7,8
Adduct.
C6
C7,8
Finger
C 8
Exten.
Flex.
Elbow
Flex
C6
Exten.
C7
Wrist
C 7
C6,7
T1
Muscle power-myotomes


Hip
L2
L4,5
Knee
L3
S1
Ankle
L4
S1
Subtalar
L4
L5,S1
Muscle. Power-myotomes

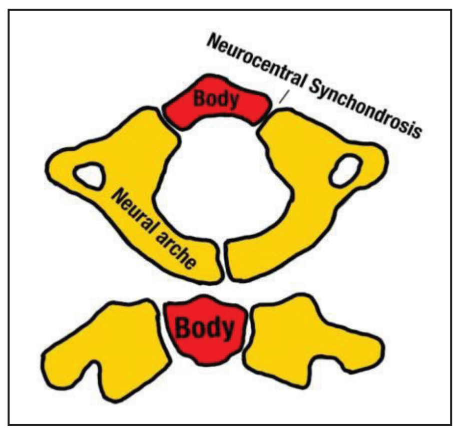
ANATOMY

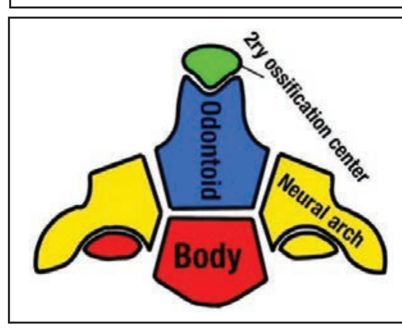
CNS
- Brain
- Spinal cord
  - Extends from brainstem to inferior border of L1 (L3 in newborn)
  - Conus medullaris: termination of spinal cord
  - Filum terminale: residual non-neural fibrous strand of spinal cord that extends from conus medullaris to coccyx
  - Thecal sac: dural sac that contains CSF, spinal cord, nerve roots & cauda equina

PNS
- 12 pairs of cranial nerves
- 31 pairs of spinal nerves - Sensory dorsal root, motor ventral root

Autonomic
- Sympathetic
  - 22 ganglia (3 cervical, 11 thoracic, 4 lumbar, 4 sacral)
  - Lies along lateral border of longus coli and psoas
  - Increase Blood pressure & Heart rate
- Parasympathetic
  - From cranial nerves III, VII, IX, X and S2-S4
  - Potentiate function of gastrointestinal tract

Cervical vertebrae
- **Occiput – C1**
  - Makes up 50% of neck flexion and extension
  - Ligamentum nuchae runs from occiput to C1
- **Atlas**
  - Lacks spinal process and vertebral body
  - Arches instead of body, pedicles and lamina
  - 3 ossification centres
    - one for vertebral body (anterior arch): appear at 1 year of age
    - One for each lateral mass: fuse to body at age 7
- **Atlas/Axis**
  - 50% of cervical rotation, pivot joint
  - Steel rule of thirds for spinal canal at this level: Cord – Dens – CSF
- **Axis**
  - Odontoid body fuses to arch at 3 – 6 years
  - Tip of dens ossifies at age 3 years and fuses to dens by age 12
  - Os odontoideum: Failure of fusion or Could be residual of old trauma)





- **C2 - C6**
  - Have bifid spinous process
  - Vertebral A - 1st branch of subclavian A
  - Ascends through foramina of transverse process C6 - C2

- Wind behind articular surface of atlas to enter skull via foramen magnum
- Spinal fractures (flexion injuries) can result in vertebral artery injury causing blindness

➢ **C7**
- Despite having transverse foramen, vertebral artery does NOT travel through it
- Sub-axial spine responsible for 70 % of lateral bending
- Cervical spine nerve roots exit above corresponding pedicle
- Lumbar spine nerve roots exit below corresponding pedicle
- 7th cervical transverse process points downwards
- 1st thoracic transverse process points upwards

➢ **Costal facets**
- Articulation between ribs and vertebral segments
- Present on all vertebral bodies and transverse processes from T1 to T9

➢ **Uncinate process**
- Lateral aspect of vertebral bodies of C3 – C7
- Articulates with disc & adjacent vertebra to form uncovertebral joint of Luschka
- Part of cervical motion segment
- Vertebral artery lies immediately lateral to it

➢ Segmental arteries
- Supply vertebral bodies and paraspinal muscles
- Between facet & transverse process

➢ **Intervertebral disc**
- What affect the disc:
  - Nutrition from vascular plexus in end-plate by diffusion
  - Smoking /DM lead to accelerated disc degeneration
  - Permeability decreased by vibration and increased by exercise
  - Intra-discal pressure is position dependent... Lowest in supine & Highest in sitting and leaning forward
  - With age
    - ✓ Decreased water, proteoglycan ,Chondroitin and Elastin
    - ✓ Increased collagen and Keratin
    - ✓ Lead to disc stiffness and less resistance to deformation
  - With OA: Increased water
- In children: blood vessels extend from cartilaginous end plate into nucleus
- In adults: blood vessels extend only to annulus (outer 1/3rd of disc)
- **Functions**
  - Allow spinal motion
  - Provide stability
  - Shock absorption
  - Nucleus distributes compression forces evenly
  - Responsible for 25% of spinal column height

➢ Sinu-vertebral nerve:
- From dorsal root ganglion
- Innervate structures within spinal canal and superficial fibres of annulus
- Neuropeptide molecules generated from annulus transmit neural stimulatus

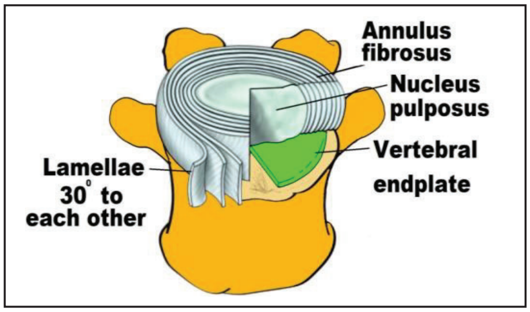
➢ End plate:
- Interface between vertebrae and discs

- Anchored to vertebra by Sharpey fibres
- Fibrocartilage in young and calcified cartilage in elderly

➢ **Spinal motion segment:** two vertebrae connected with facet joints and ligaments and disc in between

➢ **Viscoelastic**
- Creep - reduced height (deformity) with standing over time
- Hysteresis - Allows for energy absorption

Annulus	Nucleus
- Fibroblasts - type I collagen - Concentric sheets at 30 deg to each other - Connected to end-plate via Sharpey fibres - Responsible for Tensile strength - High collagen / low proteoglycan ratio - Attached to ALL & PLL	- Chondrocytes - type II collagen - High water content - Deform to spread & equalize forces - Responsible for Compression strength - Low collagen / high proteoglycan ratio



➢ **Pedicles**
- Transverse pedicle angle from 10° (mid thoracic spine) to 30° (L5)
- Sagittal pedicle angle - 15° cephalad for thoracic spine and 0° for lumbar
- C3-C6
  - Pedicles are small, making pedicle screw instrumentation difficult
  - Lateral mass screws placed at C3-C6 as alternative
- Thoracic T4 has narrowest and shortest pedicle (T4 – T6 are the smallest)

➢ **Erector spinae muscles**
- Extend trunk
- Located dorsal to vertebral column
- Innervated by dorsal rami of spinal nerves

Surface landmarks

➢ C1 →	Hard palate
➢ C2 →	Mandible
➢ C3 →	Hyoid
➢ C4 / 5 →	Thyroid cartilage
➢ C6 →	Cricoid cartilage
➢ C7 →	Largest spinous process
➢ T3 →	Scapular spine
➢ T4 →	Manubriosternal joint
➢ T7 →	Tips of scapulae
➢ L4 / 5	Highest point of iliac crest

SURGICAL APPROACHES

Transthoracic approach to thoracic spine

- **Indications**
    1. Fusion
    2. Decompression
    3. Discectomy
    4. Deformity correction
- **Position:**
    - lateral - break in table to open intercostal spaces
    - Upper thoracic spine (T2-9) - best approached from Rt side to avoid heart and aorta
    - Thoracolumbar spine (T10-L2) - best approached from Lt side to avoid liver retraction
    - In scoliosis - approach on side of convexity
    - Double lumen ET tube – for single lung ventilation
    - Skin incision over rib and curved distally to lateral border of Rectus abdominis
    - Dissection is intramuscular - splitting fibres of Latissimus dorsi and Serratus anterior
    - Divide Latissimus dorsi in the direction of the incision
    - Divide the Serratus anterior along the same line to the ribs
    - Enter chest via intercostal space or rib resection
    - Incise pleura to expose lung and diaphragm
    - Deflate lung - retract lung anteriorly
    - Incise pleura over lateral oesophagus to allow for retraction of oesophagus
    - Retract oesophagus anteriorly
    - Sweep peritoneum and ligate segmental vessels
- **Risks:** Intercostal vessels, lungs, oesophagus, Intercostal nerves (neuralgia), Artery of Adamkiewicz, Long thoracic nerve

Retroperitoneal (anterolateral) approach to lumbar spine

- Position patient at 45^{o} lateral position
- Performed from the left as aorta is more resistant to damage than inferior vena cava
- Incision parallel with lower rib
- External oblique, Internal oblique & Transverse Abdominis
- Between retroperitoneal fat and psoas fascia
    - L4: bifurcation of aorta
    - L4/5 disc space: mobilize aorta to contralateral side
    - L5/S1 disc space: work between bifurcation of aorta
- **Risks**:
    - Sympathetic chain, Segmental arteries, Aorta
    - Genito-femoral nerve (anterior surface of psoas muscle)
    - Ureter (lies between psoas fascia and peritoneum, attached more firmly to peritoneum)
    - Superior hypogastric plexus injury leads to retrograde ejaculation & sexual dysfunction

Anterior trans-peritoneal approach to lumbar spine

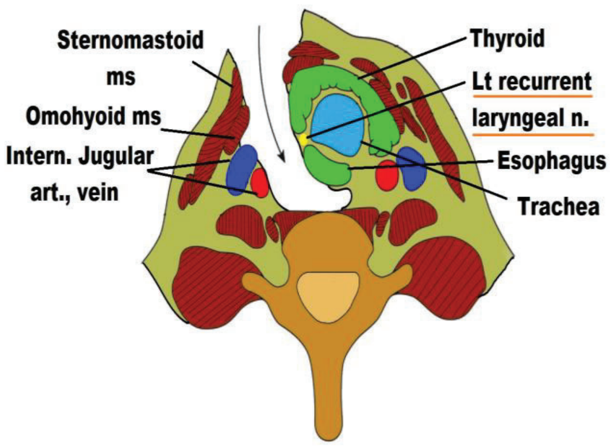
- Indications: L5-S1 spondylolisthesis
- Supine
- Midline incision or Pfannenstiel incision
- Through linea alba
- Split anterior and posterior peritoneum ,push visceral away
- **Risks**: median sacral artery (ligate) & Superior hypogastric plexus

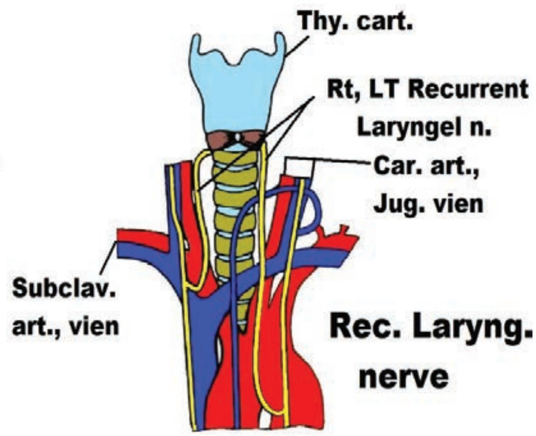
Anterior approach to cervical spine

- **Indications**
  - Anterior Cervical Discectomy and Fusion (ACDF)
  - C2 anterior screw osteosynthesis for odontoidfracture
- **Posterior triangle of neck**
  - Landmarks: Clavicle, sternocleidomastoid and trapezius
  - Contents: External jugular vein, 3 Scalenus muscles ,Spinal accessory N,Phrenic N Trunks of brachial plexus
- **Procedure**
  - GA with airway protection
  - Supine with head on horseshoe ring
  - Neck in slight extension with sandbag between shoulder blades (not in Myelopathy)
  - Turn head away from incision site
  - Cross-table lateral X-ray required for identifying correct level
  - Approach from right side as I am right handed (studies have shown no significant difference in rates of RLN injury with right or left sided approach)
  - Incision - Transverse skin crease at appropriate level/ Oblique if doing multilevel
  - Extend from midline to posterior border of SCM
- **Superficial Dissection**
  - Split Platysma in line with skin incision (supplied by cervical branch of facial N)
  - Ligate external jugular vein if in approach
  - Transect cervical facia anterior and parallel to SCM, between SCM (spinal accessory nerve) and strap muscles (segmental innervations from C1, C2, C3)
  - Incise pre-tracheal fascia anterior to SCM
  - Retract SCM lateral, retract strap muscles medially
  - Localize superior and inferior thyroid arteries and tie off if necessary
  - The carotid sheath is retracted laterally and trachea & oesophagus & medially
  - Contents of carotid sheath - Common carotid artery & IJV & Vagus N
- **Deep Dissection**
  - Incise Prevertebral fascia
  - Split longus colli muscles and anterior longitudinal ligament (segmental branches of cervical nerves)
  - Be aware of sympathetic chain that lies on longus colli lateral to vertebral body
  - Elevate longus colli muscles
  - C6 contains palpable carotid tubercle (valuable landmark)
- **Risks:**
  1. Recurrent laryngeal N injury → Temporary hoarseness of voice
     - Injury rate 2.3% (same injury rate for left RLN and right RLN)
     - RLN curves back between trachea & oesophagus. Safe as long as retractors placed underneath Longus colli

- Paralysis of one side of vocal cords → Loss of high pitched voice, hoarseness, airway problems & aspiration. If not improved over 6 weeks → ENT consult to scope patient and inject Teflon

RLN course: Right RLN curves underneath brachiocephalic artery, left RLN hooks under arch of aorta passing below ligamentum arteriosum





2. Thoracic duct on left side (approach from right)
3. Postoperative retropharyngeal hematoma - should be emergently decompressed
4. Sympathetic nerves and stellate (inferior) ganglion - Causes Horner's syndrome, avoided by sub-periosteal dissection of longus colli
5. Hypoglossal nerve injury
6. Upper cervical spine nerves
7. Oedema/perforation of oesophagus
8. Stroke - 1 %

Posterior approach to C-spine

- Sub-occipital triangle
- **Landmarks:**
  - Rectus capitis posterior (medially)
  - Obliquus capitis superior (laterally)
  - Obliquus capitis inferior (inferiorly)
- **Contents:** Vertebral artery (1.5 cm lateral to spinous process of C1), C1 nerve root
- **Procedure**
  - Prone
  - Midline incision
  - Between Paraspinal muscles (Semispinalis cervicis) - segmental supply from posterior rami
  - Stay within 1.5 cm from midline at occiput to avoid risking Vertebral A
- **Risks:**
  - High rate of wound infection and breakdown
  - Increased risk of cord injury compared to anterior approach

CERVICAL INJURIES

- More prone to injuries because - Flexible and Unprotected
- 10 % association with other spinal injuries
- Canadian C-spine study - NEXUS (National Emergency X-Radiography Utilization Study)
    - When to X-ray?
        - Age>65
        - Significant mechanism of injury
        - Presence of paraesthesia
    - When not to X-ray?
        - Absence of tenderness in posterior midline
        - Absence of neurological deficit
        - Normal level of alertness (GCS=15)
        - No evidence of intoxication
        - No distracting pain/injury elsewhere

(Cervical spine trauma for FRCS)

- Triple immobilization – Collar + Bolsters/head blocks + Spinal board (or tape)
- Patient should be removed from spinal board as early as possible and log rolled every 2 hrs to reduce risk of decubitus ulcers
- Delayed clearance associated with increased risk of aspiration inhibition of respiratory function decubitus ulcers in occipital & submandibular areas possible increase in intracranial pressure

C-spine clearance in trauma – BOA (2015)

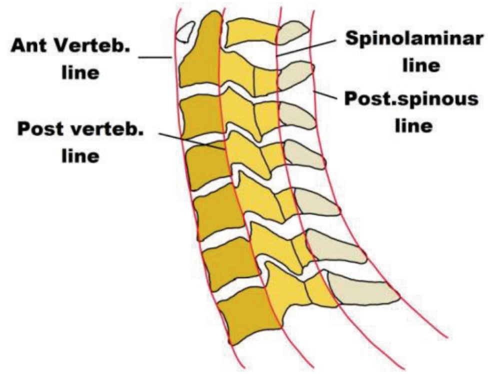
- Undertake neurological and clinical examination exam
- Protect the spine until undertaking clinical assessment or imaging.
- Get radiological clearance if unable to assess within 48h
- Thin slice (2-3mm) helical CT from base of skull to T1 with sagittal & coronal reconstruction
- Extending to T4/5 - overcomes difficulties of imaging upper thoracic spine
- Perform CT brain in all head-injured patients who have altered level of consciousness
- MRI for neurological injuries
- Radiological reporting by a senior radiologist is mandatory before the clearance.
- Remove immobilization while intubated, but re-apply before waking, and then clinically clear to exclude a ligamentous or cord injury ± MRI.

Manual in-line stabilisation (during airway intervention)

- Suspected spinal column injury (high-risk as indicated by Canadian C-spine rule)
- Low risk but unable to actively rotate neck 45o
- Reduced level of consciousness
- Spinal symptoms (paraesthesia, weakness, priapism)
- Pre-existent spinal pathology: osteoporosis, ankylosing spondylitis
- Use chin-lift manoeuvre, instead of jaw-thrust (prevent hyper-extension of neck)

Imaging

- Look at adequacy, vertebral alignment, odontoid and soft tissue
- Inadequate radiographs are the most common reason for missed injuries to C-spine
- 4 lines: without step-off and no mal-alignment
- Normal retropharyngeal space < ½ vertebral body at C1 – C3
  < Width of vertebral body C4-C7



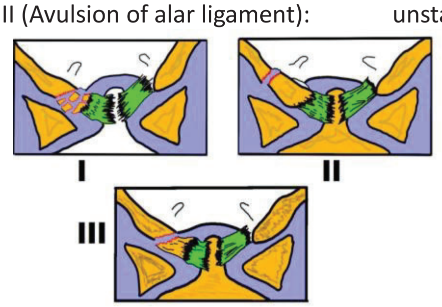
(C spine imaging)

National Spinal Cord Injury (SCI) Strategy Board guidelines (2012)

- **Transfer of trauma patients:**
  - If patient is unconscious or suspected of having unstable spinal injury and MTC (major trauma centre) within 45 minutes, transfer to MTC
  - If not, then patient taken to local trauma unit for resuscitation, primary survey with and initial trauma CT
  - If initial investigations show cervical spine dislocation, discuss with spinal cord injury unit and transfer immediately to MTC with spinal services support for immediate reduction within 4 hours
  - NICE Guidelines 2016 :transport them directly to MTC unless immediate life-saving intervention is required
- **Spinal shock**
  - Acute stage of SCI presents with flaccid paralysis and loss of reflexes below the level of injury
  - End of spinal shock marked by return of bulbospongiosus reflex
  - May last for several hours to weeks
- **Steroid use in SCI**
  - NASCIS I (1984), II (1990), III (1997) demonstrated no significant benefit of steroids but increased risk of complications
  - British association of SCI specialists do not recommend steroids in acute SCI

Occipito-cervical injuries

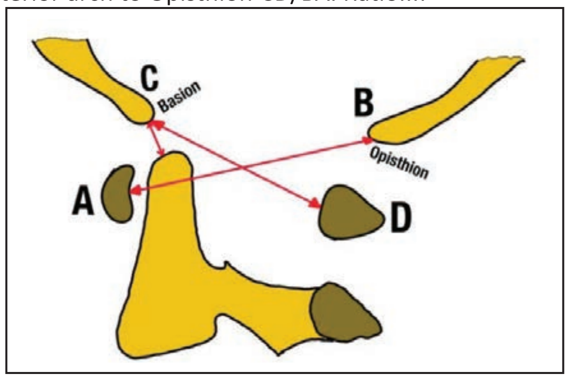
- **Occipital condyle fractures**
  - Diagnosis rarely made on radiographs due to superimposition of maxilla & occiput
  - **Anderson & Montesano classification**
    - Type I (compression): stable
    - Type II (direct blow): stable
    - Type III (Avulsion of alar ligament): unstable



  - Most common cranial nerves affected are IX, X and XI

- Treatment
    - Semi rigid or rigid collar for stable
    - Occipito-cervical fusion for unstable

➢ **Occipito-cervical dislocation**
- Most patients die of brainstem injury
- Can be acquired in Down syndrome
- **Power ratio**: distance from Basion to posterior arch/ anterior arch to Opisthion CD/BA. Ratio...:
    - 1 (normal)
    - > 1.0 (anterior dislocation)
    - < 1.0 (posterior Atlanto-Occipital dislocation)



- Treatment:
    - Stable - rigid collar
    - Unstable or associated with atlas/axis fracture – Occipito-cervical fusion
    - Safe zone for occipital screws
        - ✓ 2 cm lateral to external occipital protuberance along superior nuchal line
        - ✓ Dural venous sinuses located below external occipital protuberance

Atlas

➢ **C1 burst fracture (Jefferson fracture)**
- X rays:
    - Lateral mass overhang when fracture associated with transverse lig rupture
    - Combined lateral mass displacement > 7 mm or ADI > 3mm – fracture with transverse ligament rupture (unstable)
- MRI: to check integrity of transverse ligament
- Treatment -
    - Stable (intact transverse ligament) - Halo vest immobilisation for 6-12 weeks
    - Unstable
        - ✓ Posterior C1/C2 fusion or trans- articular screws
        - ✓ Occipito-cervical fusion when unable to obtain adequate purchase of C1

C2 fractures

➢ **Hangman fracture** - Traumatic spondylolisthesis of C2 on C3

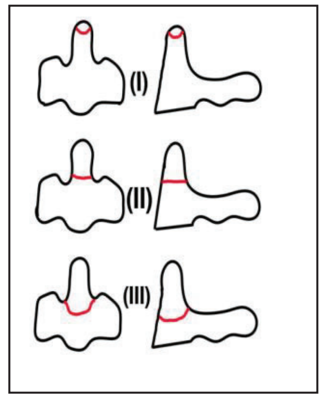
➢ From severe extension injury such as RTA or from hanging

➢ Look for tear drop fracture of inferior aspect of C2 or C3

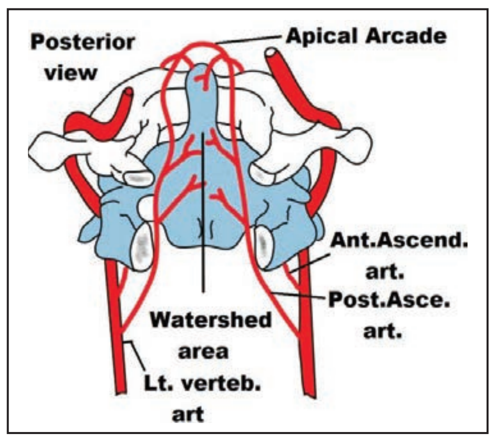
➢ **Levine & Edwards classification**
- < 3 mm horizontal displacement: Rigid cervical collar (stable)
- 3 – 5 mm displacement: Reduction and halo
- >5 mm or facet dislocation or >11^{o} angulation:
    - Posterior C1 – C3 fusion (unstable)
    - Bilateral C2 pars screw osteosynthesis

Odontoid fracture

- **Anderson & D'Alonzo Classification**
  - Type I
    - Avulsion fracture at tip of odontoid proximal to transverse ligament
    - Stable - external cervical orthosis (collar)
  - Type II
    - Fracture through waist of odontoid
    - Vascular watershed area
    - Lack of periosteum
    - High ratio of cortical to cancellous bone
    - Passes above horizontal line of upper border of superior articular facets of Axis
  - Type III
    - Fracture through cancellous body of C2 and involves C1-C2 joint
    - Stable - external cervical orthosis (Halo)
    - Instability if ADI > 4 mm
    - 10 % risk of non-union



- **Treatment:**
  - Stable (Undisplaced) External immobilization
    Old people (>80) don't tolerate halo
  - Unstable (Displaced) 35% risk of non-union



- **Risk factors for non-union**
  - > 5 mm displacement particularly posterior comminution
  - Age > 50
  - Delay in treatment >5 days
  - Angulation > 10 deg
  - Smoker
- **Approach** (based on orientation of fracture)
  1. Anterior odontoid screw
     - Higher failure rate than fusion
     - Not good in osteoporosis
     - Retain rotational movements
     - In oblique fracture pattern where screw trajectory is perpendicular
  2. Posterior C1-C2 trans-articular screws fixation
     - Contraindicated in patients with aberrant vertebral artery
     - C1-C2 fusion will lead to 50% loss of neck motion
  3. C1 lateral mass screw and C2 pedicle screw construct
  4. Trans-oral odontoidectomy
     Severe posterior displacement with spinal cord compression & neurological deficit
  5. Collar and counsel patient and family

- In elderly: High morbidity & mortality from operative treatment outweigh risk non-union
- Non-union can lead to catastrophic displacement with subsequent fall, late myelopathy
- Lateral mass fractures:
    - Hyperextension, lateral compression and rotation of cervical spine
    - Neurologic symptoms common (up to 65 %)
    - Torticollis, paravertebral muscle spasm
- CT - uncovertebral joint subluxation
- Unstable injury - requires surgery with posterior / anterior fusion
- **Cochrane Systematic review (2008)** – no difference in surgical or conservative management with Halo for odontoid type II fractures

Sub-axial fractures

- Flexion teardrop
    - Results from dive in shallow water
    - Fracture of anterior inferior portion of vertebra
    - Posterior portion of vertebra retropulsed posteriorly
    - Often associated with posterior ligamentous injury and anterior cord syndrome
    - Common in C4-C7
- Hyperextension teardrop
    - Avulsion fracture
    - Small fleck of bone avulsed of anterior endplate
    - Height of fragment bigger than width
    - ALL avulsion fracture
    - Common at C2
    - Stable injury pattern
    - Treatment:
        - Stable: Rigid collar / Halo
        - Unstable:
            - ✓ Anterior decompression & fusion with instrumentation
            - ✓ Posterior fusion with instrumentation when anterior decompression not required
- Clay shoveler’s fracture
    - Abrupt flexion injury
    - Fracture of base of spinous process

Subaxial Cervical Spine Spine SLIC Score

Morphology	
• No abnormality	- **0**
• Compression	- **1**
• Burst	- **2**
• Distraction	- **3**
• Rotation/translation/dislocation	- **4**
Disco-ligamentous complex	
• Intact	- **0**
• Indeterminate (inter-spinous widening or MRI hyper-intensity)	- **1**
• Disrupted (widened disc space, Facet perch/dislocation, kyphosis)	- **2**
Neurological status	
• Intact	- **0**
• Root injury	- **1**
• Complete cord injury	- **2**
• Incomplete cord injury	- **3**

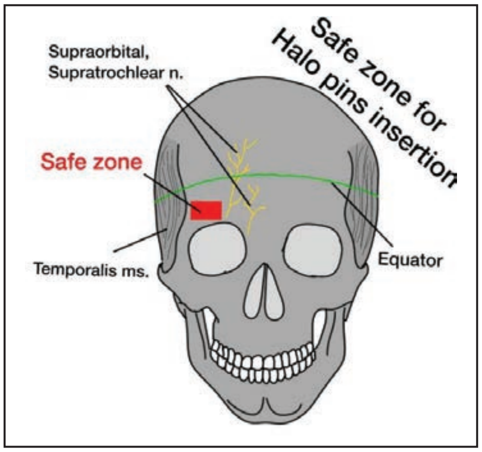
- **Vaccaro et al. Spine (2007)** gave SLIC score and recommended $\geq$ 5 – operative intervention

Non-operative stabilisation techniques

- Miami J collar: Padded, reduce skin complications (Controls flexion/extension & rotation)
- Halo vest: Fixes skull to torso
- Children <2 yrs: use Minerva cast - applied to trunk and head, Spaces cut out for face and ears
- CT prior to halo application if:
  - Clinical suspicion for cranial fracture
  - Children < 10 years to determine thickness of bone

- **Indications**
  - Occipital condyles fracture
  - Upper cervical spine fractures
  - Instability due to infection or tumour
  - Persistent atlanto-axial rotatory subluxation
- **Contraindications**
  - Skull fractures
  - Chest trauma
  - Age > 80
  - Infection
- **Application**
  - LA
  - 1 person to maintain alignment and 2 to apply
  - Choose appropriate ring (incomplete so head can rest on pillow) and vest size (measure chest)
  - 4 pins in adult and 6 -8 in children (reduced pull-out strength)
  - MRI compatible pins
    - Anterior pins: 1cm above, lateral 2/3 of eye brows
      - ✓ Lateral to frontal sinus & Supratrochlear N and Supraorbital N
      - ✓ Medial to Temporalis muscle to avoid pain during mastication & speaking

- ✓ Insert with patient eyes closed to prevent tenodesis of orbicularis oculi
- Posterior pins - 1 cm above upper tip of ear
  - ✓ 1 cm gap between Halo & skull
- ✓ Tighten with torque limiting screw driver



- **Complications**
  1. Loosening of pins - most common → Tighten or exchange
  2. Infection - can cause loosening
  3. Supraorbital & Supratrochlear N palsy:
     - Injury to supraorbital nerve leads to pain & numbness over medial third of eyebrow
  4. Abducens nerve palsy:
     - Most commonly injured nerve with halo
     - Traction injury to cranial nerve VI
     - Diplopia - loss of lateral gaze on affected side (Observation, resolve spontaneously)
  5. Dysphagia
  6. Dural puncture

Cervical dislocation


(Courtesy of L Prakash)

- <25% displacement:
  - Unilateral facet dislocation
  - Spinous process points towards involved side
  - Radiculopathy
- >25% displacement:
  - Bilateral facet dislocation
  - Spinal cord compression
  - Facet fractures - More frequently involve superior facet

- Caused by flexion-distraction injury
- MRI to exclude disc prolapse or tethered cord, or unable to assess secondary to unconscious, non-cooperative patients or any worsening neurology during or after reduction
- Closed reduction prior to obtaining MRI only in a patient who is awake, cooperative and neurologically intact

- **Closed reduction in awake patients**:
  - Supine: reverse Trendelenburg
  - Apply Gardner-Wells tongs to skull and add sequential weights Or halo traction
  - Check with image intensifier after each additional load
  - Pin placement: 1 cm above pinna, in line with external auditory meatus and below equator of skull

- Too anterior
    - Temporalis muscles & superficial temporal Ar & Vein at risk
    - Anterior pin will apply extension moment to cervical spine
- Too posterior: can apply a flexion moment to cervical spine
- Initial 5 Kg applied with 2 Kg added sequentially for each level every 10 min
- Once unlocked – reduce
- Abort if neurology worsens or patient becomes unconscious/ noncooperative

➢ **Open reduction under GA - ACDF**
- All facet dislocations need to be stabilized surgically following reduction
- No disc prolapse - posterior fusion as damage is mainly to posterior structures
- Disc prolapse - combined anterior and posterior

➢ **Fehlings et al (2012) - STASCIS** (Surgical Treatment of Spinal Cord Injury Study) in 2012 showed 19.8% of patients who received decompressive surgery within 24 hours experienced 2-grade or greater improvement on ASIA scale, compared with 8.8% of those in delayed-treatment group

Cervical pseudosubluxation

➢ Normal anterior displacement of C2 on C3 (sometimes C3 on C4) in children under 8 years Due to the increased mobility of the vertebral bodies in children, and horizontal facet joints

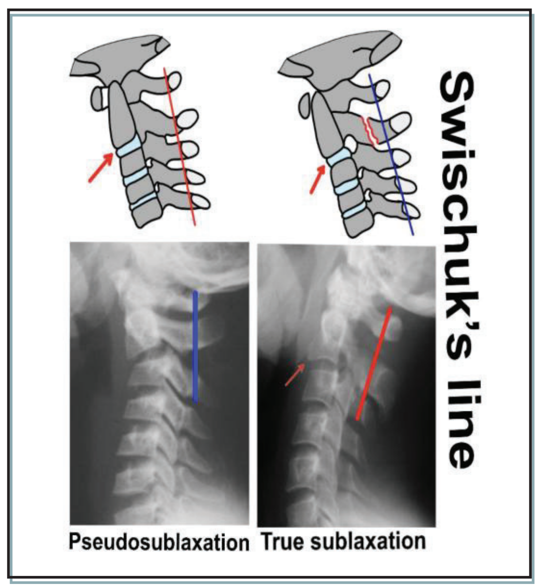
➢ Not to be confused with a true subluxation

➢ It is seen with the cervical spine flexed - should disappear with the spine extended

➢ Pseudosubluxation rarely involve displacement of more than 4 mm

➢ The Swischuk's Line (posterior cervical line)
- Connecting the spinolaminar lines of C1 and C3.
- Should normally pass within 2 mm of the Spinolaminar line of C2
- > 2 mm anterior to the posterior cervical line → True subluxation

➢ Factors that suggests Pseudosubluxation Vs traumatic subluxation
1. Reduction with neck extension
2. Spinolaminar line within 2mm of C2 spinolaminar point
3. No history or physical findings of significant trauma
4. Absence of anterior soft-tissue swelling



Paediatric spine injuries

- 83% involve the cervical spine
- More common in <8 years - large head-to-body ratio.
  - Thoracolumbar more common >8 years
- Cervical spine injury
  - Occipito-atlantal, Atlantoaxial dislocation, Atlantoaxial rotatory injuries
  - Odontoid fracture, sub-axial ligamentous injuries
  - Spinal cord injury without radiographic abnormality (SCIWORA)
- Thoracolumbar spine
  - Compression fracture (most common), Burst fracture
  - Flexion-distraction injury, Combined fracture-dislocation
- Associated injuries: Head (>30%) / Intra-thoracic / Intra-abdominal injuries

Spinal cord monitoring

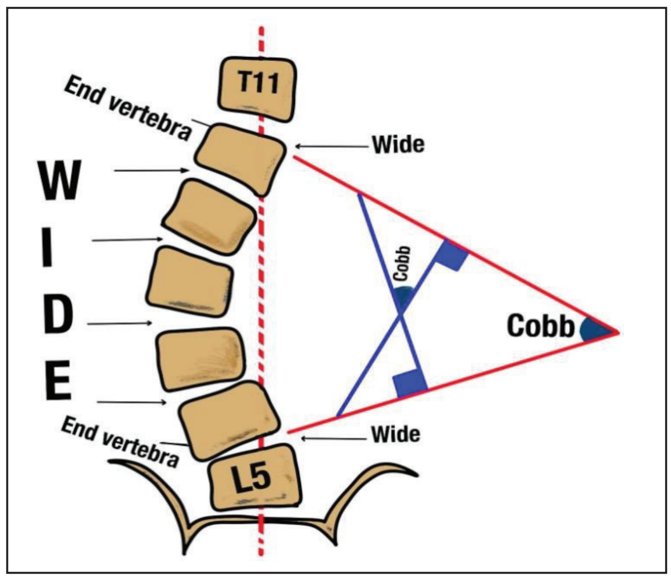
- To detect injury to spinal cord during operative procedures
  - Somato-Sensory Evoked Potentials **SSEP**
    - Dorsal column sensory pathway
    - Stimulation of posterior tibial nerve or ulnar nerve
    - Transcranial recording
  - Motor Evoked Potential **MEP**
    - Lateral and ventral corticospinal tracts
    - Transcranial stimulation of motor cortex
    - Muscle contraction in extremity decreased with injury (direct or vascular)
  - Mechanical Electromyography **EMG**
    - Monitoring of specific nerve roots
    - Stimulation of pedicle screw which breached pedicle
    - Will lead to activity of nerve root and muscle contraction

Whiplash injury

- Neck injury (sprain) caused by cervical acceleration–deceleration in any direction
- Symptoms associated with worse outcome
  1. Rapid onset of pain
  2. Sever neck pain
  3. Acute hospital admission
  4. Radiation of pain to upper limb
  5. Headache
- Gargane & Bannister classification
  - Grade A: No symptoms
  - Grade B: Symptoms not interfering with occupation/leisure
  - Grade C: Symptoms requiring intermittent analgesia/physio
  - Grade D: Disabling symptoms

SCOLIOSIS

- **History**
  - Age of onset, how was it diagnosed or who noticed first – patient or parents?
  - Rate of progression, growth spurt and menstrual History
  - Pain - Costo-pelvic impingement
  - Neurological symptoms
  - Cardiorespiratory symptoms
  - ADL, treatment received so far, family history
- **Examination**
  - Look
    - Orthosis, Café-au-lait spots, Axillary freckling, and Cavus feet
    - Dysraphism, Coronal balance - Plumb line
    - Waist line asymmetry Scapular /rib prominence (don't say hump)
  - Move: ROM
  - Special Tests: Adam forward bending...
    - Sit the patient - if deformity corrects – secondary to pelvis (Compensatory)
  - Neurology: abdominal reflexes → Syrinx
  - Examine lower limbs for LLD



- **Definition**
  - 3D curvature deformity of spine coronal, sagittal, axial
  - Cobb angle of > 10 degree
  - Structural (fixed) or Postural (flexible)
  - Can present in adolescent or adult
- **Incidence:** 1:1000 & Female 2:1 male

Types

Congenital

- Failure of normal vertebral development during 4th to 6th week of gestation
  - **A** Failure of formation: hemi-vertebra, wedge vertebra
  - **B** Failure of segmentation: vertical bar, block vertebra
  - **C** Combination: Worst prognosis
- Associations - VACTERL, Klippel – Feil syndrome, Spinal dysraphism
- Should obtain -
  - MRI to evaluate for neural axis abnormality
  - Echocardiogram for cardiac defects
  - Renal U/S for urogenital anomalies

(Courtesy of M Elgendy)

- **Treatment**
  - Observe:
    - Brace not effective (not to correct but to stop progression)
    - Block vertebra progression (1^{o}/year)
    - Hemi-vertebra progression (2^{o}/year)
    - Bar (8^{o}/year)
  - Fusion +/- Vertebrectomy if progressive
  - Growing rod

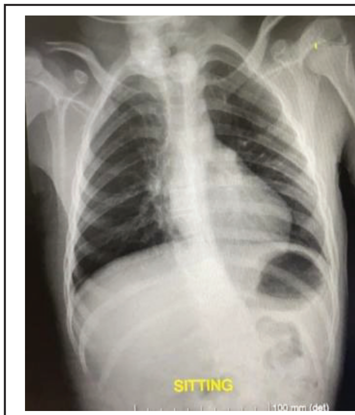
Idiopathic

- Most common
- Larger curves, apex normally below T8
- Positive family history
  - Infantile
    - May affect growth of alveoli and normal development of thoracic cage
    - Can also be described as early onset
    - Left thoracic curve
    - Resolves spontaneously
    - More common in boys
    - Pulmonary alveolar development complete at 8 years
    - MRI to rule out spinal anomalies and exclude syrinx
  - Juvenile
    - 3 -10 years
    - More common Right-sided thoracic spine
    - Highest risk of progression
    - High incidence of neural axis abnormalities → MRI
  - Adolescent
    - More common Right sided thoracic spine
    - Left thoracic curves are rare and indicate an MRI
    - Bracing is contraindicated in curves >45o
    - Progressive – growing rod
    - Follow up until skeletally mature

(Courtesy of M Algendy)

Neuromuscular (paralytic)

- Progress more rapidly
- Does not cease at skeletal maturity
- Complications:
  - Respiratory
  - Sitting imbalance, difficulty swallowing
  - Associated with pelvic obliquity
  - Longer left thoracic curve
- Causes:
  - UMN: CP, Syringomyelia, Spina Bifida, Cord tumour
  - LMN: Polio, HSMN
  - Muscular: Duchene muscular dystrophy



(Courtesy of M Elgendy)

- Brace contraindicated
- Perform surgery before pulmonary function decline occurs
- Neurofibromatosis → painful
- Treatment:
  - Aim to improve quality of life, maintain function & prevent complications
  - Boston brace until puberty (for deformity with Cobb's angle 25-45^{o}) - not always effective
  - Spinal fusion is the only treatment that has beneficial impact on deformity with
  - Cobb's angle >45^{o}
  - Concomitant anterior spinal fusion is indicated in larger curves >75 ^{o} and in young age (with Risser grade 0) to prevent crankshaft phenomenon.

Degenerative

- Asymmetric degeneration of disc space and facet joints
- More common in lumbar spine

Pathologic

- Osteoid osteoma apex of concavity
- Osteoblastoma affects body and/or posterior elements
- Scoliosis develop in response to painful paraspinal muscle spasms
- Most common cause of painful Scoliosis in adolescent
- Other causes of pain in scoliosis: Spondylolisthesis & Prolapsed disc
- **Treatment**:
  - Conservative management with NSAIDs – osteoid osteoma may take up to 36 months to resolve, Osteoblastoma usually not affected by NSAIDs
  - Radiofrequency ablation
  - Resection leads to resolution of curve if removed within 15-18 months of onset and child < 11years of age.

Classification of scoliosis

- Fixed or flexible
- Balanced or unbalanced (depending on the plumb-line passing through the gluteal fold or away from it)

King Moe classification

- I: Double major - Thoracic and lumbar (Lumbar has higher magnitude)
- II: Double major (thoracic dominant)
- III: Single thoracic prominence of ribs and elevation of shoulder
- IV: Long thoracic prominence of ribs and elevation of shoulder (L4 tilted into curve)
- V: Double Thoracic

Lenke classification

- **Structural curve**
  - 1-Main thoracic (MT)
  - 2-Double thoracic (DT)
  - 3-Double major (DM)
  - 4-Triple major (TM)
  - 5-Thoracolumbar/lumbar (TL/L)
  - 6-Thoracolumbar-main thoracic (TL/L-MT)
- **Lumbar spine modifier (CSVL)**
  - A – CSVL between pedicles
  - B – CSVL touches apical body
  - C – CSVL completely medial or away from apical vertebra
- **Sagittal modifier**
  - Hypo (-) <10^o
  - Normal (N)
  - Hyper (+) >10^o

Imaging

- **X-rays** (Scoliogram) whole spine to lumbosacral junction → Mirror image
  - Standing – AP, lateral and bending (to check if structural)
  - AP for degree of coronal deformity (Cobb's angle)
  - Lateral to look for Spondylolysthesis & kyphosis.
  - Check for primary and compensatory curve (no need to fix)
  - Pelvic x-ray to assess maturity using Risser staging and Triradiate cartilage
- British Scoliosis society suggests using rare-earth screen (X-ray intensifier made of rare-earth elements, such as yttrium & gadolinium), enabling lower radiation doses to be used while producing acceptable film
- Minimise X-ray exposure to immature skeleton & developing breast bud
- **Indications for MRI**
  1. Abnormal neurology
  2. Left sided curves
  3. Juvenile onset
  4. Rapid progression
  5. Painful deformity
  6. Preoperative planning

Definitions

- **Apex:** most displaced vertebra from the midline
- **End vertebra** is the last one that converge (last tilted into cavity), the one next to it will divert
- **Stable vertebra** most closely bisected by central sacral vertebral line
- **Neutral vertebra** last rotated (spinous process equidistant from pedicles)
- **Cobb angle** between intersecting lines perpendicular to top end-plate of superior end vertebra & bottom end-plate of inferior end vertebra

- **Rib vertebrae angle Difference (RVAD, Mehta angle)**
  - Angle between centre of endplate of apical vertebra and rib, compare both sides, Measure of rotation, Useful only in infantile group,
    - < 20 deg → spontaneous recovery
    - > 20 deg → high rate of progression
- **Plumb line:**
  - Assess vertebral alignment and balance on radiographs, draw a Line from C7 parallel to lateral edges of radiograph
    - Abnormal if >2 cm away
    - Coronal - distance from central sacral line
    - Sagittal - distance from postero-superior aspect of S1

Treatment

- **Indications**
  1. Aim to prevent/reduce progression
  2. Allow spinal growth
  3. Deformity which is significant and progressive, or anticipated to progress (immature patient)
  4. Progression at rate of 5° in 6 months. Most likely to progress:
     - Female sex
     - Skeletally immature - Risser < 2 - Risk 50%, after Risser 2 <20%
     - Peak growth velocity - best predictor of curve progression
     - Sexually immature (premenarche), significant apical rotation
     - Curves with predictable history (congenital or neuromuscular)
  5. Other indications
     - Radicular pain or neurological deficit
     - Cardiopulmonary decline
- Sagittal plane balance is the most reliable predictor of clinical symptoms postoperatively
- **Treatment**
  - Observe Cobb angle < 25° 6 monthly radiographs until skeletally mature
  - Brace Cob angle > 25° but <45°:
    - To slow progression and not to correct
    - Apex above T7 and double thoracic curves → CTLSO (Milwaukee brace)
    - Below T7 → TLSO (Boston brace)
    - To be worn 16-23h/day until skeletal growth completed or surgery indicated
  - Fusion Cobb >45° / painful / progressive in immature patients
    - Extend to end-vertebra above & below curve
    - Posterior for thoracic and double curves
    - Anterior for thoraco-lumbar and lumbar
    - Combined larges curves (> 75°) / stiff curves / Young age to prevent Crankshaft phenomenon
  - Growing rods
    - For children with significant growth remaining
    - Control deformity during spinal growth and delay arthrodesis
    - Need to be lengthened regularly as the child grows (every 6 months)
    - Can be magnetic to avoid surgery
    - Protect with brace throughout
    - Can be magnetically controlled through the skin

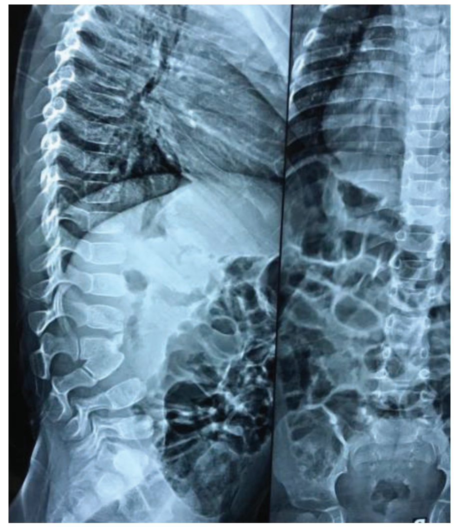
- **Complications of surgery**
  1. Cast syndrome (Superior Mesenteric artery Syndrome)
     - Following correction of scoliosis
     - Narrowed angle between aorta & SMA – compression on 3rd part of duodenum
     - Present as bowel obstruction
  2. Pseudoarthrosis (commonest complication)
     - Can lead to recurrence
     - Increased incidence when fusion ends at S1
  3. Infection: Propionibacterium acnes most common organism for delayed infection 2 weeks for culture
  4. Flat back syndrome
     - Increased risk using pedicle screws at all levels vs. selective (Segmental) placement
  5. Crankshaft phenomenon:
     - Rotational deformity created by continued anterior spinal growth in young patients who have underwent posterior spinal fusion
  6. Short stature
  7. Neurological injury : from over distraction or over correction
  8. Back pain, more likely with fusion below ending at L3-L5
  9. Metalwork failure, suggest failure of fixation
  10. Impaired pulmonary function and growth in growing child

(Courtesy of M Elgendy)

KYPHOSIS

- Excessive curvature of spine in Sagittal (Lateral) plane in excess of 50^{o} (Normal T5-T12 kyphosis is 20-50^{o})

- **Aetiology**
    1. Postural
    2. Compensatory - FFD of hip
    3. Degenerative spondylolisthesis
    4. Inflammatory - AS
    5. Post-traumatic
    6. Congenital
    7. Idiopathic – Scheurmann



(Courtesy of M Elgendy)

Congenotal kyphosis - Failure of segmentation

- Scheurmann disease: 3 adjacent vertebrae wedged by 5^{o} each
    - More common in males
    - Painful
    - Rigid - unlike postural kyphosis - does not correct with hyperextension
- Schmorl's nodes - herniation of disc into vertebral endplate

- **Treatment**
    - <50 deg: Observe
    - 50 – 80 deg: Brace with extension orthosis until maturity
    - > 80 deg: PSF with dual rod instrumentation +/- anterior release and interbody fusion
- Goals of surgery:
    - To restore spinal balance
    - Relieve pain
    - Obtain solid fusion
- Osteotomies gain 5-10^{o} correction per level
- Fusion with Intra-op neuromonitoring
- Most common major complication is instrumentation failure
- Pseudoarthrosis:
    - Thoracolumbar junction
    - Risk factors: Posterior only fusion & Age >55 & Smoking

SPINAL DYSRAPHISM

Spina bifida

- Also called Myelodysplasia or Spinal Dysraphism
- **Risk factors**
    - Folate deficiency
    - Maternal diabetes
    - 8 out of 10 have Latex allergy
- **Classification**
    - Spina Bifida Occulta - Defect in vertebral arch with confined cord and meninges
    - Meningocele - Protruding sac without neural elements
    - Myelomeningocele - Protruding sac with neural elements
    - Rachischisis - Neural elements exposed with no covering
- Elevated maternal and amniotic fluid - Alpha Feto Protein AFP
- Antenatal 18 weeks - US
- Can be associated with hydrocephalus / Arnold-Chiari / Syringomyelia
- **Treatment**
    - Multi-disciplinary approach
    - Neurosurgeon closes defect
    - Urology
    - Knee
        - Flexion contracture - hamstring lengthening
        - Extension contracture - serial casting
        - Weak quadriceps - KAFO
    - Hip
        - Dislocation
        - Most common L3 level is involved - due to unopposed hip flexion & adduction
        - Observation, High failure rate after reduction
        - Abduction contracture - division of Fascia lata
        - Flexion contracture - Iliopsoas tenotomy
    - Spine
        - Kyphosis
        - Gibbus deformity may cause skin breakdown due to pressure points when sitting - Kyphectomy with fusion and posterior instrumentation
        - Scoliosis - Due to asymmetrical paralysis of spinal and abdominal muscles and fixed pelvic obliquity
        - Thoracic levels defects - 100% Scoliosis rate
        - Rapidly progressing deformities - Consider cord tethering
        - Bracing not effective
        - ASF and PSF with pelvic fixation
        - Anterior fusion required due to dysplastic posterior elements that may impair posterior fusion

Diastematomyelia

- Fibrous, cartilaginous or osseous bar creating longitudinal cleft in spinal cord
- Can cause congenital scoliosis
- **Examination**
    - Look for spinal cutaneous manifestations
        - Hairy patch
        - Dimple
        - Subcutaneous mass near the gluteal cleft
    - Look for lower extremity deformities
        - Cavus foot
        - Claw toes
        - Club foot
- **Investigations**
    - X-ray: inter-pedicular widening
    - CT
    - Myelography for fibrous and cartilaginous
- **Treatment**
    - Non-operative if asymptomatic and does not have neurologic sequelae
    - Operative Surgical resection
        - If patient is symptomatic or has neurologic deficits
        - Must resect diastematomyelia before correction of spine deformity
        - Resect and repair duplicated dural sac

SPINAL CORD TUMOURS

- **Intra-dural intramedullary**
  - Can be benign or malignant
  - Ependymoma (most common)
  - Astrocytoma most common in children, typically at Cervico-thoracic junction
  - Total Resection
- **Intra-dural extramedullary**
  - Back pain, worse at night
  - Schwannoma Arise from dorsal nerve root
  - Meningioma Dural based lesion
  - Neurofibromatosis type 2
  - Usually benign
  - Compress neural structures radicular pain
  - Surgical resection and post op radiotherapy (for malignant)
- **Extradural**
  - Mets from brain, thyroid, lung, breast, kidney, prostate
  - Lymphoma
  - Multiple myeloma

Metastatic Spinal Cord Compression (NICE guidelines 2008)

1. Contact MSCC coordinator urgently within 24 hours for patients with cancer having any symptoms of:
   - Cervico-thoracic pain
   - Progressive lumbar pain
   - Severe unremitting back pain – non-mechanical (pain at rest, night time pain preventing sleep)
   - Pain aggravated by straining
   - Localised spinal tenderness
   - Arrange for MRI within 1 week
2. Contact MSCC coordinator immediately if symptoms of neurological deficit, spinal cord compression or cauda equina syndrome
   - Arrange MRI within 24 hours
3. Nurse flat with neutral spine alignment until stability ensured

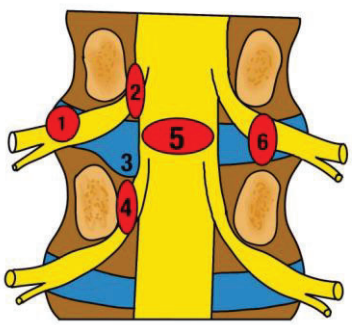
Principles of management of MSCC

- **MDT management** – oncologist, interventional radiologist, spinal surgeon
- **Analgesia** WHO three-step pain ladder (NSAIDs, non-opiates, opiate medication)
- Referral for epidural or intra-thecal analgesia
- **Bisphosphonates**
  - Offer in patients with myeloma or breast cancer – to reduce pain and risk of vertebral fracture /collapse
  - Offer patients with vertebral metastases from prostate cancer only if conventional analgesia fails to control symptoms
- **Radiotherapy**
  - Offer patients with non-mechanical pain 8Gy single fraction palliative radiotherapy even if completely paralysed
  - Patients with asymptomatic spinal metastases should not be offered radiotherapy

- **Surgery**
  - Consider Vertebroplasty or Kyphoplasty if vertebral metastases with no MSCC or spinal instability (if survival < 1 year)
  - Urgently consider spine stabilisation if imaging evidence of structural spinal instability present (Tokuhashi and Spinal Instability Neoplastic Score classification)
  - If unsuitable for surgery, consider external spinal support (CTLSO)
  - Consider major surgical treatment only if expected to survive > 3 months
  - Patients with complete paraplegia or tetraplegia for > 24 hours should only be offered surgery if required for pain relief
  - Consider en-bloc curative resection if confirmed solitary renal or thyroid metastasis
  - Pre-op radiotherapy should not be carried out if surgery is planned, postop radiotherapy should be offered routinely after wound has healed (can be offered earlier if minimally invasive stabilisation MIS performed)
- **NICE guidelines 2008**
  - Recommend loading dose of 16mg Dexamethasone as soon as possible after assessment, followed by short course of 16mg daily
  - Dose should be reduced gradually over 5-7 days and stopped (Cover with PPI and monitor blood glucose)

DISC HERNIATION

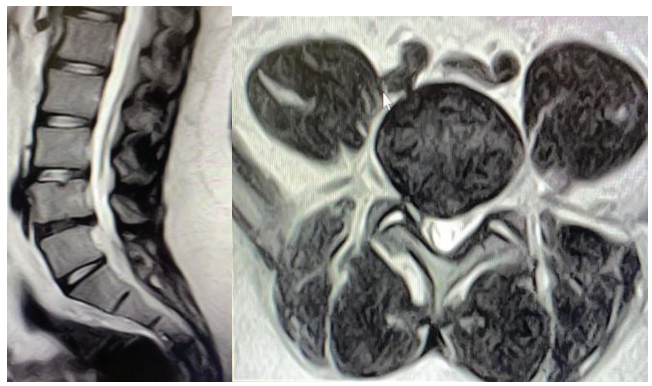
- **History**
  - Back pain, Radicular pain worse on coughing and sneezing
  - Paraesthesia
  - Red-flags in history:
  - Rule out
    - Trauma: significant trauma or apparently benign sounding trauma with pre-existing spinal conditions like Ankylosing spondylitis, osteoporosis
    - Infection: history of steroid intake, cancer, immunodeficiency, IV drug abuse, fever, chills
    - Neoplasia: night pain, thoracic pain, unexplained weight loss.
  - Recent bladder dysfunction or bowel incontinence
- **Examination**
  - Look for any deformity, gait assessment
  - Red-flags in examination: Saddle anaesthesia, widespread neurological symptoms
- **Tests**
  - SLR
  - Cross-over SLR
  - Femoral stretch
- Genetic predisposition
- L4/L5 - most common level
  - Central disc affect traversing nerve
  - Lateral disc affect exiting nerve



Types of disc herniation
1- Far lateral type
2-superior migration (Paracentral)
3-Paracentral
4-Inferior migration (Paracentral)
5- Central type
6- Foraminal type

  - **Protrusion:** Bulging nucleus pulposus (NP) and intact annulus fibrosus (AF)
  - **Extrusion:** Burst through AF and contained by PLL
  - **Sequestration:** Fragment detached and free in spinal canal
- Discogram: Normal discs don't cause pain when stimulated

- MRI with gadolinium distinguish between...
  - Post-surgical fibrosis (enhances with gadolinium)
  - Recurrent herniated disc (does not enhance with gadolinium)



(Courtesy of M Elgendy)

Treatment

- Rest: Physiotherapy, Analgesia - 80 % better in 8 weeks with non-operative care
- Sequestered hernia - Greatest spontaneous resorption via macrophage phagocytosis
- Selective nerve root corticosteroids injection
- Laminotomy and discectomy

  Indications -
  - Cauda equina Syndrome:
    - Progressive neurology
    - Intolerable pain lasting > 3 months
    - Painful foot drop (painless means nerve dead)
  - If cause is facet cyst
    - Excise (facetectomy) and fusion as primary pathology is facet joint OA
    - Most common at L4/L5, L5/S1 level

JAMA – 2006 Spine Patient Outcomes Research Trial (SPORT) – Observational Cohort Surgical v/s non-operative treatment for lumbar disk herniation. Patients with persistent sciatica improved in both groups. Operative intervention reported greater improvements than patients who elected non-operative care

- **Complications**
  - Dural tear 5% (Repair with 5-0 Prolene or fat patch or dural glue)
    - Don't insert drain
    - Supine for 48 hrs (healing and prevent low cranial pressure headache)
    - Doesn't affect clinical outcome
  - Nerve injury: 1-2 % per nerve dealt with
  - Recurrence: 5-15%
  - Vascular catastrophe caused by breaking through anterior annulus and injuring vena cava/aorta
  - Infection - 0.7 % (with Antibiotic). Double with use of microscope
  - Bleeding: Segmental vessels, venous plexus that surrounds nerve roots

Posterior approach to lumbar spine

- Image intensifier for level localisation
- Prone over Montreal mattress
- Midline incision
- Lumbodorsal fascia
- Inter-nervous plane - between two paraspinal erector spinae muscles -posterior rami of Lumbar nerves
- Detach erectors sub-periosteal
- Identify lamina
- Remove ligamentum flavum in inter-laminar window
- Use Kerrison laminectomy Rongeurs and pituitary Rongeurs
- Undercut facet joint (can remove up to 25 %)
- Retract nerve root medially
- Epidural fat
- Dura
- Cruciate cut of annulus

Wiltse Paraspinal approach

- Indications: Far lateral disc herniation
- 3 cm from midline
- Inter-muscular plane between multifidus & longissimus

Thoracic disc herniation

- T11-T12 most common level
- Scheurmann disease may predispose
- Radicular pain: band-like chest or abdominal pain along course of intercostal nerve
- Transthoracic discectomy or costo-transversectomy
- Intercostal neuralgia is most common complication following endoscopic transthoracic surgery for disc herniation

CAUDA EQUINA SYNDROME

- Cauda equina (horse tail) collection of L1-S5 peripheral nerves within lumbar canal surrounded by dural sac
- Spinal cord ends at L1/L2 level
- Lower motor neuron lesion
- **Symptoms:**
  - Bilateral leg pain
  - Bilateral lower extremity weakness and sensory disturbances
  - Decreased or absent lower extremity reflexes
  - Bowel & bladder dysfunction - Painless urinary retention and overflow
  - Incontinence
  - Bladder sphincter resting position is tightness
  - Bladder scan > 500 ml
  - Saddle anaesthesia - Reduced or absent sensation to pinprick in perianal region (S2-S5)
  - Decreased rectal tone or voluntary contracture
- Balasubramanian et al. from Middlesbrough (Br. J Neurosurgery 2010) noted saddle anaesthesia to have higher positive predictive value than any other clinical feature in diagnosing CES
- Types**:**
  - Impending/Incomplete - Diminished sensation, poor stream, irritable bladder
  - Complete Retention
Do bladder scan or catheterize to check residual
Poor prognosis
- Space-occupying lesion within lumbosacral canal
  - Disc herniation (most common)
  - Spinal stenosis
  - Tumour
  - Trauma
  - Epidural haematoma
  - Epidural abscess
- **Imaging:**
  - MRI (study of choice)
  - CT myelography: if patient unable to undergo MRI (Pacemaker).

(Courtesy of M Elgendy)

- **Approach for decompression:** Posterior discectomy - bilateral extensive laminectomy. Or Wiltse paravertebral approach
- Spine (2000): Meta-analysis
  - Significant improvement in sensory and motor deficits as well as urinary and rectal function in patients underwent decompression within 48 hrs versus after 48 hrs from onset of cauda equina syndrome.
- Euro Spine J – Cohort – 2007 – Leicester: Duration of symptoms prior to surgery does not influence outcome. Better outcome in patients who are continent of urine at presentation compared with those incontinent.
- **Standards of care for established and suspected Cauda Equina Syndrome – British Association of Spine Surgeons,**
  - Surgical emergency - Immediate assessment
  - MRI before transfer, if cannot be done – discuss with local spinal unit urgently
  - Transfer to spinal or neurosurgical unit if confirmed for immediate decompression s
  - Counsel patients that aim of surgery to preserve function present at time of surgery

- **NV Todd, Dickson (Newcastle study) published in Br. J Neurosurgery 2016** about guidelines for managing patients with CES. They categorized CES into following depending on their presentation
  - **Early** Bilateral progressive sensory-motor deficits without incontinence / retention
  - **Impending** Incomplete urinary disturbance without retention
  - **Retention**

SPONDYLOLYSTHESIS

- Forward slippage of one vertebra on another
- **History**
  - Back pain
  - Radicular symptoms
  - Neurological claudication
- **Examination**
  - Gait - Shuffling
  - Crouch from hamstring tightness
  - Feel - step off

Spondylolysis

- Disruption of pars inter-articularis (bone between superior and inferior articular facets) leading to stress fracture
- Most common cause of back pain in children
- Other causes
  - Infection
  - Scheurmann
  - Tumour
- **Risk factors:**
  - Increased prevalence in sports that involve repetitive hyperextension
  - Increased pelvic incidence
- **Radiographs** Disruption of neck of Scottish dog
  - Coned CT: To reduce exposure to radiation
  - SPECT: The most sensitive imaging modality
  - Lamina of affected level remains posteriorly placed – Central and lateral stenosis seen less commonly than foraminal (Spondylolysis affects the exiting nerve root)
- Slip progression
  - More common in females
  - Usually occurs in adolescence - rare after skeletal maturity

(Courtesy of M Elgendy)

Wiltse & Newman classification

1. Congenital
2. Dysplastic facets: Misaligned or improperly developed - Most likely to progress
3. Isthmic: Most common at L5/S1 level
4. Traumatic: pedicle fracture - not the pars
5. Degenerative: Degeneration of disc and facets - Facet joints change direction. 8 times more common in women than men
6. Pathological: Tumour or infection
7. Iatrogenic: Post surgical

Meyerding classification (Grading)

- Superior end-plate of S1 is divided into quadrants and slip measured
  - I: <25%
  - II: 25 – 50%
  - III: 50 – 75%
  - IV: 75 – 100%
  - V: >100% - Spondyloptosis
- Most common at L5-S1 in paediatric population and L4-5 in adults
- **Flexion-extension studies**: Instability defined as 4 mm of translation or 10° of angulation of motion compared to adjacent motion segment
- **Pelvic incidence**:
  - Line from centre of S1 endplate to centre of femoral head
  - Second line perpendicular to S1 endplate
  - Increased incidence correlates severity of isthmic spondylolisthesis
  - Anatomically fixed
- **Slip angle**:
  - Between inferior endplate of L5 and line perpendicular to posterior border of sacrum
  - Slip angle of > 50° associated with greater risk of progression

Management

- **Isthmic**
  - Non operative -
    - Stretching of hamstrings, core stability
    - Stop aggravating activity
    - TLSO bracing for 6 to 12 weeks
    - Will heal but can re-fracture
  - Operative
    - Pars blocks
    - Nerve roots injection
    - Fusion – If No response to non-operative management
    - Fusion + decompression - if neurological signs present
    - Stabilize in situ to reduce risk of nerve injury if >50% - reduction could cause nerve palsy

- **TLIF**
  - Trans-foraminal lumbar interbody fusion
  - Wiltse approach
  - Fuses anterior and posterior columns
  - Bone graft and interbody spacer (cage) stabilize anterior portion
  - Posteriorly locked in place with pedicle screws, rods and bone graft
- **ALIF**
  - Done through retroperitoneal approach
  - Grafts used include autologous iliac crest, structural allograft, and cages
  - Increase chance of union by complete discectomy and endplate preparation
- **PLIF:** Never fuse > 2 levels except in deformity correction
- **SPORT trial, JBJS – 2009**
  - Compared with treated non-operatively, patients in whom degenerative spondylolisthesis and associated spinal stenosis treated surgically maintain greater pain relief & improvement in function for 4 years
- **Pars Inter-articularis Repair**
  - Treat as fracture – fix not fuse
  - Consider fusion in above 20 years if they already have facet degeneration
  - For L1 – L4 - bone graft and pedicle screw or TBW or Infra-laminar hook
- **Vertebrectomy and fusion** - In Spondyloptosis
- Complications
  - L5 is most common nerve root injury with reduction
  - Sexual dysfunction with ALIF - From damage to Hypogastric plexus or Genito-femoral nerve
  - Catastrophic neurologic injury
  - Accelerated degeneration of adjacent discs

LUMBAR STENOSIS

- Progressive narrowing of lumbar spinal canal
- **Aetiology**
  - Congenital: short pedicles with medially placed facets (achondroplasia)
  - Acquired
    - Bony
      - Facet osteophytes
      - Posterior vertebral body osteophyte
      - Spondylolisthesis
    - Soft tissue
      - Herniated/bulging disc
      - Hypertrophy ligamentum flavum
      - Synovial facet cysts

- **Types**
  - Central
  - Lateral recess - between dural sac and neural foramen
  - Foraminal

- **History**
  - Location of pain
  - Which one worse - back or leg?
  - Cramps
  - Weakness - giving way
  - Balance
  - Red flags?
  - Co-morbidities: obesity, smoking
  - **Claudication:** Reduced walking distance with leg pain and fatigue
    - Ask: 'what stops you walking? ' & 'How far down does the pain go to? '
    - **Neurological claudication**
      - Pain worse with extension
      - Pain relieved with flexion (sitting, leaning over shopping cart)
      - Bending forward increases spinal canal space available
      - Poorly localized pain in lower back, buttocks, thighs or legs
      - Symmetrical paraesthesia and weakness
    - **Vascular claudication**
      - Improves with standing
      - No paraesthesia
      - Symptoms in calf

- **Imaging**: MRI: comment on causes of stenosis

- **Treatment**
  - Non-operative
    - Physiotherapy
    - Epidural steroid injections
    - Spine – 2010, Spine Patient Outcomes Research Trial (SPORT)
    - Patients with symptomatic spinal stenosis treated surgically compared to those treated non-operatively maintain greater improvement in pain and function through 4 years postop, but recently the benefit of surgery is reported to diminish by 8 years follow -up
    - Comorbid conditions are strongest predictor of clinical outcomes after decompression for lumbar spinal stenosis
- **Technique**
  - Resect inferior half of spinous process
  - Resect lamina to level of insertion of ligamentum flavum
  - Undercutting of facets and removal of ligamentum flavum from lateral recess
  - When to add fusion?
    - Back pain
    - >2 levels
    - If removing > 50% of facet joints

- **Complications**
  - Infection: **Most common**
  - Neurological deficit 2%
  - Dural tear: 10 % (ligamentum flavum adhered to dura)
  - Failure to improve due to inadequate decompression
  - Pedicle screw pull-out - affected by degree of osteoporosis
- Most common cause of failed surgery is occurrence of disease above or below decompressed level - Adjacent segment disease

THORACO-LUMBAR SPINE BIOMECHANICS & INJURIES

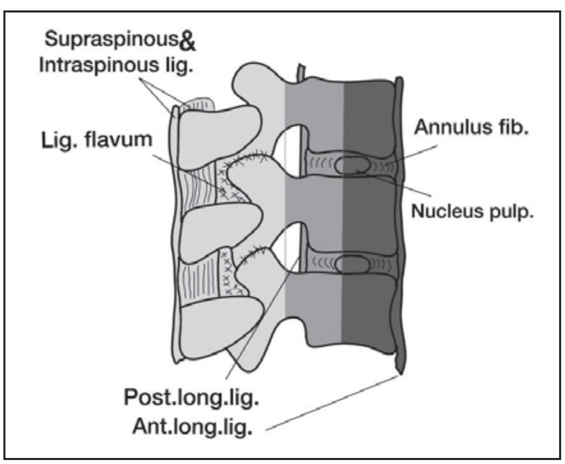
- **Functions of spine**
  - Allow movements
  - Carry load
  - Protect neural structures

- Instability:
  - Panjabi and White 1975
  - Loss of the ability of spine under physiological loads to limit displacement so as not to damage neural structures and to prevent deformity or pain
  - Stabilizers Passive – adjoining vertebrae and intervertebral disc (spinal motion segment), ligaments
  - Active – muscles and tendons
  - Neural- proprioception
- Holdsworth classification: 2 columns - Anterior is anterior to PLL

- **Denis classification:**
  - 3 columns - Tension band construct
    - Anterior: Anterior 1/2 of vertebral body, disc & ALL. Undergoes compression and provides support
    - Middle: Posterior 1/2 of vertebral bodies, disc & PLL
    - Posterior: Pedicles, facet joints, spinous process, Posterior ligamentous complex (supraspinous, interspinous, ligamentum flavum, facet capsule)

  - To quantify stability: Injury involving > 1 column is unstable
  - Unstable fractures require either brace or surgical stabilization
- **AO classification (Magerl)**
  - A: Anterior compression / burst
  - B: Flexion distraction
  - C: Rotation

Spinal Stability as defined by the 3 column concept



Mechanisms of injury

1. **Compression** -
   - Failure of anterior vertebral body without disruption of posterior body cortex. Common at T10 to L3
   - **X-rays**:
     - Anterior wedging
     - Flexion/extension to assess stability if still in pain
     - Usually < 30% loss of height
   - **Causes**:
     - Osteoporosis - MRI to evaluate for acute Vs chronic
     - Metastatic cancer - Fractures above T5
     - Younger patient with no history of fall - Infection
     - Multiple myeloma
   - **Complications**:
     - Nerve root, spinal cord compression
     - Compromised pulmonary function (from kyphosis)
   - **Treatment**:
     - Orthosis
     - Kyphoplasty: if still symptomatic after 6 weeks
       - Expansion device (Balloon) inserted through needle and filled with cement
       - Indicated for patients with painful bone metastases
       - Aim to reduce pain and stabilise bones
       - High viscosity cement under low pressure to avoid embolization via Batson plexus
     - Vertebroplasty Balloon not used - only cement.
       Complications from extravasation of cement
     - Anterior stabilisation - If > 50% compression or > 30 deg wedging
   - **RCT (NEJM, 2009)** No beneficial effect of Vertebroplasty as compared with sham procedure in patients with painful osteoporotic vertebral fractures in reducing pain or disability

2. **Burst**
   - Involves anterior and middle columns
   - Fracture extension through posterior cortex with retropulsion into spinal canal
   - Often associated with posterior ligamentous injury
   - Widening of inter-pedicular distance on AP radiograph
   - Loss of height of posterior cortex of vertebral body
   - Maximum canal occlusion and neural compression occur at moment of impact
   - **Imaging**:
     - CT scan: sagittal and axial
     - MRI: For spinal cord compression & injury to PLC
   - **Management:** TLSO - Neurologically intact and mechanically stable. PLC intact. Retropulsed fragments resorb over time
     - Decompression & stabilization if neurologic deficits with radiographic cord compression
     - Progressive kyphosis – common with PLL injury
     - Anterior decompression for neurological compression
     - Avoid laminectomy - further destabilize
     - Corpectomy (Vertebrectomy) & strut
     - Posterior instrumented stabilization

- **CORR, 1999** – Meta-analysis. Operative management of thoracolumbar burst fractures without neurologic deficit may improve residual kyphosis, but does not improve pain or function at 4 years after injury and is associated with higher complication rates and costs.
- **Bailey et al (Spine, 2014)** and **Urquhart et al (Journal of Neurosurgery Spine, 2017)** suggest no difference in functional outcome with or without TLSO for burst fracture with no neurological deficit
- **Mumford et al (Spine, 1993)** and **Dai et al (CORR, 2001)** – No difference in canal remodelling which gets completed, with most of the bony retropulsion or intra-spinal fragments resorbed by 1 year.

3. Chance

- Described by Chance in 1948
- Involve anterior (fail in compression) and posterior (fail in tension) columns
- Flexion distraction - Bony injury from spinous process to vertebral body
- Seatbelt injury – seat belt sign
- Could be bony or ligamentous
- Fanning of spinous processes (widening of interspinous space)
- **Management**
    - TLSO: 3 points fixation via sternum, suprapubic and Thoracolumbar pads, if minimal displacement and neurologically intact
    - Posterior instrumentation stabilization
        - Single level above & below in fit & healthy
        - Two levels above & below in Osteoporosis
- **Complications**
    - Intestinal perforation - Most common, if the centre of rotation passes anterior to vertebral body
    - Syringomyelia

Thoracolumbar facet dislocation

- Acceleration/deceleration injury
- ATLS approach
- Step off deformity
- **Treatment**: Posterior reduction with instrumented fusion

TLICS Classification

- Thoraco-Lumbar Injury Classification and Severity Score

(Focus on Posterior structures and neurology)

	TLICS	**3 independent predictors**		
1	**Morphology** immediate stability	- Compression - Burst - Translation/rotation - Distraction	1 2 3 4	- Radiographs - CT
2	**Integrity of PLC** longterm stability	- Intact - Suspected - Injured	0 2 3	- MRI
3	**Neurological status**	- Intact - Nerve root - Complete cord - Incomplete cord - Cauda equina	0 2 2 3 3	- Physical examination
	Predicts	- **Need for surgery**	0 – 3 4 > 4	- nonsurgical - surgeon's choice - surgical

Khurana et al (Euro Spine Journal, 2018)

- CT for thoracic and lumbar fracture can predict PLC injury by considering:
  - Vertebral translation
  - Pedicle or laminar fracture
  - Inter-spinous widening
  - Spinous process fracture
  - If one finding on CT, recommended to get MRI (as specificity of PLC injury is only 59%), but if $\geq$ 2 findings on CT (specificity almost 88%) and MRI scan can be avoided
  - MRI scans are useful for finding:
    - Disc injury
    - Epidural hematoma
    - PLC injury
- **Kim et al (Korean study) Asian Spine Journal 2015**
  - Suggested thoracolumbar fractures to be stable if:
    - <50% vertebral height loss
    - <30o kyphosis
    - <50% canal encroachment
    - Facets intact
    - No translation / PLC injury
    - Neurologically intact

(Spinal Trauma for FRCS)

MULTIPLE SCLEROSIS

Chronic inflammatory disease that causes demyelination and widespread axonal injury in central nervous system leading to motor and sensory dysfunction

- **Risks**
  - Genetic
  - Stress
  - Smoking
  - Low Vit. D
- **Features**
  - Fatigue, depression, mood disorders
  - Optic neuritis, ataxia
  - Dysarthria, dysphagia
  - Osteoporosis
  - Muscle weakness
  - Incontinence, frequency, retention
- **Examination:** Upper motor neuron
- **Imaging:** MRI with Gadolinium, shows multiple focal demyelination scattered in brain and spinal cord
- CSF analysis elevated IgG
- **Patterns**
  - Remitting relapsing (RRMS) – 85%
  - Primary progressive MS (PPMS)
  - Secondary progressive MS – change starts after 10-20 years
  - Clinically isolated syndrome (CIS)
- **Treatment**
  - Immunomodulators: Corticosteroids
  - Immunosuppressant: Interferon Beta
  - Antispasticity: Baclofen, Gabapentin,Botox injections
  - Physiotherapy: Balance & stretching

SYRINX

- Fluid-filled neuroglial cavity within the spinal cord (Syringomyelia), in the brain stem (syringobulbia)
- Syringomyelia: Syrinx within spinal cord. Often presents with central cord syndrome, back pain, radicular pain
- Syringobulbia: Syrinx within brain stem. Cranial nerve involvement (Headache)
- **Causes**
  - Spinal trauma
  - Meningitis (due to scaring)
  - Tumour
  - Chiari malformation:
    - Cranio-cervical junction abnormality
    - Obstruct CSF flow
    - Associated with developmental scoliosis
- Symptoms are similar to central cord syndrome
- **Investigation**: MRI with gadolinium to rule out associated tumour
- **Treatment**:Non-operative: Observe - asymptomatic, non-enlarging

  Operative: Decompression of foramen magnum and upper cervical cord +/- shunting

BACK PAIN

- **Waddell inorganic signs** (1979) - Five signs tested
  - If 3 or more present, patient likely to have poor response to surgery. Indicates non-organic or psychological component
- **DROST**
  - Distraction (SLR)
  - Regional (Non anatomical distribution of symptoms)
  - Over reaction
  - Simulation (Rotation, axial loading)
  - Tenderness (Superficial tenderness)
- **Causes**
  1. Muscle strain - most common
  2. Discogenic - Disc degeneration. Exacerbated by bending & sitting
  3. Facet degeneration - facet joints injections, CT or fluoroscopy guided
  4. SIJ arthritis - fusion
- Discography: if injection of fluid into affected disc reproduces pain, and injection in adjacent control level does not, then provocative discography is positive.
- **Modic changes**: On MRI
  - Described by Michael Modic in 1988
  - End-plate changes related to spine degeneration
  - Strong correlation between having Modic change and back pain
- **Treatment**
  - WHO analgesic ladder
  - Neuropathic analgesics
  - Cochrane review:
    - No difference between rest and stay active, including in sciatica
    - Carbamazepine & Pregabalin effective in chronic neuropathic pain
  - Disc replacement
    - Motion-sparing to reduce the risk of adjacent-segment disease.
    - Contraindications
      - ✓ Pars defects
      - ✓ Facet arthrosis/ankylosis
      - ✓ Spondylolisthesis
      - ✓ Previous laminectomy
      - ✓ Scoliosis
- **Fairbank, 2005 BMJ**
  - RCT compared surgical stabilisation of lumbar spine with intensive rehabilitation programme for patients with chronic low back pain
  - No clear evidence that spinal fusion surgery was more beneficial

NICE Guidelines (2016) for low back pain and sciatica

- Rule out alternative diagnosis - MESCC, spinal injury, spondyloarthritis, cancer
- Assessment: STarT back risk assessment tool
- Analgesics – Do not offer paracetamol alone or opioids for chronic low back pain. Offer NSAIDs or weak opioids (only if NSAIDs contra-indicated)
- Offer choice of Amitriptyline, Duloxetine, Gabapentin or Pregabalin as initial treatment for sciatica, do not use Tramadol for long-term
- Perform radiofrequency denervation in chronic low backache only after a positive response to diagnostic medial branch block
- Epidural injections may be considered for acute and severe sciatica, but not for neurogenic claudication or central spinal stenosis
- **Surgical interventions**:
  - Consider spinal decompression if non-surgical treatment has not improved pain or function and radiological findings are consistent with sciatic symptoms
  - Do not offer spinal fusion for low back pain
  - Do not offer disc replacement

COCCYDYNIA/COCCALGIA

- 3-5 fused bones
- Pain in the region of coccyx, typically is triggered by or occurs while sitting
- Most resolve in weeks to months with or without conservative treatment
- **Treatment modalities**
  - Doughnut cushions, hot and cold fomentation
  - Physiotherapy
  - NSAIDs
  - Injections
  - Manipulation under GA
- **Coccygectomy**
  - For disabling Coccygodynia with radiographic subluxation / instability / a spicule
  - >80% pain relief, but takes long time to recover from procedure – months to a year
  - Wound complication - Up to 20

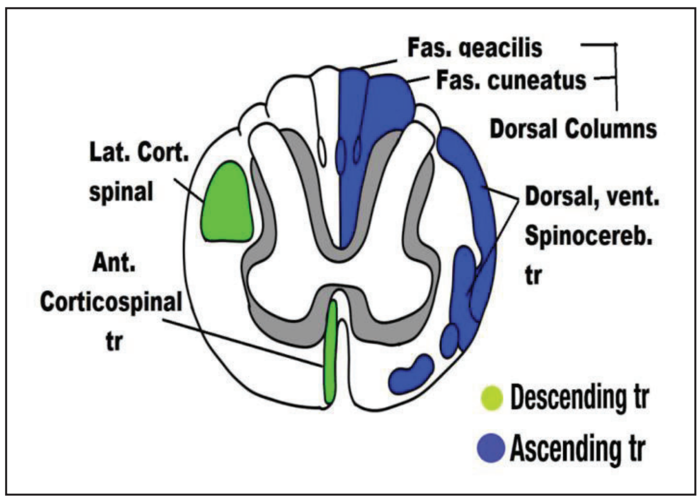
SPINAL CORD INJURIES

Blood supply

- Anterior spinal artery
  - From vertebral Artery
  - Primary supply of anterior 2/3 of spinal cord
  - Including both lateral corticospinal tract and ventral corticospinal tract
- Two posterior spinal arteries
  - From cerebellar A
  - Primary blood supply to dorsal sensory columns
- Artery of Adamkiewicz
  - Arises from left segmental artery, which branches from aorta
  - Supplies anterior two thirds of spinal cord via anterior spinal artery
  - Travels on left side between T9-L2 in 60% of patients
  - Magnetic resonance angiography MRA is least invasive method
- **CSF**
  - Colourless fluid that occupies subarachnoid space
  - Between Pia and Arachnoid mater
  - Ultra-filtrate of blood plasma
  - Produced by choroid plexus in third, fourth, and lateral ventricles
  - Mechanical and immunological protection

Spinal cord pathways

- Sensory (ascending)
  - Dorsal - Ipsilateral
  - Deep touch, proprioception & vibration
- Spinothalamic
  - Lateral (contralateral pain & temperature)
  - Ventral (contralateral light touch)
- Motor (descending)
  - Lateral corticospinal – ipsilateral
  - Upper lmb pathways are more medial (central)
  - Ventral corticospinal - contralateral



- **Neurologic level of injury**
  - Lowest segment with intact sensation and antigravity muscle strength bilaterally
  - Regions where no myotome to test, motor level presumed to be same as sensory
- **Sacral sparing**
  - Motor (FHL)
  - Sensory (Perianal sensation (S4 – S5)
  - Reflex: Contraction of external anal sphincter upon stroking of skin around anus
  - Indicates incomplete spinal cord injury

- **Spinal shock**
  - Temporary loss of spinal cord function and reflex activity below level of SCI
  - Transient paralysis & areflexia
  - Ends with Bulbocavernosus reflex (usually 3 days) – gentle tug on indwelling catheter to check for anal contraction response
- **Neurogenic shock**
  - Circulatory collapse/vasodilatation from loss of sympathetic tone
  - Hypotension without tachycardia
  - Treat cardiac bradycardia arrest with Atropine to suppress parasympathetic system
- **American Spinal Injury Association (ASIA) impairment scale:** Allows for categorization of spinal cord injuries
- **Frenkel classification**
  - A - Complete palsy
  - B - Normal sensation
  - C - Useless motor
  - D - Useful motor
  - E – Normal

Treatment

- Steroids National Acute Spinal Cord Injury Study (NASCIS)
  - No evidence to support use of steroids in management of spinal cord injury
  - Immunosuppression and infection risk outweigh benefit
- Surgical decompression and stabilization
  - Provides pain free and stable spine for rehabilitation
  - GSW with worsening neurology
  - Retained bullet fragment within thecal sac
  - CSF leads to breakdown of lead products - lead poisoning
- Management of traumatic spinal cord injuries – BOA guidelines
  - Discuss with spinal cord injury unit within 4 hrs
  - Log-rolling every 2 hourly, at least 30o side-to-side turns
  - Psychological support
  - Skin, gastric, bowel and bladder care
- **Bulbocavernosus reflex**
  - Most distal spinally mediated reflex
  - Contraction of anal sphincter by gentle tug on Foley catheter or squeezing glans/clitoris
  - Absence indicates presence of spinal shock
  - Presence indicates end of spinal shock

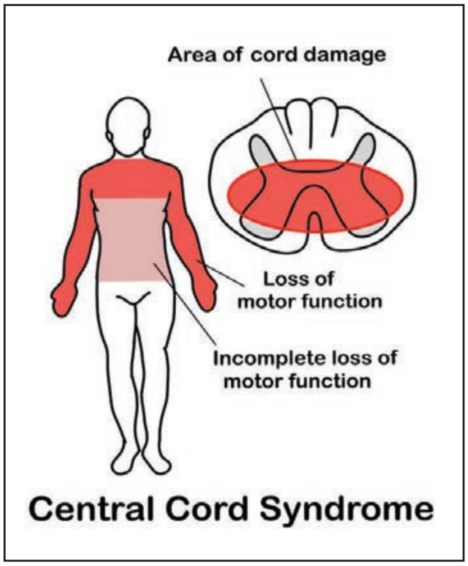
Complete spinal cord injury

- No spared motor or sensory function below affected level
- Must have recovered from spinal shock before injury can be determined as complete

Incomplete spinal cord injury

- Distinct patterns from different injury mechanisms
- Some preserved motor or sensory function below injury level including sacral sparing
- Severity of neurologic deficit is the most important prognostic variable

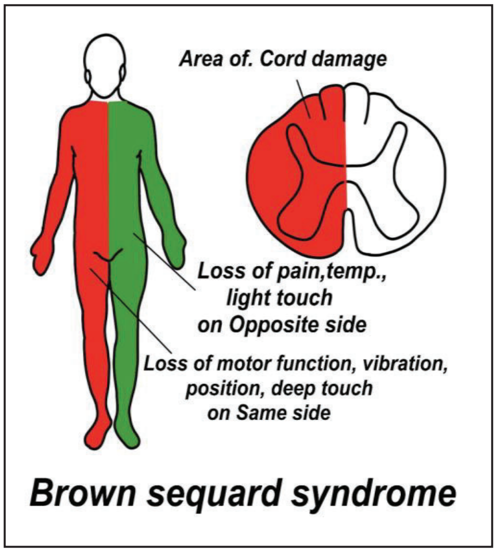
1. **Central cord syndrome**
    - Most common
    - Hands and upper extremities are located centrally in corticospinal tract
    - Blood supply comes from periphery to centre
    - Motor loss affects upper extremity >lower
    - Finger and wrist motor function more affected than shoulder and Biceps function
    - Sensory deficits are minimal
    - In elderly with minor extension injury mechanisms due to
        1. Anterior osteophytes
        2. Posterior infolded ligamentum flavum
    - MRI - multi-level stenosis
    - Good prognosis although full functional recovery rare
    - Stabilization for instability
    - Decompression for cord impingement

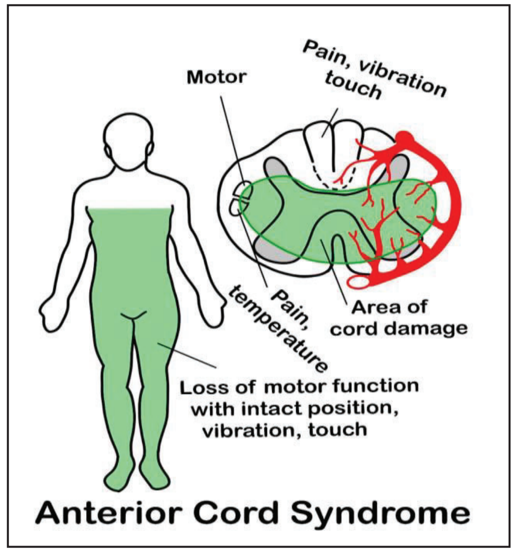


2. **Anterior cord syndrome**
    - Flexion/compression injury
    - Loss of Motor, pain, temperature and light touch
    - Preserved dorsal column pathway
    - Caused by
        1. Direct compression of anterior spinal cord
        2. Anterior spinal artery injury
    - Worst prognosis

3. **Brown – Sequard syndrome**
    - Caused by cord hemi transection
    - Seen with penetrating trauma or facet dislocation
    - Ipsilateral deficit
        - Lateral corticospinal tract: motor function
        -Dorsal columns proprioception: vibratory sense
    - Contralateral deficit (Lateral Spinothalamic: pain, temperature, light touch)
    - Spinothalamic tracts cross at 2-levels below
    - Best prognosis

4. **Posterior cord syndrome**
    - Loss of proprioception, vibration & deep touch





Autonomic Dysreflexia

- Patients with injury at or above T6
- Stimulus causes reflex sympathetic over-activity below level of cord injury – leads to vasoconstriction and **systemic hypertension** – this stimulates carotid and aortic baroreceptors, causing increased vagal tone and **bradycardia**
- Normal peripheral vasodilatation to relieve hypertension cannot occur due to spinal cord injury
- **Symptoms**: pounding headache, flushing and sweating above cord injury level and cold peripheries below the injury level, blurring of vision
- **Common initiators**: Bladder distension, bowel distension with faecal impaction, pressure ulcer, ingrown toe nail, child birth, fissure-in-ano
- **Treatment**
  - Catheterise
  - Flush catheter if blocked
  - Look for other initiators – faecal evacuation
  - Sublingual Nifedipine or GTN. Or IV hypotensive with high dependency unit support
- **Acute Traumatic Central Cord Syndrome (ATCCS)** (Level III recommendations by **Baltimore, J. Neurosurgery 2013**)
  - ITU management of ATCCS with severe neurological deficits
  - Maintain mean arterial pressure 85-90mm Hg for 1st week after injury to improve cord perfusion
  - Early reduction of fracture-dislocation injuries
  - Surgical decompression of compressed spinal cord recommended, especially if compression is focal and anterior
- Management of Traumatic Spinal Cord Injury (SCI)-BOAST
  - All units should have named, linked spinal cord injury centre, who will agree protocols for nursing, joint protection and therapy.
  - Follow BOAST 2 for C-spine protection and clearance.
  - If managing SCI should have 24 hours of CT & MRI facilities.
  - Serial neurological assessment on ASIA charts
  - Centres treating SCI should have theatre access within 4 hours of injury.
  - Any agreed transfers to a Spinal Cord Injury centre should be within 24h.
  - If unfit or transfer not needed, should have outreach visit by the fifth day.
  - Spinal cord injuries should be recorded in the National SCI Database.

MYELOPATHY

- Compression of spinal cord
- **Causes**
  - Spondylosis
  - Trauma
  - Congenital
  - Ossification of PLL (C5/6)
  - Tumour
  - Epidural abscess
- Gait instability is most important clinical predictor of Poor prognosis
- **Investigation**
  - Normal diameter of cervical spinal canal 18 mm
  - When diameter < 12 mm causes stenosis and myelopathic symptoms
  - Average diameter of spinal cord in cervical spine is 10 mm
  - Torg-Pavlov ratio (canal/vertebral body width) of < 0.8 (normal is 1.0)
  - MRI Effacement of CSF canal diameter < 10mm & Myelomalacia - bright signal on T2
- **Treatment**
  - Analgesia
  - Gabapentin for radicular symptoms
  - Physiotherapy Traction
  - Indication for surgical stabilization:
    - Instability
    - Cord compression
    - Functional impairment
  - ACDF Corrects kyphosis -
    - Combine with posterior fusion if > 2 level disease
    - Using plate and interbody cage or strut graft (better fusion)
    - Access to posterior osteophytes or OPLL limited
    - With discectomy alone - Corpectomy
    - Titanium or PEEK (Bio inert plastic) mesh filled with autograft
  - Laminectomy and posterior fusion: If kyphosis < 10 deg. Add anterior fusion if kyphosis > 10 deg
  - Laminoplasty: Decompression of multilevel myelopathy without compromising stability and motion
    - Does not address neck pain
    - Contraindicated with rigid cervical kyphosis > 13 deg (flexion and extension films to diagnose)
  - Disc replacement
    - Preserve motion
    - Prevent adjacent disc disease
    - In young with no spondylosis
- **RCT, Spine J (2009):** outcomes after ProDisc-C implantation were either equivalent or superior to those same clinical outcomes after fusion
- **NICE Guideline: Prosthetic IV disc replacement in cervical spine (2010):** At least as efficacious as fusion in short term and may result in reduced need for revision surgery in long term.
- **Complications**
  - Pseudoarthrosis- Most common

- Post-laminectomy kyphosis - increased with preoperative kyphosis or facet resection with multiple posterior laminectomy without fusion
- Adjacent segment disease - 25% require additional procedure within 10 years

CERVICAL SPONDYLOSIS

- **History**
  - Loss of balance, deterioration of gait, multiple falls
  - Decreased dexterity, difficulty writing
  - Weakness
  - Numbness and tingling
- **Examination**
  - Hypertonia
  - Hyperreflexia, Babinski upgoing, Hoffman reflex
  - Ankle clonus
- **Pathology**
  - Chronic disc degeneration
  - Facet and uncovertebral joints of Luschka arthropathy
  - Ligamentum flavum thickening
  - Osteophytes formation
- Most common level C5-6: Associated with most flexion and extension in sub-axial spine
- Lateral radiographs - for foraminal stenosis caused by uncovertebral joint arthrosis

RADICULOPATHY

- A range of symptoms produced by the impingement of a nerve root in the spinal column
- **Causes:** Spondylosis & Disc herniation
- CT Myelography -
  - Useful in patients who cannot have MRI due to contraindications
  - Useful in patients with prior surgery and hardware causing artefact on MRI
- **Treatment**
  - 75% of patients with radiculopathy improve with non-operative management
  - Improvement via resorption of discs and decreased inflammation around irritated nerve roots
  - ACDF - Gold standard
  - Posterior foraminotomy - Avoids need for fusion
- **Cochrane systematic review (2010)**
  - No long-term benefit (at 1 year follow up) of surgical decompression though there is evidence to suggest improved short-term pain, weakness and sensory loss when compared to physiotherapy alone in cervical radiculopathy.
  - No difference found for myelopathy between surgery and conservative treatment at 3 year follow up

UPPER LIMB

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CONTENTS

ANATOMY OF THE SHOULDER

Bony Considerations

- **Glenoid:** from 5^{o} of retroversion to 10^{o} of anteversion to the plane of scapula and 5^{o} superior tilt
- **Humeral head:** 20-30^{o} of retroversion to the epicondylar axis and 130^{o} neck shaft angle

Muscles

- **Trapezius**
  - Origin: Base of skull, cervical and thoracic vertebrae
  - Insertion: Lateral 1/3rd of clavicle, acromion and the spine of scapula
  - Innervation: Spinal part of the accessory nerve
  - Action: Rotation of the scapula during abduction above the horizontal
- **Latissimus Dorsi**
  - Origin: Iliac crest, lumbar fascia, spinous processes of T7-T12
  - Insertion: Anterior inter-tubercular groove
  - Innervation: Thoracodorsal nerve
  - Action: Adducts humerus & internally rotates shoulder
- **Teres major**
  - Origin: Inferior tip of the scapula
  - Insertion: Inter-tubercular sulcus of the humerus
  - Innervation: Lower scapular nerve
  - Action: Shoulder Adduction and Extension
- **Brachialis**
  - Origin: Anterior surface of the distal half of humerus
  - Insertion: Coronoid process of ulna
  - Innervation: Musculocutaneous and radial nerves
  - Action: Major flexor of Forearm.
- **Biceps**
  - Origin:
    - Long head supraglenoid tubercle of glenoid
    - Short Head tip of coracoid
  - Insertion: Tuberosity of radius and fascia of the forearm via bicipital aponeurosis
  - Innervation: Musculocutaneous nerve.
  - Action: Supinator of forearm and flexor when supine
- **Pect. minor**
  - Origin: 3rd, 4th and 5th ribs
  - Insertion: Coracoid of scapula
  - Innervation: Medial pectoral nerve
  - Action: Stabilizes scapula

- **Coracobrachialis**
  - Origin: Coracoid (Conjoint Tendon)
  - Insertion: Medial surface of Humerus
  - Innervation: Musculocutaneous nerve
  - Action: Adducts and flexes humerus
- **Pect. major**
  - Origin:
    - Clavicular Head anterior surface of the medial half of clavicle
    - Sternocostal Head anterior surface of sternum and superior six costal cartilages
  - Insertion: Lateral lip of the intertubercular groove of the humerus
  - Innervation: Medial & lateral pectoral nerves
  - Injury:
    - Avulsion from humerus ecchymosis and swelling
    - Defect in anterior axillary fold
    - Repair with suture anchors or bone tunnels
- **Deltoid**
  - Origin:
    - Anterior Head Lateral 1/3 of Clavicle
    - Lateral Head Acromion of Scapula
    - Posterior Head Spine of Scapula
  - Insertion: Deltoid tuberosity of the humerus
  - Innervation: Axillary Nerve remember innervates from back to front
  - Action:
    - Anterior; Flexes and internally rotates the humerus
    - Lateral; Abducts the humerus
    - Posterior; Extends and Externally rotates the humerus

Superficial venous drainage of upper limb

- Comprises cephalic and basilic veins. Linked by the median cubital vein in the cubital fossa
  - **Cephalic vein** overlies anatomical snuffbox and ascends lateral forearm and
  - **Basilic vein** ascends medial forearm

Rotator interval

- Coracoid process separates anterior border of supraspinatus tendon from superior border of subscapularis tendon, creating triangular rotator interval
- Contains : SGHL , coracohumeral ligament, biceps tendon

SHOULDER EXAMINATION

History

- Name Age Occupation Dominance Hobbies Premorbid function.
- Nature of the pain, ask about neck pain and radiculopathy symptoms
- Stiffness
- Painful & stiff think about: frozen shoulder, OA, AVN, and rotator cuff arthropathy
- Weakness – think about muscular (cuff tear) or neurological (plexus injury)
- Young patient – think about instability
    - Does it feel unstable, previous traumatic dislocation, level of sport activity and number of dislocations, age of first dislocation, types of sport (overhead/contact)
- Neurological symptoms
- Function assessment
- Can reach mouth with the hand, clam hair, female undo the bra and reach perineum for hygiene
- Previous treatment and Patient's expectation
- PMH
- Assess general patient fitness: (History of DM and hypothyroidism are risk factors for frozen shoulder)

Examination

- Pay particular attention to maintaining modesty in female patients
- You can do the whole shoulder exam while the patient is standing
- **Sequence**
    - Look ◊ feel ◊ move ◊ special tests (start with C-spine screening)
    - Impingement, ACJ, RC , biceps Instability
    - Neurological assessment
- Look: "Can you please take your top off?"
    - Any scars or obvious muscle wasting
    - Front: ACJ, SCJ & clavicle deformity
    - Side:
        - Wasting of deltoid and loss of contour might indicate axillary nerve or brachial plexus injury, also following GHJ arthrodesis
        - Loss of C-spine lordosis
    - Back:
        - Scapular position
        - SS & IS fossae: wasting indicates suprascapular nerve entrapment or rotator cuff tear
    - Scars:
        - Arthroscopy portals
        - Multiple long scars from neck to shoulder in shoulder arthrodesis
- Feel:
    - Neck tenderness
    - Temperature
    - SCJ, ACJ,and clavicle
    - Sub-acromial region
    - Biceps tendon groove

- SS & IS fossae
- Medial border of scapula

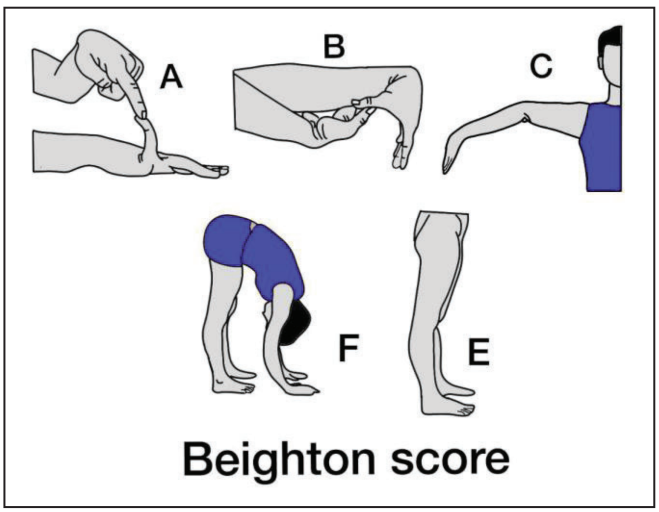
➢ <u>Move:</u> Start with C spine screening

- Look from behind while doing forward flexion and abduction to observe for scapula dyskinesia
- Say 'I would ideally like to have a mirror to watch the patient's face for pain'
- Forward elevation checking for symmetry of movements (Winging)
- Abduction
  - High arc pain in ACJ (last 30 deg of abduction)
  - Painful arc 60 – 120° in impingement
  - Observe scapulothoracic rhythm on both sides and check for winging
  - Unable to initiate shoulder abduction might indicate supraspinatus weakness
  - Able to hold arm abducted after passive abduction indicate the deltoid supports this
  - Tear or SSN problem (injury or impingement)
  - Palpable click with arm abduction and external rotation in LHB subluxation
- Ext rot: "tuck your elbow by your side and turn arm outwards "
  - Active restriction indicates: infraspinatus weakness, ◊ tear or SSN problem
  - Active and passive restriction indicate: OA, frozen shoulder or chronic locked posterior dislocation
  - No active nor passive movements in GHJ arthrodesis (isolate GHJ by stabilizing the scapula with one hand)
  - Increased passive movements in subscapular tear
- Internal rotation:
  - Normally T4-T8 (T9 is tip of scapulae)
  - "Can you reach between your shoulder blades?"
  - Stabilize scapula to isolate scapulothoracic movements
- Adduction
- Extension

(Shoulder examination)

➢ **<u>Tests:</u>**

- Whenever testing for instability it is important to examine the contralateral side for comparison. The most reliable test is the apprehension and relocation test. Also, assess the Beighton score



- Cross body adduction (scarf) test (for ACJ pain):
  - Ask for the location of pain
- O'Brien test
  - Arm 20° adducted and 90 forward elevated with thumbs down. Resisted elevation causes ACJ pain.
  - +ve in SLAP tear
  - Reduced pain when thumb points upwards
- Neer's sign
  - One hand on scapula and other passively elevate shoulder in the plane of scapula with internal rotation
  - Positive if passive forward flexion >90° causes pain & subacromial impingement
- Neer's test: Reduction of pain following injection of LA
- Hawkin's test:
  - Shoulder abducted to 90^0 & elbow flexed to 90^0
  - Gentle passive internal rotation in subacromial impingement
  - Pain with flexion, adduction, and active internal rotation in sub coracoid impingement
  - When it is a rotator cuff problem – examine power and lag tests
  - "Keep your arm there and don't let me move it "
- Jobe (empty can) test:
  - Resisted elevation in the plane of scapula with arm internally rotated & shoulder at 90 deg (external rotation tests deltoid)
  - Apply force over the proximal arm to exclude triceps
  - Pain - tendonitis/bursitis
  - Weakness – tear
  - Pain arising from subacromial space can be due to impingement or rotator cuff pathology
- Drop Sign
  - Passively elevate the arm in scapular plan to 90°.
  - Ask patient to slowly lower arm
  - Positive when weakness or pain causes them to drop arm to side – supraspinatus weakness
- External rotation against resistance in adduction for infraspinatus
- External Rotation Lag Sign
  - Flex elbow to 90^0
  - Rotate shoulder to maximal external
  - "When I let go of your arm keep it there"
  - If arm drifts into internal rotation
  - Positive for infraspinatus weakness or massive tear
- Internal rotation against resistance in 900 abduction for teres minor
- Hornblower's test
  - Shoulder placed in 900 of abduction & 90^0 of external rotation
  - Positive if arm falls into internal rotation – teres minor weakness
- Gerber lift off test:
  - Ask patient to put hand behind their back
  - Initially ask to lift hand off back
  - If they can do it against resistance
- Belly press test:
  - Active: bring elbows forwards

  - Passive: Internal Rotation Lag Sign & +ve in a massive tear
- Sulcus test: sitting or standing
  - Pull down in external rotation
  - Indicates inferior capsule laxity
- Anterior & posterior drawer tests:
  - Sit, Abduct shoulder, stabilize scapula, move humeral head.
- Anterior apprehension test:
  - Anteriorly directed force to humeral head with the shoulder in abduction and external rotation
  - Positive when a patient feels that their shoulder is going to dislocate
- Jobe relocation test:
  - Feels relief when humeral head pushed backwards following above test
- Posterior apprehension (jerk) test: Supine
  - Flex shoulder to 90^0 with internal rotation.
  - Apply posterior force through long axis of humerus
- Kim's test: Subluxation with posteriorly applied force as arm is dynamically adducted by an examiner
- Yerguson's test
  - Elbow flexed 90^0 with forearm pronated
  - Patient supinates forearm against resistance
  - Pain in bicipital groove indicates long head of biceps tendon pathology
- Speed's test:
  - Arm placed in 90^0 of forward elevation with elbow extended and forearm supinated
  - Press arm down against patient resistance
  - Pain in anterior deltoid / bicipital groove indicates long head of biceps tendon pathology
- Perform neurological examination, arthrodesis may be due to neurological injury

STERNOCLAVICULAR JOINT INJURIES

- Medial clavicle
  - First bone to ossify and the last physis to close at age 20-25
- Stability
  - Posterior capsular ligament
    - Most important structure for anterior-posterior stability
  - Anterior sternoclavicular ligament
    - Primary restraint to superior displacement
  - Costoclavicular (rhomboid) ligament
    - Anterior fasciculus resists superior rotation and lateral displacement
    - Posterior fasciculus resists inferior rotation and medial displacement
  - Intra-articular disk ligament
    - prevents medial displacement of clavicle
    - Secondary restraint to superior clavicle displacement
- Types:
  - Traumatic dislocation = Usually high energy
    - Anterior (Commonest and less serious)
    - Posterior (mediastinal structures at risk)
  - Atraumatic subluxation
    - Occurs with overhead elevation of the arm
    - Patients may demonstrate signs of generalized ligamentous laxity
    - Subluxation usually reduces with lowering the arm
    - Treatment is reassurance and local symptomatic treatment.
- Presentation:
  - Anterior dislocation
    - Bruising and prominent medial end of the clavicle
  - Posterior dislocations
    - Can compress the vital neck structures causing dysphagia, dyspnoea, and vascular compromise
    - Can cause pneumothorax and in rare cases lead to death
- Physical exam
  - Anterior:
    - Prominence a medial end of clavicle that increases with arm abduction and elevation
  - Posterior:
    - Ecchymosis and obvious deformity
    - Protraction of scapula
- Investigations:
  - X-ray: widening joint space, angled view shows an inferior displacement of the medial clavicle indicate posterior dislocation
  - CT
- Management:
  - Conservative for:
    - Chronic anterior dislocation especially in elderly
    - Atraumatic subluxation.

- Surgical:
  - Closed reduction and stabilisation
  - Open reduction and stabilisation
  - Medial clavicle excision

QUADRANGULAR SPACE SYNDROME

- Compression form: muscle hypertrophy, labral cysts, trauma
- Atrophy and weakness of teres minor and deltoid
- EMG: Axillary nerve involvement
- MRI: compression
- Diagnostic Lidocaine block
- Treatment:
  - Physiotherapy
  - Nerve decompression

ACROMIOCLAVICULAR JOINT INJURIES

- ACJ
  - Diarthrodial synovial joint with a fibrocartilagenous intra-articular disc.
- Stabilizers:
  - Dynamic- Deltoid and Trapezius
  - Static- AC ligaments, coracoclavicular (CC) ligaments, deltotrapezial fascia and capsule

	Components	Direction of stability
Acromioclavicular ligament	Superior, inferior, anterior, and posterior components Superior ligament is strongest, followed by posterior	Horizontal stability
Coracoclavicular ligaments	Trapezoid and conoid Ligaments	Vertical stability
	Trapezoid ligament inserts 3 cm from the lateral end of clavicle.	Horizontal and vertical loads
	Conoid (more important ligament) Inserts 4.5 cm from the lateral end of clavicle in the posterior border	Vertical stabilizer of AC joint
Others	Deltotrapezial fascia, capsule	Additional Multidirectional stabilizers- mainly vertical stability.

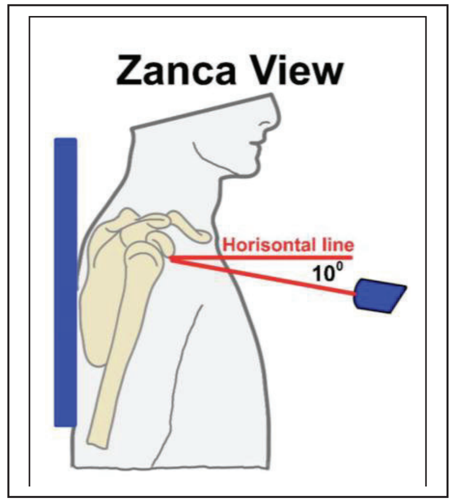
CLASSIFICATION OF ACJ INJURIES

- The most commonly used classification is the Allman & Tossy (Allman, 1967; Tossy et al, 1963) who classified ACJ injuries into type I- III. In 1998, Rockwood proposed a modification by adding grades IV- VI.

Rockwood classification of ACJ injuries into six grades	
• **I**	• AC joint sprain
• **II**	• Subluxated ACJ with intact CC ligaments
• **III**	• Dislocated ACJ with disrupted CC ligaments
• **IV**	• Superiorly and posteriorly dislocated ACJ
• **V**	• Dislocated ACJ with100–300% separation
• **VI**	• ACJ dislocated and Inferiorly displaced under the Coracoid

RADIOGRAPHIC EVALUATION

- Bilateral AP radiograph: compare distance from the top of the coracoid to the bottom of the clavicle to the contralateral side.
- Zanca view: 10°cephalic tilt and 50 % penetration, improved visualization of ACJ by eliminating overlying structures
- Axillary view: assess for posterior clavicle displacement (type IV)



Treatment

- Non-operative (I, II, and most type III injuries)
  - Sling for 3 weeks, early range of motion, return to activities at 12 weeks
  - **Systematic review – Spencer – Clin orth rel res**
    - Surgical treatment not better than non-operative
      - Higher complication rate
      - Longer recovery prior to return to sport/work
  - In children sleeve fractures can look like type III, but both AC and CC ligaments still attached remodels very well
- Operative (IV, V, and VI injuries)
  - Consider in type III injuries in labourers and elite athletes
  - The current literature is full of surgical techniques (>100 techniques) used to treat acute and chronic ACJ Injuries. These techniques include primary repair of the CC ligaments, augmentation with autogenous tissue like coracoacromial (CA) ligament, augmentation with absorbable and non-absorbable suture as well as synthetic material, and CC stabilization with metallic screws.
  - There are six basic operative techniques used to treat ACJ Injuries: AC ligament repair, dynamic muscle transfer, CA ligament transfer, CC ligament repair, distal clavicle resection with CC reconstruction, and anatomic reconstruction of the CC ligaments.
  - Mckee – Toronto - COTS RCT – 2015 non op Vs op; No difference in DASH and constant scores at 2 years

➢ <u>Rehabilitation protocol</u>
- In 1997, Gladstone et al published a four-phase rehabilitation protocol for non-operative management for athletes. This protocol is still used with some modifications (Table)

Phase	Protocol
I	• Pain control, immediate protective range of motion, and isometric exercises
II	• Strengthening exercises using isotonic contractions
III	• Unrestricted functional participation with the goal of increasing strength, power, endurance, and neuromuscular Control
IV	• Return to activity with sport-specific functional drills.

Complications
➢ ACJ degenerative changes: (distal clavicle excision).
➢ Chronic instability: (distal clavicle excision with stabilization of the stump).
➢ <u>Tip</u>: AC joint arthrosis best treated with distal clavicle excision if the patient failed a conservative treatment

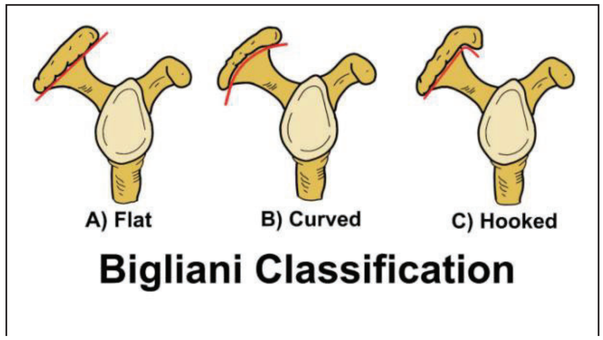
ACJ OA
➢ Investigations:
- X-ray: Zanca view.
- MRI increased signal

➢ Treatment
- ACJ injection with corticosteroids- can be both diagnostic and therapeutic
- ACJ resection arthroscopic or open (Mumford procedure)
  - Keep superior lig. It is most important for stability
  - Resect only 0.5-1cm of distal clavicle to avoid instability
  - Open procedure requires meticulous repair of deltoid-trapezial fascia to prevent wound dehiscence

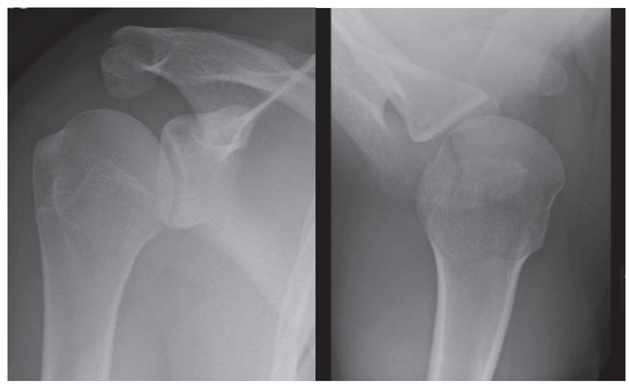
DISTAL CLAVICLE OSTEOLYSIS
➢ Caused by repetitive micro-fracture in distal clavicle- Common in weight lifters.
➢ Leads to inflammation, bone resorption and arthritis
➢ Treatment: same as ACJ OA.

SUBACROMIAL IMPINGEMENT

- <u>Causes</u>
    - Anatomical: bony spur, thickened AC lig or bursa and os acromiale
    - Functional: poor cuff control
- <u>Types of acromion- Bigliani Classification:</u>
    - Based on supraspinatus outlet view
      I - Flat
      II - Curved
      III – Hooked



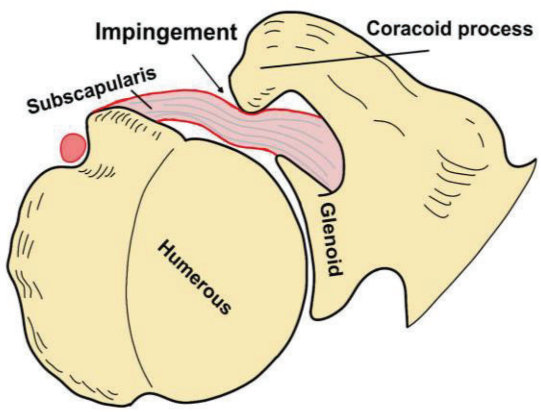
- 3 ossification centres unite to form acromion
    - Meta-acromion (base)
    - Meso-acromion (mid)
    - Pre-acromion (tip)
    - Os acromiale between meta and meso


(Courtesy of M Imam)

- <u>Assessment</u>
    - True AP of shoulder: evaluate acromiohumeral interval - normal distance is 7-14 mm
- <u>Management</u>
    - BESS/BOA care pathway
        - Non-operative minimum 3 months
            - Physiotherapy
        - Operative
            - Avoid acromioplasty and CA ligament release to preserve CA arch in patients with massive, irreparable rotator cuff tears
            - <u>Can Shoulder Arthroscopy Work (CSAW) trial – Lancet - 2018</u>
                - ✓ Surgical groups had better outcomes for shoulder pain and function compared with no treatment but this difference was not clinically important
                - ✓ Surgical decompression appeared to offer no extra benefit over arthroscopy only
                - ✓ The difference between the surgical groups and no treatment might be the result of a placebo effect or postoperative physiotherapy
        - Os acromiale fuse with bone graft and stabilization, excision can lead to deltoid dysfunction. Only consider removal when it's a small fragment

SUBCORACOID IMPINGEMENT

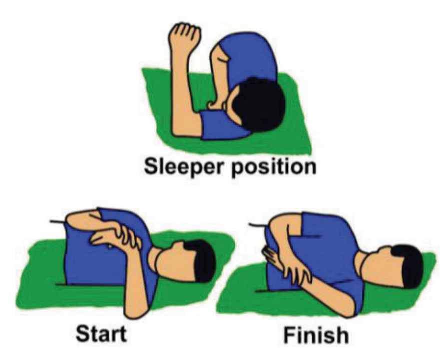
- Impingement_of subscapularis between coracoid and lesser tuberosity
- Coracoid
  - Muscle attachments: coracobrachialis, short head of biceps and pectoralis minor
  - Ligament attachments: coracohumeral, coracoacromial and coracoclavicular
- Coracohumeral distance of < 6 mm considered abnormal
- Treatment:
  - Ultrasound guided injection
  - Arthroscopic coracoplasty +/- subscapularis repair



Subcoracoid impingement

INTERNAL IMPINGEMENT

- Pathology on under-surface of rotator cuff
- Impingement of intra-articular under-surface of posterior supraspinatus against posterior-superior glenoid.
- Due to anterior capsular laxity and posterior capsular tightness.
- In abducted and externally rotated position; posterior rotator cuff impinges on posterosuperior labrum
- Associated with
  - GIRD (Glenohumeral Internal Rotation Deficit)
    - Caused by repetitive throwing
    - Increased external rotation and decreased internal rotation
  - PASTA (Partial Articular-Sided Supraspinatus Tendon Avulsion)
- Treatment:
    - Posterior capsular stretching sleeper stretch exercise
    - Arthroscopic repair or posterior capsular release



Sleeper stretching exercise

CALCIFIC TENDONITIS

- History: Pain   Acute presentation mimic septic arthritis
- Examination:
  - Look   Muscle wasting: deltoid, Supraspinatus and Infraspinatus
  - Feel   Muscles tenderness in fossae and insertions
  - Move
    - Active: Supraspinatus weakness unable to initiate shoulder abduction
    - Passive: difference between active and passive
      - Ask the patient to push against the wall for winging if any dyskinesia
  - Special tests: Power & lag tests for each muscle together
    - Feel muscles while testing the power
    - Supraspinatus; Jobe test, drop sign
    - Infraspinatus; External rotation with resistance, lag sign
    - Teres minor; External rotation in abduction, Hornblower's sign
    - Subscapularis; Belly press, lift off
    - Examine the deltoid power resisted abduction at 90 deg flexion
  - Calcification and tendon degeneration near rotator cuff insertion
  - Build-up of calcium crystals
- Phases
  - Formation; calcific deposits
  - Resting
  - Resorption; inflammation 2nd to phagocytosis. (Most painful)
- Investigations
  - US very sensitive
  - Plain X-Ray can show calcium deposits.
- Treatment
  - Physical therapy
  - Subacromial injection
  - Ultrasound guided lavage/needling of deposits (barbotage).
  - ECSW therapy
  - Arthroscopic/open decompression of deposits
    - Snowstorm appearance
    - Risk of shoulder stiffness


(Courtesy of M Elgendy)

ROTATOR CUFF TEARS

- Incidence of cuff tears with dislocation increases with age
- Classification according to shape
  - Longitudinal
  - Crescent shaped
  - U shaped
  - L shaped
- Causes
  - Extrinsic; Impingement, osteophytes
  - Intrinsic; Age , diabetes
- Ultrasound; limited ability to evaluate other intra-articular pathology
  - BESS guidelines: as accurate as MRI at detecting FT tears compared to arthroscopic findings
  - Partial thickness tears, LHB, bursal thickening and fluid, not reliable evidence to support the use of USS
  - Size and retraction of full thickness tears is inaccurate
- MRI; better than US in patients with OA and frozen shoulder as they can't move
- Medial biceps tendon subluxation indicative of subscapularis tear
- Irreparable tears
  - fatty atrophy >50% usual cut off
  - Retraction beyond glenoid
  - Superior displacement of humeral head & AHI < 7mm
- <u>Grades of Goutallier classification of rotator cuff muscle fatty degeneration</u>
  - **0**: normal muscle
  - **1**: some fatty streaks
  - **2**: less than 50% fatty muscle atrophy
  - **3**: 50% fatty muscle atrophy
  - **4**: greater than 50% fatty muscle atrophy
- <u>Sher – JBJS – 1995</u>;
  - 35 % of asymptomatic individuals had tear
  - Increases with age: Incidence in > 60 is 40% (10% with OA)
- <u>Treatment</u>
  - Pain relief
  - Rotator cuff and deltoid strengthening and scapular stabilization
  - Surgery Indications:
    - Symptomatic tear failing to respond to conservative treatment
    - Reduced Activities of daily living and pain
    - Partial tear in young (debridement in old)
      - Mini open/arthroscopic
        - ✓ No difference in post-operative outcome or incidence of re-ruptures
        - ✓ Decreased post-operative pain in short-term in arthroscopic repair

- ✓ Techniques:
  - ☒ Side to side (margin convergence)
  - ☒ End to bone
- ✓ Prepare shallow footprint at the level of tendon insertion lateral to articular surface to allow tendon-to-cancellous bone healing
- ✓ Single or double row anchor repair or trans-osseous (bone tunnels) suture repair
- ✓ Double row suture technique mattress sutures in medial row and simple sutures in lateral row

o <u>UKUFF trial BJJ 2017</u>

- ✓ Open Vs arthroscopic in older than 50
- ✓ No difference in clinical outcome in 2 years
- ✓ Management of Recurrence or massive tears
  - ☒ Pec major transfer for subscapularis tears
  - ☒ Latissimus dorsi transfer for Supraspinatus and Infraspinatus tears. Need intact subscapularis to counter-pull
- ✓ Critical/dead-man angle between axis of pull of tendon and anchor
  - ☒ Ideal is 45^0 to improve pull out strength
- ✓ Evolving treatment: biological repair with extracellular matrix graft jacket. Relief pain but doesn't restore full strength

- Post op rehabilitation
  - Early passive ROM for 4 weeks
  - Then start an active assisted ROM for 4 weeks
  - Then active ROM

Rotator cuff for FRCS

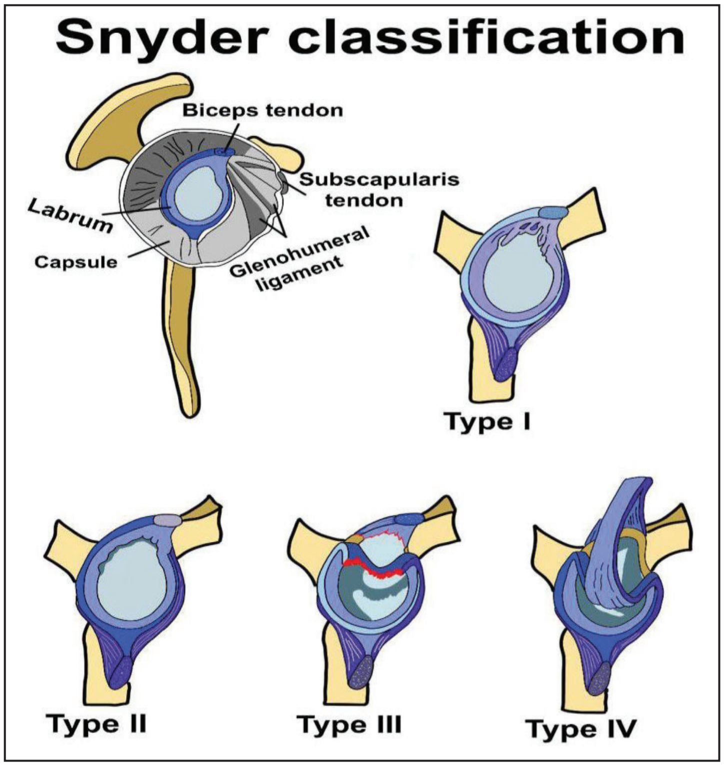
➢ <u>Differential Diagnosis</u>: Suprascapular nerve entrapment

➢ <u>Complications</u>

- Infection:
  - Caused by common skin flora.
  - Propionibacterium acnes the most common organism in delayed or indolent cases.
- Suprascapular nerve injury with aggressive mobilization of supraspinatus during repair
- Re-tear up to 50 % (majority asymptomatic)

SLAP LESIONS

- Superior labrum from anterior to posterior tears
- Highest incidence at the site where biceps tendon anchors
    - Has the poorest blood supply
    - Blood supply to the labrum from capsule
- Causes: repetitive overhead activities
- Most common pattern of biceps tendon attachment to superior labrum is at 12 o'clock position
- Anatomical variants:
    - Sub-labral foramen/recess in 12% of population
    - Buford complex incidental finding in 1.5% of shoulders
        - Cord-like MGHL and absent anterosuperior labrum
        - If reattached leads to severe restriction of rotation and elevation
- Snyder classification: (now extended to include 10 types)
    - Type I: degenerative fraying of biceps and labrum debridement
    - Type II: detached labrum and biceps tendon anchor.
    - Type III: bucket handle tear of labrum with intact anchor
    - Type IV: bucket handle tear of labrum with detached anchor

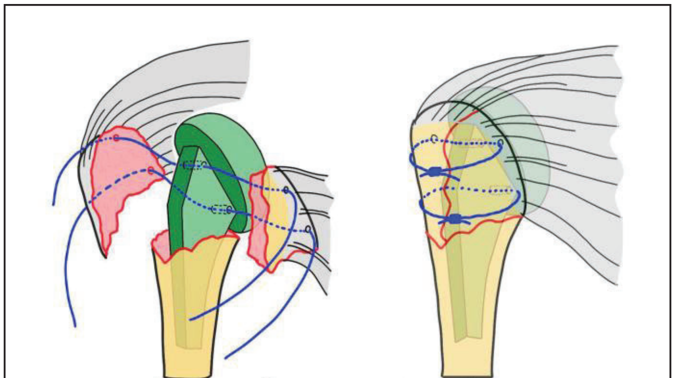


- MRI:May shows an associated para-labral ganglion cyst in the spinoglenoid notch
- Surgery
    - Controversial typical in overhead athletes but results of repair not consistent
    - Repair vs tenotomy.
- Post op: Focus on healing and re-establishing motion, followed by strength training

SHOULDER OA

- History:
  - Night pain
  - Activities of Daily Living: eating, brushing hair, personal hygiene
- Examination:
  - Look:
    - Muscle wasting: particularly in rotator cuff arthropathy
    - Geyser sign
      - Fluid collection over the ACJ
      - Indicate recurrent effusion with synovial fluid free to communicate between glenohumeral joint & subacromial bursa
      - Can also be caused by ACJ cyst
  - Feel; ACJ, biceps tendon
  - Move;
    - Limited active and passive movements mainly external rotation
    - Functional assessment
      - Hand to mouth for eating and shaving
      - Behind head for brushing hair
      - Behind back for wiping the bottom
- Investigations
  - Radiographs:
    - True AP 30^{o} angled in coronal plane
    - Axillary to look for posterior glenoid wear
  - CT:
    - Indicated if large bony defects present on radiographs
    - To assess the glenoid wear, version, and overall bone stock
  - MRI to evaluate rotator cuff
- <u>Rotator cuff arthropathy</u>
  - Anterosuperior escape of humeral head.
  - Acromial acetabularization.
  - Anterior subluxation on axillary view due to damaged subscapularis
  - Pattern of wear is typically superior and posterior
  - Biomechanically occurs because of loss of fixed fulcrum (concavity compression) function of rotator cuff resulting in unopposed deltoid action.
- <u>Management</u>:
  - Non-operative
    - physiotherapy to maintain ROM and improve deltoid function
    - Patients with rotator cuff arthropathy can benefit from SAD and biceps tendon decompression
  - Hemiarthroplasty
    - Best indications are AV, trauma, or poor glenoid bone stock (RA)
    - Trauma stem has holes for GT and LT reattachment
    - In a young active – high risk of glenoid replacement loosening
    - Can be used in rotator cuff arthropathy- must have intact deltoid and CA arch
    - Used when glenoid bone stock inadequate

- Progressive glenoid arthrosis and erosion requires conversion to TSR
- Increased rate of revision surgery compared to TSR
- Implant height:
    - o Tip of GT 10 mm below tip of articular surface of humeral head
    - o Distance from top of prosthesis to upper border of pec major 6 cm
- Tuberosity displacement following reattachment is the most common cause of failure for fractures treated with hemiarthroplasty
- Role for Pyrocarbon heads: closer Young's modulus to bone, less wear to glenoid. Still low numbers also an option in OA in young active



Anatomic reconstruction of GT,LT on a traumatic prosthesis

- Resurfacing
    - Maintains anatomy by placing the prosthesis in the native anatomical location
    - Requires well preserved head bone stock and intact rotator cuff and no significant glenoid disease
    - Smaller operation and reduced risk of dislocation
    - Good option in young patients to preserve bone stock
    - Easy to overstuff
- Numbers reducing as TSA and Hemiarthroplasty more consistent

- **Total Shoulder Arthroplasty**
  - Indications
    - glenoid wear
    - Glenohumeral arthritis with intact cuff
  - Contraindications
    - Non-functioning deltoid
    - Rotator cuff tear:
      - ✓ Loosening due to unopposed contracture of deltoid – (Rocking horse phenomenon- movement of the humeral head sup ↔ inf or ant ↔ post)
      - ✓ Superior migration and eccentric loading (edge loading)
    - Infection
    - Insufficient glenoid bone stock: erosion down to coracoid or excessive eccentric erosion resulting in a need for "high sided reaming" > 15 degrees
  - Glenoid
    - Build up with iliac crest bone graft and not cement
    - Only 1.5 cm deep
    - Glenoid component pear shaped to match glenoid
    - Concentric reaming to improve contact
    - Peg design biomechanically superior to keel design, to counter shear stress
    - Polyethylene-backed superior to metal-backed components (lateralize joint line – tightness)
    - Uncemented glenoid has the lower rate of loosening
  - Humeral osteotomy:
    - 0 – 30° retroversion, increased retroversion improves ext rotation.
    - 45° to long access
  - Complications:
    - Stiffness
    - Malposition of components ◊ instability and dislocation
    - Glenoid erosion or loosening
      - ✓ <u>most common</u> cause of failure in RA
      - ✓ From poly debris (Osteolysis)
    - Humeral/glenoid fracture
    - Stem loosening: same rate in cemented & cementless (1-2%)
      - ✓ Rotator cuff tear repair to avoid glenoid loosening
    - Subscapularis repair failure & anterior shoulder instability
  - **NICE 2010**; No difference in function & pain relief between resurfacing & TSR
  - **AAOS 2009**; suggests total shoulder arthroplasty over hemiarthroplasty
  - **Meta-analysis - Bryant – JBJS – 2005**; at minimum of 2 years follow-up, TSA provided better pain relief and function than hemiarthroplasty for patients with OA
  - **NJR.**; cumulative revision estimate at three years was 3.4%
    - median preoperative Oxford Shoulder Score (OSS) was 16, rising to 36 at 6 months
    - Overall 90.8% of elective patients had improvement in OSS, with 8.3% worse and 0.9% the same

Shoulder arthroplasty for FRCS

Mechanics of gleno-humeral arthroplasty

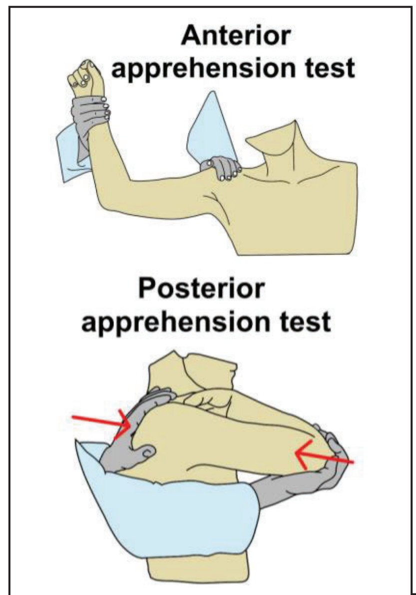
- **Reverse shoulder replacement**
  - Better than hemi in trauma with comminuted GT fracture as healing unpredictable especially in elderly
  - Use convex glenoid (hemispheric ball) and concave humerus (articulating cup)
  - Acromiohumeral distance < 7mm and disrupted shoulder Shenton line indicate rotator cuff massive tear
  - Moves glenohumeral joint's centre of rotation medially & inferiorly compared to native anatomy
  - Based on Gramont's principle
  - Prosthetic design can be subclassified by Routman et al into designs with centre of rotation (COR) 5mm or less from glenoid face (medialised glenoid MG) or > 5mm from glenoid face (lateralised glenoid, LG)
  - Increase deltoid lever (moment) arm to compensate for rotator cuff deficiency – increase power
  - MG designs improve fixation by decreasing shear stress and imparts greater moment arm for deltoid but potentially shorten and weaken residual cuff muscles and produce less "deltoid wrapping" contributing to instability
  - LG designs medialise COR relatively less resulting in shorter deltoid moment arm but can give a better "deltoid wrapping" effect improving tensioning of the deltoid.
  - There also designs to medialise or lateralise the humerus too.
  - Must have intact deltoid and adequate glenoid bone stock
  - Mount glenosphere onto baseplate
  - Reconstruction socket achieving fixation in glenoid, coracoid and acromion. salvage for failed RSR
  - Consider latissimus dorsi transfer for a better external rotation
  - Complications
    - o Glenoid prosthetic loosening the most common mechanism of failure due to high torque forces
    - o Scapula notching decreased by placing the glenoid component as inferior as possible with inferior tilt Instability and dislocation
    - o Stiffness
    - o Infection
    - o Impingement
    - o Periprosthetic and scapula fracture
    - o Axillary nerve injury

Courtesy of M Elgawadi

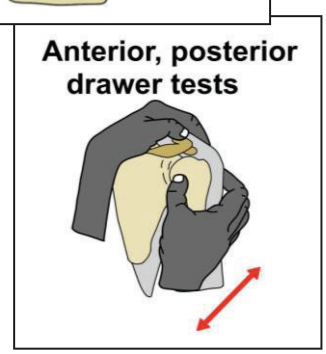
- **Pre-operative planning for shoulder Arthroplasty**
  - Essential to assess glenoid bone loss
  - Aids decision making about type of implant
  - Axial CT is best method to assess glenoid bone loss
  - Friedman et al described a method using an axial slice at the level of the coracoid tip. The version is equal to the angle subtended by a line drawn between the scapular axis (from medial tip of scapula to midpoint of glenoid) and glenoid face (between anterior and posterior margins of the glenoid face)
  - Walch et al described glenoid wear patterns in primary osteoarthritis classifying them into:
    - o A (central erosion)
    - o B (posterior humeral subluxation**)**
    - o C (> 25 degree retroversion)
  - We can also assess cuff mass via the sagittal view on CT or MRI
  - If cuff loss or excessive retroversion needs reverse
  - If intact cuff but excessive retroversion may need bone block or metallic wedge augment (with anatomical TSR) or a reverse

SHOULDER INSTABILITY

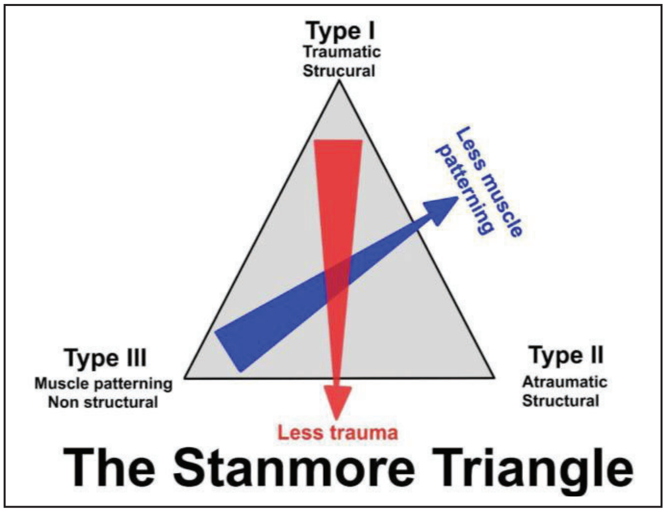
- **Shoulder restraints**
  - **Static**
    - Glenoid labrum fibrocartilage which deepens the glenoid by 50% thus increasing the surface area and provides origin of the capsular ligaments.
    - Articular surface thicker at the periphery like the meniscus in the knee provides foundation of the concavity-compression effect of the
    - Glenohumeral osseous morphology
    - Negative intra-articular pressure
    - Gleno-humeral capsular ligaments
      - o Superior GHL & coracohumeral ligaments: Restraint to anterior translation at 0o of abduction.
      - o Middle GHL: AP stability at 45o of abduction & external rotation.
      - o Inferior GHL: Acts as a hammock, 2 bands.
        Anterior band: Restraint to anterior translation in 0o abduction & ext-rotation.
        Posterior band: Restraint to posterior subluxation at 90o flexion and int-rotation
  - **Dynamic**
    - Rotator cuff muscles innervated by C5-C6
    - Long Head of Biceps tendon acts as head depressor
    - Proprioception important in multidirectional instability



- History:
  - Young patient
  - Mild anterior shoulder pain
  - Instability
    - Traumatic or atraumatic
    - 1st episode: mechanism - treatment
    - Frequency
    - Neurological symptoms
  - ADL Work- hobbies - sports
    Ask about generalized laxity
  - FHx: facioscapulohumeral muscular dystrophy
- Examination
  - Look
  - Feel
  - Move: ROM (quick screening)
  - Tests
    - Sit down
    - Sulcus test
    - Anterior & posterior drawer
    - Anterior & posterior apprehension: “please let me know if you feel your shoulder is going to come out of socket”
    - Jobe relocation test: following the anterior apprehension test. Apply posterior pressure and discomfort will go away
    - Mention **Beighton Score** (see before)



- Stanmore classification (Bayley triangle)
- Spectrum:
  - Traumatic /structural: TUBS
  - Atraumatic /structural: Capsular dysfunction from stretching
  - Habitual /non-structural: AMBRI



- **AMBRI**
  - o Atraumatic, Multidirectional, Bilateral, Rehabilitation (Tx), Inferior capsular shift (Surgical Tx)
  - o Causes:
    - ✓ Congenital : Ligaments laxity, Ehlers-Danlos, Marfan's
    - ✓ Acquired: Repetitive microtrauma, Abnormal muscle patterning
  - o Treatment
    - ✓ Strengthen dynamic stabilizers: Kinetic closed chain exercises
      - ❖ Physical therapy to strengthen peri-scapular muscles to actively compress humeral head into glenoid cavity and support shoulder girdle
    - ✓ Capsular shift: from inferior to superior
      - ❖ Failure of extensive non-operative management
      - ❖ Risk to axillary nerve
      - ❖ Rotator interval closure: plicate by suturing SGHL & MGHL

- **TUBS**
  - Traumatic Unilateral dislocations with a Bankart lesion requiring Surgery
  - Associated injuries: Bony, Ligaments, Tendons, NV
  - Investigations:
    - Axillary: Best view
    - Gareth apical oblique view
    - MRI arthrogram (gadolinium)
      - o Anterior & posterior labrums best seen on axial images
      - o Bankart lesion appears as loss of normal triangular shape or contrast material leaking
      - o ABER: Abduction external rotation position improves accuracy.
    - CT arthrogram: to assess bony component of instability

- **Bankart lesion**
  - Soft tissue: Avulsion of anterior inferior labrum & anterior band of IGHL
  - Bony: fracture of anterior inferior glenoid
    - If > 25% then requires bone graft or coracoid transfer

- **Perthe's lesion**
  - Variation of Bankart lesion
  - The anterior inferior labrum is torn and lifted from the edge of the glenoid but still attached to the intact lifted periosteum from the anterior aspect of the glenoid.
  - Labrum may appear in a normal position at surgery, but functionally unstable
  - Seen on MRI or CT Arthrogram

- **Management**
  - Non-surgical Vs surgical (Epileptic patient at least 6 months seizures free before considering surgery)
  - Instability severity index score is based on pre-operative questionnaire, clinical examination, and radiographs
  - A score of ≤ 6 points a risk of recurrence 10% with arthroscopic stabilization
  - A score of > 6 points a risk of recurrence 70% and open surgery more appropriate
  - Open repair: if bony defect, HAGL OR Hill Sachs
  - Arthroscopic: less soft tissue injury, quicker rehab
    - Prepare glenoid
    - Anchors: 3 <3.5 mm at 45 deg
    - 3-6 O'clock in Rt shoulder and 6-9 O'clock in Lt shoulder
    - Supplemented with capsular plication
  - Bristow: Coracoid transfer with conjoint tendon to anterior inferior glenoid defect
  - Latarjet: Arthroscopic or Open, coracoid passed through split in proximal 3rd of subscapularis. Provides a triple effect
    - Bony by increase a glenoid surface area
    - Conjoined tendon through sub-scab works as a dynamic stabilizer
    - Capsule reconstruction
    - Overall complication 15-30 %
  - Putti-Platt: lateral advancement/double breasting of subscapularis, and medial advancement of capsule
    - Does not address pathology.
    - Results in early OA (uneven stresses on glenoid) and limitation of Ext-Rot.
- **HAGL lesion** : Humeral Avulsion of Glenohumeral Ligaments

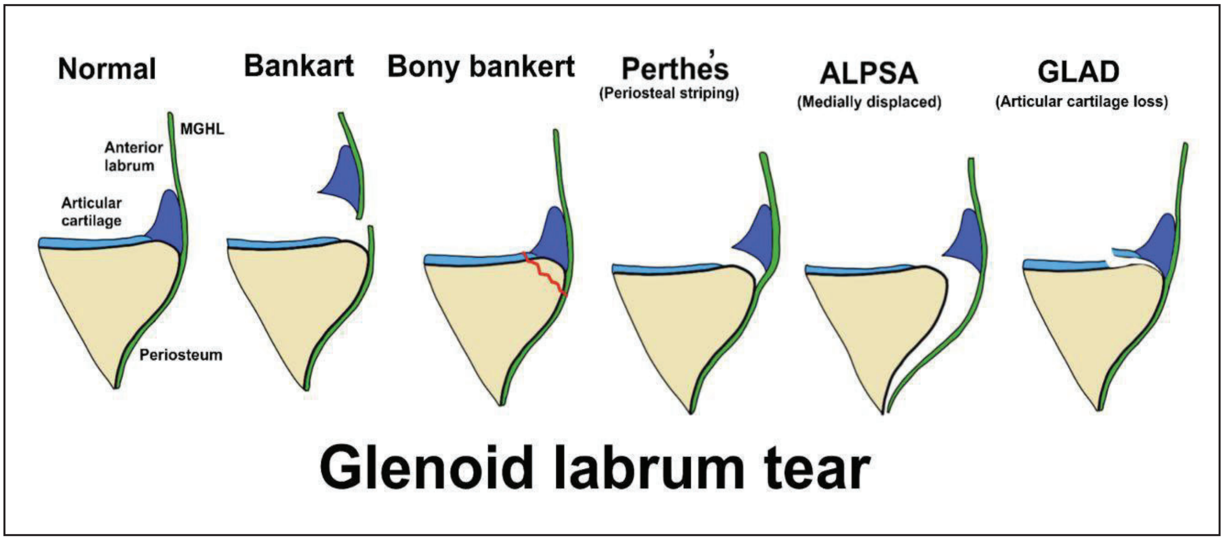
- **ALPSA**:
  - Anterior Labral Periosteal Sleeve Avulsion
  - Displaced tear of anteroinferior labrum

- **GLAD**: Glenoid labral articular defect
  - Sheared off portion of articular cartilage along with labrum

- **Hill Sachs lesion**
  - Cortical depression in posterolateral head of humerus
  - Forceful impaction of humeral head against anteroinferior glenoid rim when shoulder dislocates anteriorly
  - Pathognomonic sign of dislocation
  - Engaging lesion: contact with glenoid in < 40^{o} of external rotation – lever shoulder out of joint needs bone graft as it can lead to re-dislocation.

HILL SACHS
(Courtesy of M Elgawadi)

- Best view is Stryker notch view
- Management: Connolly procedure for instability
  - Transfer infraspinatus with portion of greater tuberosity into defect
  - Remplissage technique posterior capsule and infraspinatus tendon sutured into Hill-Sachs lesion



Posterior shoulder dislocation

- ➢ Shoulder locked in internal rotation
- ➢ Usually caused by electric shock or epileptic seizure: stronger internal rotators (lat dorsi, pec major, subscap, teres major) overpower weaker external rotators (infraspinatous & teres min)
- ➢ Get CT before reduction to check not locked as increases torque on proximal humerus causing potential fracture
- ➢ Reduction: flexion, adduction and axial traction
- ➢ Kim lesion: incomplete avulsion of posterior labrum
- ➢ Reverse Hill Sachs lesion:
  - Anteromedial head against posterior glenoid rim
  - Common in locked posterior dislocations

(Courtesy of M Elgendy)

- ➢ Management:
  - McLaughlin: transfer subscapularis tendon with lesser tuberosity into defect
  - Immobilize: In neutral rotation, abducted to 30 deg and shoulder posterior to plan of body
  - Posterior Bankart repair
  - Posterior capsular shift
  - Hemiarthroplasty: reverse Hill-Sachs defect > 50% of articular surface
  - Missed dislocation and late presentation: consider CT scan and referral to shoulder specialist

Inferior Shoulder Dislocation (Luxatio Erecta)

- Greatest risk of neurological (axillary) & vascular (late axillary artery thrombosis) injuries.
- Presents with arm overhead with shoulder in full abduction, and elbow in flexion

REDUCTION OF ANTERIOR SHOULDER DISLOCATION

- Assess neurovascular state and documented clearly before attempt manipulation
- Review the X-ray carefully for any fracture extending to the surgical neck, can displace during manipulation
- Adequate analgesia consider intra-articular LA injection
- Conscious sedation administered and monitored by airway competent doctor
  - Kocher:
    - Bend elbow – adduct – ex rotate to unlock head
    - Then flex –abduction - int rotate
  - Hippocratic: Traction-counter-traction, sheet (or foot) through axilla, slight abduction
  - Stimson: Prone - Apply weight to forearm
  - Milch: Abduct & externally rotate arm - push humeral head with contralateral hand
- Repeat examination and X rays post reduction
- Place in stable position
- If can't reduce closed – open reduction via delto-pectoral approach
- What can block reduction?
  - GT fracture
  - LHB caught posterior to humerus head
- Re-dislocation rate increased in younger patients
  - < 20 yr 90%
  - 20 – 30 60%
  - 30 – 40 30%
  - >40 10%
- Prospective comparative study – Finestone – 2009 –BJJ
  - Bracing in external Vs internal rotation for traumatic anterior dislocation of shoulder
  - No significant difference (p = 0.74) between groups in recurrence of dislocation
- Cochrane: Traumatic anterior dislocation of shoulder treated by post-reduction immobilisation with arm in either external or internal rotation
  - No difference between two groups in return to pre-injury sports, re-dislocation or shoulder instability
- External rotation brace: maximum contact between labrum and glenoid in 45 deg external rotation
  - Compliance is a problem
- Cochrane review: Limited evidence supports primary surgical intervention

SHOULDER APPROACHES

Deltopectoral approach

- Workhorse for shoulder surgery
- Indications: Proximal humerus fractures shoulder arthroplasty stabilization of unstable shoulder
- Beach chair Position
  - Tilted feet up to avoid patient sliding down table
  - Knees bent to avoid stretching the sciatic nerve
  - Risk of reduced cerebral perfusion
- Surface Landmarks: Tip of coracoid process and extend distally and laterally to the insertion of deltoid
- Internervous plane
  - Deltoid muscle (axillary nerve)
  - Pectoralis major (medial and lateral pectoral nerves)
  - Deltopectoral interval identified by localizing cephalic vein and fat stripe
    - Care to preserve cephalic vein throughout the procedure
  - Incise clavipectoral fascia
  - Subdeltoid sweep in fractures
  - Conjoined tendon muscles and pectoralis major retracted medially
    - Musculocutaneous Nerve enters biceps 5-8cm distal to coracoids- retract conjoint tendon carefully
  - Deltoid retracted laterally
  - Blunt dissection to lift the conjoint tendon from subscapularis
  - Fascia on lateral side of the conjoint tendon swept to reveal subscapularis
  - Long Head of Biceps tendon should be identified as it provides an orientation to greater and lesser tuberosities lateral most point
  - For proximal humeral fractures: stop here and move laterally to reduce fracture.
  - Leash of vessels mark inferior margin of subscapularis – brachial plexus below
  - Stay suture on subscapularis 1-2 cm from insertion with arm in external rotation
    - Other method included osteotomy of lesser tuberosity with Subscapularsis.
  - Repair with arm in 30o of external injury rotation
  - To optimize exposure recess deltoid insertion on acromion & humerus
  - Coracoid osteotomy
  - Extend into anterolateral approach to humerus shaft
  - Tight shoulders may require release of upper part of pectoralis major tendon

Lateral (deltoid splitting/McKenzie approach) to shoulder

- Indications:
    - proximal humerus fractures
    - rotator cuff repair
    - subacromial decompression
    - Reverse Shoulder Replacement good access to glenoid
- No internervous plane
- 5 cm incision from tip of acromion distally in line with arm
- Deltoid split in line with fibres, stay suture at apex of split to prevent propagation
- Axillary nerve lies 5 cm distal to acromion, runs from posterior to anterior
- Damage will denervate anterior deltoid
- Subacromial bursa can be excised to reveal underlying rotator cuff and proximal humerus

Posterior approach to shoulder (Judet)

- Indication
    - Bone block stabilization of posterior shoulder dislocation
    - Fixation of scapula neck fractures
    - Biopsy/excision of tumours
- Position
    - lateral
    - prone
- Internervous plane: between infraspinatus (Suprascapular N) & teres minor (axillary N)
- Incision: along scapular spine
- Approach:
    - Deltoid retracted distally/laterally to expose infraspinatus.
    - Use plane between Infraspinatus and Teres Minor (easier to find the plane at the lateral side), exposing the Posterior shoulder capsule.
- Structures at risk:
    - Axillary nerve
    - Suprascapular Nerve
    - Posterior Circumflex Humeral artery

(Shoulder approaches for FRCS)

SHOULDER ARTHROSCOPY

- Indications:
  - Rotator cuff repair
  - Labral/SLAP repair
  - Subacromial decompression
  - AC joint pathology
  - Biceps tenotomy/tenodesis
- Position
  - Beach chair advantage: ability to convert to open surgery if required
  - Lateral decubitus advantage: joint distraction and less need for assistants.
- Posterior portal
  - 2 cm inferior and 1 cm medial to posterolateral corner of acromion, between infraspinatus (suprascapular nerve) and teres minor (axillary nerve)
  - Primary viewing portal
  - Risk to axillary nerve if made too inferior and to suprascapular nerve if made too medial
- Lateral portal
  - for subacromial decompression
  - 1-2 cm distal to lateral edge of acromion.
  - Passes through deltoid (axillary nerve)
- Anterior portal
  - For passing instruments
  - Inside-out technique
  - Lateral to coracoid process and anterior to AC joint
  - Above lateral half of subscapularis and medial to biceps pulley
  - Risk to cephalic vein if made too lateral
  - Musculocutaneous nerve if made too inferior
- Anteroinferior: placing anchors for anterior labral repair
- Posteroinferior: placing anchors for posterior labral repair.

AVN OF HUMERAL HEAD

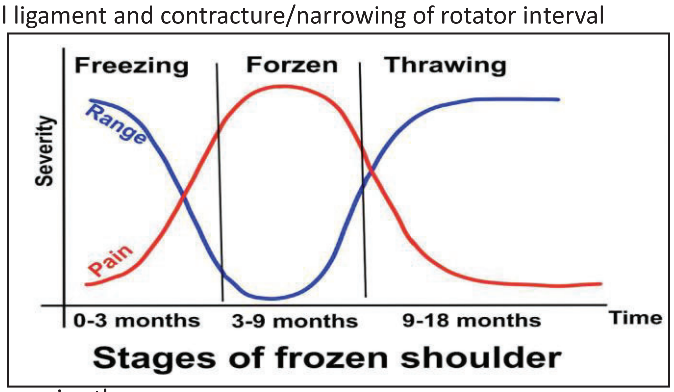
- History:
  - Painful arthritic shoulder in a relatively young patient
  - Think of causes, ask about: medications, trauma, haematological, alcohol, smoking, DM, radio and chemotherapy
- Causes: Same as hip AVN
- Cruess classification:
  - Stage 1: Pre-radiographic diagnosis MRI +ve
  - Stage 2: Sclerosis
  - Stage 3: Subchondral fracturing / crescent sign
  - Stage 4: Collapse of subchondral bone and loss of sphericity
  - Stage 5: Degenerative changes of glenoid
- Should also have hip radiographs performed
- Most common initial site is superior middle portion of humeral head
- Treatment: similar to hip AVN
  - Core decompression for pre-collapse stage
  - Humeral head resurfacing: Stage III with sufficient epiphyseal bone stock for fixation

FACIO-SCAPULOHUMERAL MUSCULAR DYSTROPHY

- Neuromuscular disorder which causes progressive muscle weakness in face, shoulder girdle, and upper arm
- Autosomal dominant
- Presentation:
  - Scapular winging with marked decrease in shoulder flexion and abduction
  - Transverse smile and absence of eyes and forehead wrinkles
- Investigations:
  - CPK: normal
  - EMG: mild myopathic changes
  - Muscle Biopsy: nonspecific
  - Genetic Testing
- Treatment
  - Non-operative: PT/OT, speech therapy
  - Scapulothoracic fusion.

FROZEN SHOULDER (ADHESIVE CAPSULITIS)

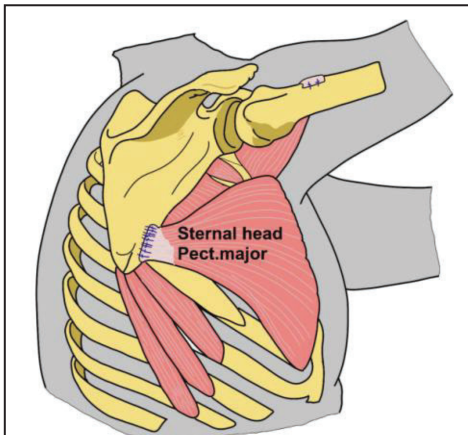
- History:
  - Most commonly female 40-60
  - Pain: Spontaneous onset and progressive
  - Painful loss of motion of shoulder without underlying cause
  - Stiffness
  - ADL
  - Tx received
  - Medical Hx: DM – trauma - hypothyroidism
- Examination:
  - Look: wasting
  - Move: global restriction of active and passive ROM especially external rotation
- Codman criteria for frozen shoulder
  - Global restriction of shoulder movements
  - Idiopathic aetiology
  - Usually painful at onest
  - Normal x-ray
  - Limitation of external rotation and elevation
- Pathology: Bunker – JBJS – 1995: Thick capsule, Increased vascularity, Increased collagen
  - Proliferation of fibroblasts which transform to myofibroblasts.
  - Essential lesion involves coracohumeral ligament and contracture/narrowing of rotator interval



- Classification
  - Primary
  - Secondary: trauma, or surgery
- Stages
  - Freezing: Painful
  - Frozen: Stiff
  - Thawing: Gradual return of motion
- MRI: loss of axillary recess
- Treatment
  - Physio:
    - Gentle stretching rather than aggressive therapy
    - Very painful in freezing stage
  - Consider supraclavicular nerve block for pain
  - MUA with or without steroid injection, possible complication fracture
  - Arthroscopic/open capsular release
    - Rotator interval & middle GH & CH ligament release
    - Use hook tip radiofrequency device
    - Inferior capsular release risk axillary N
  - Hydrodilatation X-ray / USS guidance or as part of arthroscopic surgery
LA
Contrast
Inject with steroid

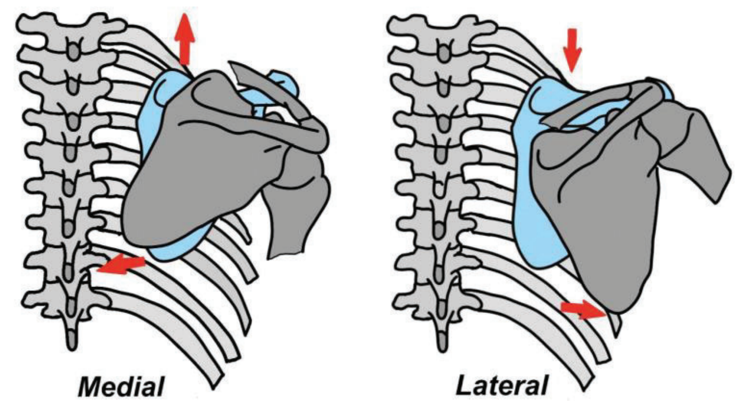
SCAPULA WINGING

- **Medial**
  - Inferior border tilted medially
  - Cause: Long thoracic N (Serratus anterior)
    - Stretch/compression injury
    - Iatrogenic axillary clearance for breast cancer
  - Examination: Press against wall
  - Treatment:
    - Muscle strengthening
    - Decompress space occupying lesion
    - Pectoralis transfer if no resolution after 1-2 years



Tendon transfer for medial scapular winging

- **Lateral**
  - Inferior border tilted laterally
  - Cause:
    - Spinal accessory nerve (CN XI) to Trapezius more common
    - Dorsal scapular Rhomboids
    - Iatrogenic injury: looking for lymph nodes in posterior neck
  - Conservative treatment less effective
  - Scapulothoracic fusion

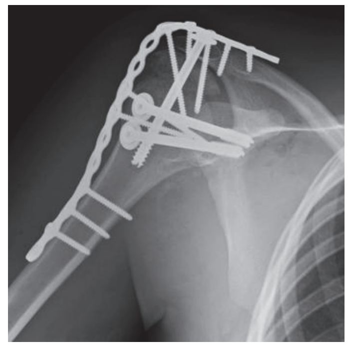


Scapular Winging

SHOULDER ARTHRODESIS

- Examination
  - Look: scars, wasting
  - Move: no active nor passive movements at GHJ
  - Neurological examination: can be due to neurological injury such as brachial plexus palsy

- Indications
  - Paralysis, brachial plexus injury.
  - Chronic infection.
  - Refractory instability.
  - Failed arthroplasty.
  - Reconstruction after tumour resection
- Contraindications
  - Ipsilateral elbow arthrodesis
  - Contralateral shoulder arthrodesis
  - Lack of functional scapulothoracic motion
  - Trapezius, levator scapulae, or serratus anterior paralysis
  - Charcot arthropathy during inflammatory stages because of continued bone fragmentation
  - Elderly patients
  - Progressive neurologic disease
  - Poor bone stock: CT for assessment
- Position
  - Goal to allow the patient to reach mouth for feeding.
  - 30^{o} internal rotation, 30 deg flexion, 30 deg abduction.
  - To increase available fusion area.
  - Decortication of glenohumeral articular surface.
  - Articulation between humeral head and under surface of acromion.


(Courtesy of M Imam)

SCAPULOTHORACIC CREPITUS

- Pain at scapulothoracic junction with overhead activity
- Causes: osteochondroma, Bursitis
- Scapulothoracic dyskinesia = abnormal scapula motion
- Treatment: Physio & scapula stabilization exercises

PROXIMAL BICEPS TENDINOSIS, RUPTURE & SUBLUXATION

- Transverse humeral ligament between lesser and greater tuberosities converts intertubercular groove into a canal that contains long head of biceps
- Hypovascular area
- Subscapularis tendon tear - LHBT subluxes medially out of the groove
- subscapularis most important restraint to medial instability of LHBT
- Imaging
  - Ultrasound: dynamic test
  - MRI: increased T2 signal, and displacement out of bicipital groove
  - Coincides with subscapularis tears


(Courtesy of L Prakash)

- Treatment
  - Non-operative:
    - Leads to 20% loss of supination & 10% loss of elbow flexion
    - Elderly low demand & in chronic ruptures
  - Biceps tenodesis:
    - Acute rupture in young active
    - Remove damaged section and reattach remaining tendon to humerus
    - Absorbable interference screw
  - Tenotomy in a low demand patient
  - Debridement in tendinosis not effective

DISTAL BICEPS RUPTURE

- Examination:
  - Look: Reverse Popeye deformity – loss of contour
    Migrates proximally also present in proximal rupture (migrates distally)
  - Move: Supinates and flexes forearm
  - Tests:
    - Hook test with partial tear or no tear examiner will be able to get their finger under tendon near insertion from lateral side
    - Squeeze test leads to passive supination

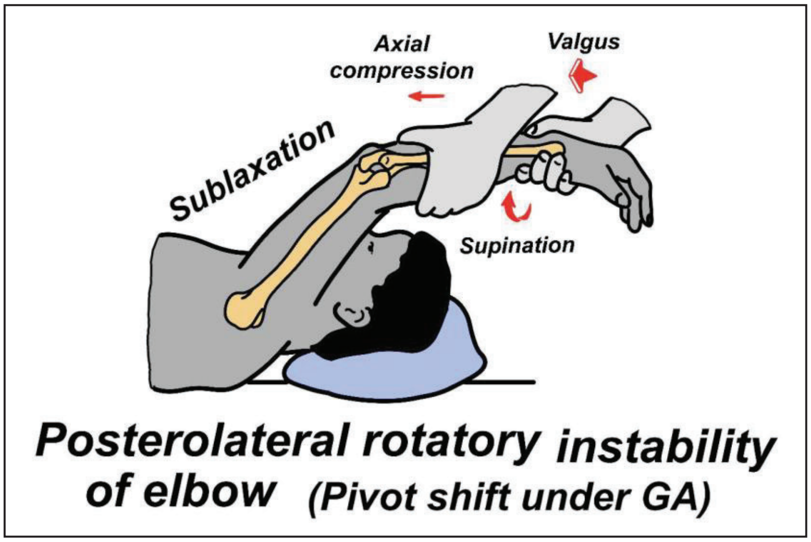
(Courtesy of M Elgendy)

- Mechanism: Eccentric overload
  - Will lose; 40-50% supination, 30% flexion, 15% grip strength
  - Repetitive lifting cause brachialis fatigue
- Indications for repair
  - Young active & manual worker
  - Full rupture
  - Partial rupture not improving
- Surgical technique
  - Within 2 weeks prior to obliteration of the tendon tunnel
  - Anterior one incision anterior approach to elbow, preferred approach.
    - Curved incision 5 cm proximal to flexion crease along lateral border of biceps
    - Or transverse 4 cm distal to the flexion crease
    - Continue distally by following the medial border of the brachioradialis
    - Internervous plane
      - Proximally: B/W brachialis (musculocutaneous N) & brachioradialis (radial N)
      - Distally: pronator teres (median nerve) & brachioradialis (radial N)
    - Supinate forearm to expose tuberosity and protect PIN
    - Bone suture anchors/interference screw/endobutton into radial tuberosity
  - Two incisions (Boyd – Anderson) anterior & posterolateral
  - Chronic rupture:
    - Non-anatomic salvage procedure, Attach to brachialis
    - Or reconstruction with hamstrings/Palmaris
    - Or attempt primary repair in 90 deg flexion tendon will gradually stretch
- Complications:
  - Lateral forearm cutaneous nerve injury most commonly injured using two-incision technique
    - Pierces deep fascia lateral to biceps tendon
    - Radial N
  - Synostosis & HO; Higher risk with two incision approach
  - PIN injury; Incise supinator muscle at its origin with forearm supinated to protect nerve
    - Higher risk with 1 incision approach
  - Use of suture anchors reduced risk
  - Radial Nerve
  - PIN

ELBOW EXAMINATION

- History:
  - Hand dominance
  - Loss of ROM (stiffness)
  - Pain: location
  - Locking & clicking: in arthritis, loose bodies, instability, OCD
  - Medical Hx: Trauma, Rheumatoid arthritis
  - Social Hx: Job, Sports
- Look
  - All standing & from front
  - Extend: (Carrying angle)
    - between long axis of humerus and forearm
    - Full extension and supination
    - cannot be commented in an elbow with a fixed flexion deformity
    - 10^{o} in male and 15^{o} in female
  - Valgus deformity of elbow suggestive of old lateral condylar fracture
  - Varus or gunstock deformity suggestive of mal-united supracondylar fracture
  - Flexors or extensors muscles group wasting
  - FFD, Scars, Bursa, Scars
- Feel
  - Radial head
  - Lateral epicondyle
  - Olecranon and olecranon fossa for any palpable osteophyte
  - The posterior triangle turns into a straight line on extension indicates the joint congruent
  - Medial epicondyle
  - Feel for subluxing ulnar nerve
  - Biceps tendon
  - Triceps tendon
- Move
  - Extension/Flexion: $0 – 140^{o}$
    - Axis of flexion/extension at the centre of trochlea
  - Supination and pronation with elbow flexed 90° tucked to side of body to prevent compensation by shoulder motion
    - Normal 80° in both directions 50°enough for daily function
    - Axis of pronation/supination at capitellum
    - Reduced in Madelung deformity, synostosis, fracture malunion, and radial head dislocation
- Special Tests
  - Valgus stress
    - Position elbow at $20 - 30^{o}$ of flexion (unlocks olecranon) - externally rotate the humerus
    - Moving valgus stress: apply valgus load to fully flexed elbow, and then extend
  - Varus stress
    - 30^{o} flexion with full IR at shoulder
    - Assess for gap between the radial head and capitellum

- Posterolateral rotatory instability: O'Driscoll pivot shift test
  - Shoulder flexed - Elbow extended & supinated
  - Flex with a valgus force – Radial head subluxation
  - Or push up on arms while getting up from a chair with forearm supinated



ANTICUBITAL FOSSA

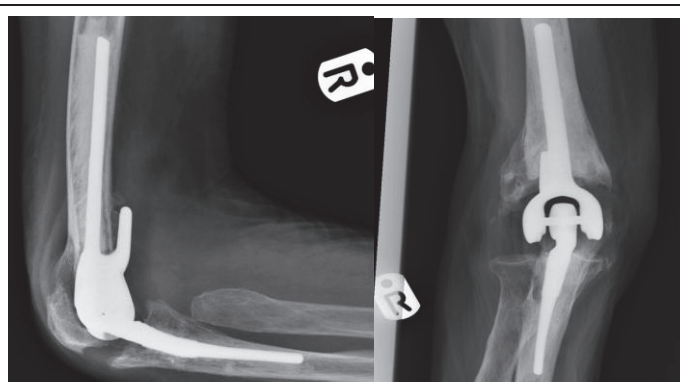
- Borders
  - Medial: Lateral border of pronator teres
  - Lateral: Medial border of brachioradialis
  - Superior:Intercondylar line
- Contents (From medial to lateral)
  - Median nerve
  - Brachial artery
  - Biceps tendon

ELBOW STIFFNESS

- Functional motion
  - 30° to 130° flexion/extension.
  - 50° supination and 50° pronation
  - Firm or soft end stiffness, firm indicates a bony block
- Pathoanatomy
  - Intrinsic
    - Fractures
    - Arthritis (RA, OA, post-traumatic)
    - OCD: loose bodies
  - Extrinsic
    - Heterotrophic ossification
    - Ligament, capsule or other soft issues structures contracture
- Treatment:
  - Static, progressive splinting + physiotherapy +/- Steroid injection
  - Open debridement & soft tissue release to improve ROM
  - Arthroscopic Debridement, capsular release, removal of osteophytes, and loose bodies
  - Ulnohumeral distraction interposition arthroplasty in young high demand patients
  - Olecranon fossa debridement for the loss of extension
  - Outerbridge-Kashiwagi (OK) procedure: Posterior approach
  - Lateral column procedure
    - For the loss of flexion
    - LCL lengthening
  - Open medial approach
  - Synovectomy: in RA
    - Assess the ulnar nerve and consider transposition if required

ELBOW REPLACEMENT

- Indications
  - Advanced OA
  - Complex distal humerus fractures in elderly with poor bone stock
  - RA: Best survival
  - Chronic instability
  - Unsuitable for labourers as can only lift up to 10 pounds
- Types
  - Radiocapitellar resurfacing
  - Linked (constrained): Dee design
    - Most stable but highest loosening rate
  - Sloppy hinge (semi-constrained)– Coonrad – Morrey allows anatomical Varus/Valgus movements (10^o)
    - May be used in the presence of ligamentous insufficiency & bone loss
    - Better range of motion due to soft-tissue release
    - Reduces stress at the bone-implant interface
    - Anterior hinge to control the rotation
    - Good for both RA and trauma
  - Distal humeral hemiarthroplasty
    - For comminuted distal humeral fractures in young
  - Unlinked (unconstrained)
    - Used with competent ligaments & adequate bone stock
    - Rely on soft tissue for stability
    - Can dislocate
    - Good for OA



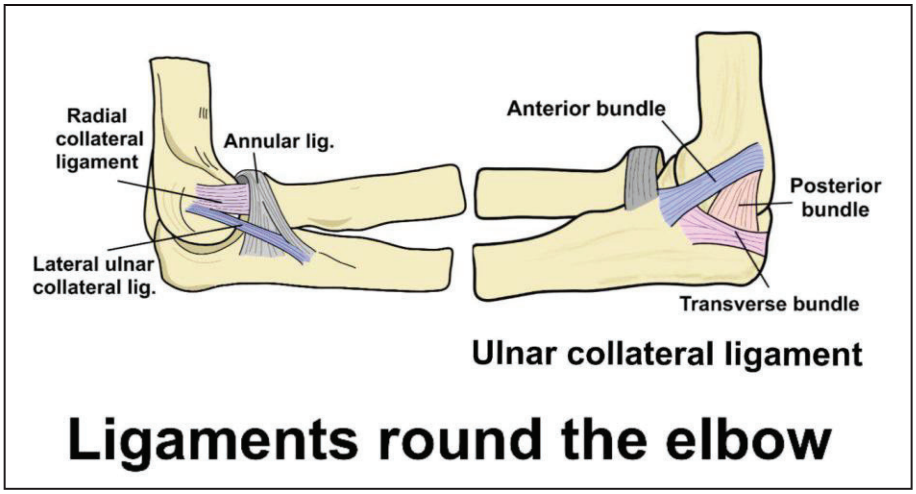
(Courtesy of M Imam)

ELBOW INSTABILITY & DISLOCATION

- History:
  - Pain, Instability, Clicking
- Ex Tests
  - Radiohumeral: pivot joint
- Anatomic considerations:
  - Radial head: Covered by cartilage for 240 deg the lateral 120 deg contains no cartilage
  - Common flexors
    - Originate from medial epicondyle
    - Pronator teres – FCR - palmaris longus – FDS – FCU
  - Common extensors
    - Originate from lateral epicondyle
    - ECRL – ECRB – EDC – EDM – ECU - Anconeus
  - The elbow has a large joint reaction forces due to short lever arms around elbow: biceps inserts not far from COR

Elbow Stabilizers

- Primary static
  - MCL
    - Anterior band:
      - Tight throughout ROM (Isometric)
      - Most important to stability against valgus stresses
      - Inserts on the anteromedial facet of coronoid (Sublime tubercle)
    - Posterior band:
      - Taut in flexion
      - Its tightness results in reduced flexion.
    - Transverse band:
      - Commonly Avulsion fracture is from of medial apophysis
      - When associated with radial head fracture causes posterolateral rotatory instability
  - LCL: consists of
    - RCL (attaches to annular ligament)
    - LUCL
      - Primary restraint to Varus instability
      - Inserts at crista supinatoris on the proximal ulna
      - Most commonly injured at the humerus origin
      - When associated with the anteromedial coronoid fracture - Varus posteromedial rotatory instability.
    - Annular ligament: gives stability to Proximal radioulnar joint
  - Coronoid / Ulnohumeral joint
    - Buttress effect in the prevention of posterior dislocation
    - Provides varus buttress
    - Loss of more than 50% of coronoid height results in instability.



- Secondary static
  - Radial head/Radiocapitellar joint:
    - Anterior and valgus buttress
    - Most important
  - Capsule
  - Origin of flexors and extensors
- Dynamic stabilizers
  - Anconeus, Brachialis, Triceps, biceps

Pathophysiology

- Acute trauma
- Overuse

Dislocation

- Posterolateral is the most common
- Simple or complex
- Complex associated with fracture.
- Terrible triad: a dislocation accompanied by:
  - Radial head fracture
  - Coronoid fracture
  - LUCL tear with or without MCL tear
- Anterior bundle of MCL and capsule attach just distal to coronoid
- Regan & Morrey classification for coronoid fracture
  - avulsion of tip
  - Fracture involve 50% or less of coronoid
  - Fracture involve >50% of coronoid
- LCL injury
  - Injury progresses from lateral to medial - (known as the Circle of Hori)
  - LCL is 1st to fail followed by the anterior capsule & anterior bundle of MCL is last

- Imaging
    - Oblique views to assess intra-articular involvement
    - CT scan to assess the radial head and coronoid fracture
    - MRI arthrogram
        - Diagnostic
        - Capsular T-sign with contrast extravasation

Treatment

- Acute
    - Usually unstable in extension
    - Full extension should be avoided in early rehab
    - Simple unstable
        - Ex – fix then hinged brace
        - Open reduction of elbow
        - Use the Posterolateral approach
        - Radial head relocation and ORIF vs replacement
    - Complex
        - ORIF if unstable
        - Coronoid ORIF
            - Fix if elbow unstable, suture passed through 2 drill holes
            - Or posterior to anterior lag screws if fragment large
        - Medial approach between 2 heads of FCU
        - LCL repair
            - Usually avulsed from origin on lateral epicondyle
            - Reattach with suture anchors or trans-osseous sutures
            - Repairs performed with the elbow at 90o of flexion
        - MCL repair
- Chronic
    - Open reduction and capsular release and hinged Ex -Fix
    - Annular lig reconstruction using triceps fascia
        - Interference screw or suspensory fixation (Endobutton)
        - Or figure of 8 through bony tunnels
    - LUCL reconstruction

Complications

- Most common complication is stiffness
- Little leaguer elbow
    - Medial elbow pain in adolescent pitchers
    - Caused by:
        - medial epicondyle stress fractures
        - Ulnar collateral ligament (UCL) injuries
        - Flexor-pronator mass strains
        - Medial apophysitis

LATERAL EPICONDYLITIS (TENNIS ELBOW)

- Pathology:
  - Overuse injury due to eccentric overload
  - may involve microtears
- Examination:
  - Feel: Tenderness of ECRB, millimetres distal to epicondyle
  - Tests:
    - Cozen: resisted wrist extension with elbow in extension and forearm pronated
    - Middle finger extension (Maudsley): ECRB inserts on 3rd MC
      - Resistance applied just distal to PIPJ of middle finger
      - Pain at lateral epicondyle
- Differential Diagnosis
  - Radiocapitellar degeneration
  - Radial tunnel syndrome
    - Pain 4 cm distal to epicondyle
- Investigations
  - X-Ray may show calcification at Extensor origin
  - MRI: can show increased signal intensity
  - US can shows a thickening of ERCB
  - Histology: shows signs of fibroblast hypertrophy, disorganised collagen and vascular hyperplasia
- Treatment
  - Non-operative:
    - Strap and eccentric physiotherapy exercises
    - Steroid injections (12 months)
    - Smidt – Lancet – 2002 – RCT:
      At 6 weeks injection better, 26 & 52 weeks physio better
  - PRP:
    - BJSM - 2014 – Systematic review, strong evidence that PRP injections not efficacious
  - Operative
    - ECRB release
    - Complications:
      - Injury to LUCL
      - Injury to radial N

(Tennis Elbow release)

GOLFER ELBOW

- Presentation:
    - Pain with resisted forearm pronation and wrist flexion
    - 7 times more common than Tennis elbow
- Pathology
    - Medial epidondylitis of flexor pronator origin
    - Affects FCR & PT
- Treatment
    - Counterforce bracing
    - Open debridement of PT/FCR
- Risks: Medial antebrachial cutaneous nerve

OSTEOCHONDRITIS DISSECANS

- Affects capitellum
- Juvenile form called Panner's disease
- Flattened capitellum avascular necrosis
- Investigations:
    - X-rays:
        - Show irregularity of capitellum with areas of radiolucency
        - Indicates some level of resorption especially near the articular surface
        - Some sclerosis may be present
    - MRI
- Treatment
    - Conservative:
        - Rest, modify activities, immobilize
        - Self-limiting in 6 -18 months
    - Surgery
        - Micro-fracture
        - Fixation, Can cause loose bodies later

ELBOW ARTHROSCOPY

- Indications
  - Loose body and osteophyte removal
  - Synovectomy
  - Capsular release
  - OCD
- Contraindications
  - Trauma and scaring
  - Previous ulnar nerve transposition
- Technique
  - Fully distend joint through lateral soft spot before placing portals
  - Careful nick and spread technique
- Portals
  - Direct lateral:
    - centre of triangle formed by lateral epicondyle, radial head and olecranon
    - Initial entry to inflate joint
  - Anterolateral: 1 cm distal and anterior to lateral epicondyle
  - Anteromedial: 2 cm distal and anterior to medial epicondyle
    - Inside out technique
  - Proximal medial: 2 cm proximal to medial epicondyle
  - Direct posterior: 2 cm proximal to tip of olecranon
- Risks
  - Technically demanding
  - High risk of NV injury
  - Transient ulnar nerve palsy (most common)
  - Posteromedial portal most risky
  - Radial nerve palsy (second most common)

RADIOULNAR SYNOSTOSIS

- A bridging bone or fibrous tissue between radius and ulna
- Congenital or acquired (Post-traumatic)
- History: Painful when incomplete
- Examination
    - Look:
        - Child.
        - Forearm held in pronation
        - Reduced size of forearm and muscles wasting
        - Scars
    - Feel: radial head
    - Move:
        - Limited supination < 40^{o}
        - Pronation and supination blocked both actively & passively
    - Function: check: hand to mouth //behind head // behind back
    - Neurological: radial N
    - Examine the contralateral forearm
    - Think of:
        - Congenital radial head dislocation ◊ reduced extension
        - Madelung deformity
        - Nail-patella syndrome
- Congenital
    - Radius and ulna divide from distal to proximal therefore synostosis usually in the proximal half. Failure of differentiation results in a bony or fibrous synostosis
    - Bilateral (60%)
    - Can be associated with;
        - DDH
        - CTEV
        - Congenital radial head dislocation
        - Apert Syndrome
        - Carpenter Syndrome
        - Arthrogryposis
        - Kleinfelter Syndrome
    - Management:
        - Observe
        - Unilateral usually little functional deficit
        - Radius rotational osteotomy:
            - o Unilateral set in supination of 20° (The ideal position depends on patient needs)
            - o Bilateral fix dominant in mid pronation 40o and other in neutral
        - Cannot recreate proximal radial-ulnar joint with excision as it will re-ossify and recur

- Post-traumatic
  - Risk factors
    - Both bones forearm fractures at the same level
    - Use of one incision for both radius and ulna
    - Delayed surgery > 2 weeks
    - Violating or bone grafting into the interosseous membrane
    - Prolonged immobilization
    - Open fracture
    - High energy and comminuted fracture
    - Associated head trauma
  - Vince & Miller classification
    - Distal has the worst prognosis with excision
    - Middle 3rd has the best prognosis with excision
    - Proximal 3rd
  - Management:
    - Excision of synostosis (The result of surgery unpredictable): for midshaft (Type II), others have a poor prognosis
      - Tensor Fascia Lata or fat graft interposition
      - Followed by irradiation and Indomethacin
      - Excision indicated when mature lamellar bone formed
      - Too early before bone maturation can lead to recurrence
      - Too late can lead to joint contractures
    - Excision of the radial head for proximal Synostosis
      - Causes instability

CONGENITAL DEFORMITIES OF THE UPPER LIMB

- 1 in 600 children born with a congenital upper limb deformity
- **Swanson's Classification**
  - Failure of formation
    - Transverse: Phocomelia (Patient can have remnants of digits)
    - Longitudinal: Radius, Ulna, Fibula, Tibia hemimelia, Cleft hand, longitudinal tibia deficiency, PFFD
  - Failure of differentiation: Syndactyly, Clinodactyly, Arthrogryposis
  - Duplication - Polydactyly
  - Overgrowth – Macrodactyly, Congenital hemi-hypertrophy
  - Undergrowth - Thumb hypoplasia
  - Constricting band syndrome
  - Complex – Intercalary

Radius hemimelia (radial club hand)

- Definition
  - Longitudinal deficiency of radius
  - Related to Sonic HedgeHog gene
  - Absence or hypoplasia of pre-axial structures: radius, radial carpus and thumb
  - Bilateral in up to 75% cases
  - Ulna is bowed, thickened, and only 60% of its normal length
  - Syndromic or non-syndromic
- Classification – Heikel – How much of the radius is present?
  - Short radius (Type 1)
  - Hypoplastic radius (Type 2)
  - Partial absence of the radius (Type 3)
  - Absent radius
- Examination
  - Radial angulation of wrist and short forearm
  - Usually the hand 90^{o} perpendicular to the forearm
  - Thumb frequently deficient as well
  - Possible scars from corrective surgery (pollicization)
  - Full functional assessment of shoulder, elbow and hand functions: ROM // Grips
  - Only consider centralization/pollicization in the presence of active elbow flexion
- Investigation
  - Check the child with radial club hand for associated congenital abnormalities
    - Fanconi anaemia life threatening from of aplastic anaemia
    - Holt-Oram syndrome
    - VACTERL
    - VATER: Vertebral anomalies, Anal atresia, Tracheo-Esophageal fistula, Renal & Radial anomalies
    - TAR: Autosomal recessive condition with thrombocytopenia and absent radius

- Radiographs
  - Ulna is curved and thickened and only 60% of its normal length
    - Radius hypoplastic or absent
    - Carpal bone fusion or absence
    - Absence of digits
- Treatment (Should be MDT approach including genetic counselling)
  - Observation:
    - hand deformity allows for extra reach to mouth in the absence of elbow flexion
    - Passive stretching of tight radial-sided structures splint
  - Operative
    - Aim: balanced and stable wrist
    - Maintain wrist and fingers movements
    - Improve limb function
    - Centralization of carpus on ulna and wrist fusion and thumb reconstruction
    - Night time splint until maturity to prevent recurrence

  Contraindications for surgery
    - Severe neurovascular abnormalities
    - Stiff elbow
    - Good function
    - Surgery can be dangerous if there are other congenital abnormalities

Ulnar club hand

- Deficiency of ulna
- Decrease in elbow function
- Painless, and functions well
- Not associated with systemic conditions
- Can be accompanied by loss of ulnar digits (oligodactyly)
- Swanson's classification of ulnar club hand
  - Hypoplastic Ulna (type 1)
  - Total absence of the ulna
  - Humero-radial synostosis (congenital fusion of the elbow joint)
  - Deficient ulna and absent wrist
- Treatment: Radial head resection and creation of a one-bone forearm

Constriction Bands

- Streeter's dysplasia
- More common in fingers and toes
- May be deep with distal oedema
- Congenital amputation
- Treat with Z plasties

Madelung deformity

- Definition
    - Premature fusion of volar ulnar aspect of the distal radius growth plate
    - Develops increased radial inclination and volar tilt and ulnar-carpal impaction
    - Autosomal dominant
- History: Asymptomatic until adolescence and worsens with growth
- Examination:
    - Usually female
    - Bilateral with a short forearm
    - Ulna grows normally – ulna head prominent
- Causes
    - Idiopathic: hypothesis due to tethering by Vickers ligaments and volar radioulnar ligaments
    - Congenital/genetic
    - Posttraumatic
    - Dysplastic: Ollier// Achondroplasia // MED
    - Leri Weill dyschondrosteosis:
        - Skeletal dysplasia characterized by short stature, genu varum and bilateral Madelung deformities
- Management
    - Monitor patients without pain
    - Immature:
        - Epiphysiodesis of the distal radius to prevent further deformity
        - Release Vickers ligament & ulna epiphysiodesis
    - Mature
        - Closing wedge osteotomy of radius & Ulna shortening (Sauve-Kapandji)
        - Wrist fusion for OA or sever pain and instability

Miscellaneous

- Arthrogryposis – stiff joints, absence of skin creases
- Symphalangism – stiffness of PIPJ +/- ankylosis
- Congenital trigger thumb – common, palpable swelling – Notta's node, most resolve by 1-year, surgical release if continues

VOLKMANN ISCHAEMIC CONTRACTURE

- Sequelae of compartment syndrome of the forearm
- Causes
  - Muscle ischaemia from compartment syndrome
  - Brachial artery injury
- Contracture positioning
  - elbow flexion
  - forearm pronation
  - wrist flexion
  - thumb adduction
  - MCP joints extension
  - IP joints flexion
- Volkmann sign:
  - Able to fully extend IPJs only if wrist flexed.
- Tsuge classification
  - Mild
    - Affects fingers flexors- No sensory disturbance
    - Treatment:
      - Dynamic splinting
      - Common flexor release or tendon lengthening
  - Moderate
    - Affects fingers & wrist flexors, and median & ulnar nerves
    - Treatment:
      - Radical release
      - BR to FPL and ECRL to FDP tendon transfers
  - Severe
    - Affects fingers flexors & wrist flexors & extensors
    - Tx as above

BRACHIAL PLEXUS

- Purpose of examination is to determine the level of lesion:
    - Pre or Post ganglionic,
    - Supra or Infra clavicular
- History: (Mechanism of injury)
    - Open/close
    - Pain
    - ADL: Comb, button shirt, eat, Private hygiene

Examination:

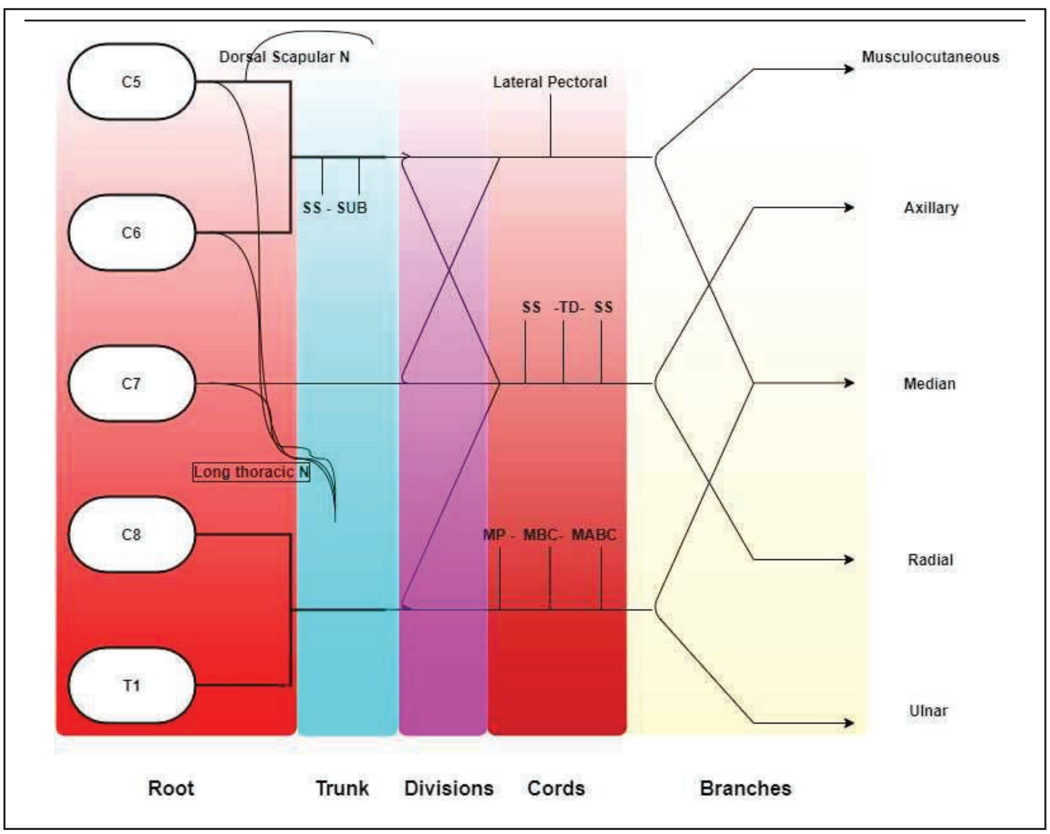
- Look
    - Front (Eyes for Horner)
        - Clavicle deformity
        - Posterior triangle of the neck for scars
        - Pec major
        - Arm posture "Waiter's tip"
        - Hand clawing and muscles wasting
    - Side: Wasting supra and infra clavicular fossa
    - Behind: Winging
    - Look at axillae for scars
- Neurological examination
    - Dermatomes: Be systematic
    - Motor: Make sure the patient has full range of passive movements (no evidence of arthrodesis) before testing power.
        - Roots:
            - Shrug shoulder (trapezius)
            - Not a brachial plexus nerve but important donor site for nerve or muscle transfer
            - Brace back/squeeze shoulders backward ◊ rhomboids (feel muscles)
            - Scapula winging (serratus anterior): Push against the wall or examiner arm and feel muscle
        - Trunks: Suprascapular N
        - Cords:
            - Lateral (C5, C6):
                - ✓ Deltoid
                - ✓ Rotator muscles
                - ✓ Elbow flexion
            - Posterior
                - ✓ Push down on abducted arm – latissimus dorsi
                - ✓ Elbow extension
        - Medial
                - ✓ Hand flexion & abduction
                - ✓ Press hands on the pelvis feels for pec major contracture

- When presented with a patient with a <u>wasted hand</u> think of potential <u>differential diagnosis</u>
  - Neurological:
    - Central: MS (Bilateral), CVA (unilateral)
    - Cord: Syringomyelia (Bilateral)
    - Anterior horn: Polio (Bilateral), Syphilis
    - Root: Cervical spondylosis, neurofibromata
    - Brachial plexus: Cervical rib, lung tumour, trauma
    - Peripheral: HSMN, RA, Peripheral nerve compression, Guillain-Barre,
  - Non-Neurological:
    - Disuse: secondary to arthritis.
    - Contracture: (Arthrogryposis, burns, Volkmann's..)
    - Myopathy secondary to alcohol, DM, nutrition.
    - Congenital myopathies.
    - Inflammatory: Polymyositis

Brachial Plexus Anatomy

- C5 – T1 nerve roots
- Mnemonic

Rob	**T**aylor	**D**rinks	**C**old	**B**eer
Roots (red)	Trunks (Turquoise)	Divisions (Dianne = Pink)	Cords (Chocolate)	Branches (Beige)



- Anterior and middle scalene insert on first rib
- Posterior scalene inserts on second rib
- Tubercle on upper surface of 1st rib for scalenus anterior separates anterior groove for subclavian vein and posterior groove for subclavian artery and lower trunk
- Prevertebral fascia covers the brachial plexus and continues as axillary sheath
- <u>Supraclavicular</u>
  - Roots lie in the posterior triangle of neck between scalenus anterior and Medius with subclavian A
    - 3 branches:
      - Dorsal scapular C5 (Levator scapulae & rhomboid minor & major)
      - Br to Phrenic N (Diaphragm)
      - Long thoracic (serratus anterior)
  - Trunks
    - Superior:
      - Suprascapular N, supra & infraspinatus
      - Subclavius N
    - Middle and Inferior: no branches
  - Divisions
    - Anterior and Posterior (No branches)
- <u>Infraclavicular</u>: **Cords**
  - Lateral: From anterior divisions of superior and middle trunks, has 3 branches
    - Musculocutaneous; BBC (Biceps, Brachialis, Coracobrachialis)
      - Becomes lateral antebrachial cutaneous N
      - Exits between biceps and brachialis
    - Lateral pectoral N: Pec major & minor (press hands on hips)
    - Lateral head of the median nerve
  - Posterior: From all 3 posterior divisions, has 5 branches
    - Axillary N: Deltoid & teres minor
    - Radial N: All muscles in the posterior compartment of the arm & forearm
    - Upper subscapular N: Subscapularis
    - Lower subscapular N: Teres major
    - Thoracodorsal N: Latissimus dorsi
  - Medial: From the anterior division of inferior trunk, has 5 branches
    - Medial pectoral N: Pec major & minor
    - Medial cutaneous N of arm sensory
    - Medial cutaneous N of forearm sensory
    - Medial root of median N
    - Ulnar

  - **<u>(Stinger)</u>**
    - Upper trunk brachial plexus neurapraxia from traction injury.

Anatomical Classification of brachial plexus injuries

- Preganglionic root avulsion
  - Proximal to dorsal root ganglion
  - Poor prognoses as nerves have little potential to regenerate
  - Irreparable
  - lesions suggesting preganglionic injury:
    - Horner's syndrome:
      - disruption of sympathetic chain
      - appears 2-3 days following injury
      - T1 root lesion
      - Ipsilateral ptosis drooping eyelid injury to nerve to Muller muscle
      - Ipsilateral miosis pupillary constriction injury to long ciliary N (dilator)
      - Ipsilateral anhidrosis (dry eye)
      - Enophthalmos sinking of orbit
    - winged scapula medially: loss of serratus anterior (long thoracic nerve) rhomboids (dorsal scapular nerve) leads to medial winging (inferior border goes medial)
    - Elevated hemidiaphragm (phrenic nerve injury)
    - Weakness to latissimus dorsi (thoracodorsal)
  - Presents with motor deficits (flail arm)
  - Sensory deficits
  - Absence of a Tinel sign or tenderness to percussion in the neck
  - Histamine test: drop of histamine placed on skin, scratch through it
    - Normal response is vasodilatation and wheal formation
    - Normal if injury proximal to dorsal root ganglion

- Postganglionic Distal to dorsal the root ganglion

Leffert classification

- Open
- Closed
- Radiation
- Obstetric
  - (**Obstetric Erb's & Klumpke palsy)**
    - Risk factors:
      - Large babies
      - Shoulder dystocia
      - Forceps delivery
      - Breech position
      - Prolonged labour
    - 90% of cases will resolve without intervention
    - Key to treatment is maintaining passive motion while waiting for nerve function to return
    - Erb's
      - From excessive abduction of the head away from shoulder causing nerve roots traction injury
      - Adducted & internally rotated shoulder pronated & extended elbow (waiter's tip)
      - C5 & C6 deficiency (deltoid, supra/infraspinatus, biceps)

- Good prognosis: majority regain full function by 18 months
- Poor prognosis lack of bi-ceps

- Klumpke
    - Deficit of all small muscles of hand (ulnar and median nerves) Claw hand
    - Root injury C8 & T1
    - Poor prognosis
    - Treatment:
        - ✓ Observe, maintain passive movements
        - ✓ Nerve repair/grafting: if no improvement by 3 months

- **<u>Brachial neuritis (neuralgic amyotrophy, Parsonage-Turner syndrome)</u>**
    - Autoimmune process
    - Sudden onset weakness, periscapular pain with sensory loss
    - Usually unilateral characterized by progressive neurologic deficits and motor weakness
    - Effect mainly LT nerve, upper trunk of BP most commonly involved has a good prognosis vs lower trunk poor prognosis
    - Risk factors: recent viral infection and recent immunization
    - Three Phases
        - Sever pain
        - Flaccid paralysis
        - Recovery, usually slow
    - Examination: Weakness in abduction & ex-rotation
    - Investigation
        - NCS, EMG shows denervation of involved muscles
        - MRI shows a high signal in affected muscles
    - Treatment
        - First pain control and adequate analgesia followed by physiotherapy
        - 89% of patients achieve fully functional recovery at 3 years

Investigations for Brachial plexus injury

- CXR:
    - high diaphragm indicates phrenic nerve involvement
    - Fractures to first or second ribs suggest damage to overlying brachial plexus
    - Scapulothoracic dissociation is associated with root avulsion
    - C Spine: transverse process fracture likely indicates root avulsion
- MRI: Neuroma, oedema, Pseudomeningocele
    - Empty nerve root sleeve (empty foramen sign)
- CT myelogram
    - <u>Gold standard</u> for defining level of nerve root injury
    - Wait 14 days, allows blood clot to dissipate and meningocele to form
- EMG/NCS:
    - help distinguish preganglionic from postganglionic
    - Fibrillations from 14 days
    - Not useful in 1st 10 days as the distal part of nerves continue to conduct for several days

Treatment

- Advancing Tinel sign is best clinical sign of effective nerve regeneration
- MDT approach: physio, psychologist
- BOA standards: discuss with plexus/complex nerve injury specialist within 3 days of injury
- <u>Observation</u> in gunshot injuries
- <u>Immediate repair</u>/graft indications:
    - Sharp penetrating trauma (excluding GSWs)
    - Iatrogenic injuries
    - Open injuries
    - Progressive neurologic deficits
    - Expanding hematoma or vascular injury
- Donors:
    - Sural
    - Medial antebrachial cutaneous
- Late tendon transfer:
    - Do not delay beyond 6 months
    - C8-T1 injury in adult: re-innervation unlikely due to distance b/w injury site & hand intrinsic
    - Trapezius to deltoid for shoulder abduction
- Shoulder arthrodesis for flail shoulder
- Neurotisation (nerve transfer)
    - Transfer working nerve to non-functioning more important denervated muscle
    - Extra plexus
        - Spinal accessory (CN XI) to suprascapular muscles
        - Intercostals
    - Intra plexus
        - Phrenic
        - Portion of median/ulnar
        - Pectoral to musculocutaneous muscles

NERVES OF THE BRACHIAL PLEXUS

Suprascapular nerve

- From upper trunk
- Supplies Supraspinatus and infraspinatus
- Provides sensation to glenohumeral & ACJ – can cause shoulder pain
- Sites of compression neuropathy:
  - Suprascapular notch under suprascapular ligament ◊ affects both muscles.
  - Spinoglenoid notch under Spinoglenoid ligament ◊ affects infraspinatus only
- Pathoanatomy
  - Traction injury
  - Ganglion
  - Fracture callus
  - Labral lesion for Spinoglenoid
- Investigations
  - EMG & NCS
  - MRI: to identify compressive mass
- Treatment
  - Arthroscopic or open decompression and ligament release

Spinal accessory nerve

- Has two parts:
  - Spinal part (C3/C4)
  - Cranial part CN XI
- Travels through the posterior triangle
- Supplies sternocleidomastoid and trapezius
- Injury causes lateral scapula winging

Axillary nerve

- Lies behind axillary artery, and in front of Subscapularis
- Passes downward to the lower border of Subscapularis
- Winds backward, in company with posterior humeral circumflex artery and vein, through quadrilateral space
- Divides into:
- Anterior (supplying deltoid)
- Posterior (supplying teres minor, posterior part of deltoid and upper lateral cutaneous nerve of the arm)

Ulnar nerve

- Anatomy of ulnar nerve
  - C7, C8, T1.
  - From medial & lateral cords of brachial plexus.
  - Passes through intermuscular septum in mid-arm.
  - Behind medial epicondyle.
  - Between two heads of FCU.
  - Lies anterior to FDP.
  - Gives off dorsal cutaneous branch 5cm proximal to wrist.
  - At the wrist lies between FDS & FCU.
  - Through Guyons canal at the wrist (between pisiform & hook of hamate), medial to ulnar artery
  - Motor branch winds round the hook of hamate
  - Motor branches to FCU, ulnar side of FDP, all small muscles of hand except LOAF.
  - Sensory - ulnar 1 1⁄2 digits both sides; autonomous zone = tip of little finger.
- Differential diagnosis
  - Cervical radiculopathy.
  - Cervical spondylosis / cord pathology.
  - Thoracic outlet syndrome/ Cervical rib.
  - Pancoast tumour.
  - Amyotrophic lateral sclerosis (MND).
  - Localised peripheral neuropathy (cubital/ Ulnar tunnel).

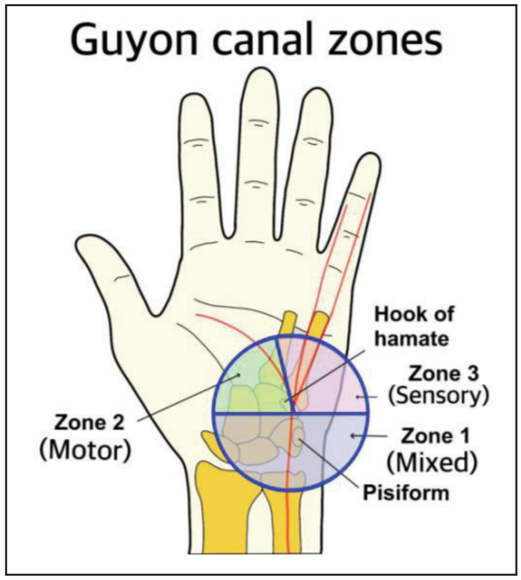
Cubital tunnel syndrome

- 5 Points of possible constriction:
  - Hiatus in the medial intermuscular septum
  - Arcade of Struthers: Thick band from medial head of triceps to medial intermuscular septum
  - Cubital tunnel: under Osborne’s ligament (cubital retinaculum)
  - FCU fascia: Made from the two heads (Humeral and ulnar) of FCU
  - Anconeus epitrochlearis: is an accessory muscle
- Symptoms
  - Vague dull ache around the media elbow and forearm, intermittent paraesthesia the ulnar side of hand.
- Signs
  - Look for:
    - Elbow carrying angle and any deformity
    - Old surgical scars in elbow, axilla or neck
    - Wasted hand & hypothenar muscles (guttering)
    - Wartenburg’s sign: Little finger spontaneous abduction (see below)
    - Wasting ulnar border of forearm (FDP & FCU)
    - Wasting of 1st dorsal Interosseus and hypothenar eminence.
  - Hypoasthesia ulnar side of hand + distribution of dorsal cutaneous nerve (diff. to low lesion).
  - Tinels test, behind medial epicondyle.
  - Froments sign.
  - Ulnar clawing if severe: ulnar paradox - less clawing if FDP & Intrinsics weak.
  - Card test (adduction of fingers)

- Investigation
  - NCS reduced nerve conduction velocity
  - EMG evidence of muscles denervaion
- Management
  - Conservative
    - Avoidance of repetitive bending of elbow and extension block night splint.
    - Injection contraindicated
  - Surgical
    - Simple decompression
    - Partial medial epicondylectomy: risk destabilizing elbow
    - Transposition of nerve anteriorly, subcutaneous or submuscular +/- medial epicondylectomy
      - When nerve is unstable (subluxes on flexion and extension of elbow)
  - In the presence of arthritis
    - Bad bed from malunion, callus, metalwork, and scarring
    - Risks devascularizing nerve
    - Longer recovery
  - Top Tips
    - Place incision anterior to medial epicondyle so the nerve does not lie directly under wound
    - Be aware and protect the medial antecubital cutaneous nerve of forearm which often cross FCU
    - Similarly, motor branch to FCU in the distal part of cubital tunnel.
  - Controversy
    - Decompression- J Hand Surg Am 1999 Sep; 'Cubital Tunnel Syndrome does not require transposition of the ulnar nerve'
    - Austrian paper 1996, Steiner- 89% good or very good results at 2 years follow up
    - Transposition - subcutaneously/ submuscular
    - J Hand Surg Am 1999 Sept, Kleinman 'anterior transposition is the logical approach to complete nerve decompression.
- Results
  - Sensation improves better than motor function.
  - Can improve over 3-5 years period.
- Complications
  - painful hypertrophic scar
  - Neuromas.
  - Complex regional pain syndrome
  - Dislocation of nerve
  - Persistent symptoms due to inadequate decompression (commonly proximal intermuscular septum)
  - Irritation of superficially placed nerve.
  - Disruption of blood supply to nerve.

Ulnar tunnel syndrome (Compression at Guyon's canal)

- Anatomy of Guyons canal
  - Floor = transverse carpal ligament to pisiform.
  - Ulnar wall (pisiform).
  - Radial distal wall (hook of hamate).
  - Roof (volar carpal ligament).
  - Contains only (ulnar nerve and artery).
    - Ulnar nerve bifurcates within the tunnel into superficial sensory and deep motor branches
    - Artery directly under hook of hamate
  - From ulnar: Tendon – Artery – Nerve



- Nerve here supplies
  - Hypothenar muscles & Palmaris brev
- Causes:
  - Repetitive indirect trauma most common
  - Ganglia from triquetrohamate joint causing SOL
  - Trauma: fracture of the distal radius, ulna, and hook of hamate
  - Ulnar artery aneurysm or thrombosis
  - Pisotriquetral arthritis
  - Pisiform instability
  - Inflammatory arthritis
- Presentation:
  - Sensation on the ulnar side of dorsum of hand intact as sensory branch leaves proximal to Guyon's canal
  - Decreased sensation in ulnar 1.5 fingers
  - FCU intact
  - Ulnar half of FDP intact (ulnar paradox)
  - Clawing of the ring and little fingers caused by loss of Intrinsics function
  - Weakened grip from loss of MCP joint flexion power
  - Weak key pinch from loss of adductor polices
  - Weakness of fingers crossing
  - Card test for palmar interossei adductor power
  - Froment's test: FPL (median N) compensate for weak adductor polices
  - Wartenberg's sign:
    - Persistent small finger abduction and extension during attempted adduction
    - Due to weakened 3rd palmar interosseous and unopposed EDM
    - Always comment on this when examining ulnar nerve
  - Weak opposition of little finger
- Compression sites
  - Zone 1: Proximal to bifurcation, both motor & sensory symptoms
  - Zone 2: Deep motor branch, motor symptoms only (thrombosis)
  - Zone 3: Superficial sensory branches, sensory symptoms only

- Investigations
  - NCS, show delayed motor latency from wrist to 1st dorsal interosseous
  - MRI if you suspect space occupying lesion
- Management
  - Conservative:
    - splinting & avoidance of repetitive trauma
  - Surgical:
    - Decompression
    - Tendon transfer to correct claw fingers & key pinch & adduction of small finger
    - To stabilize MCPJ: Zancolli capsulodesis, FDS looped volar to A1 pulley and sutured back to itself
  - Ulnar paradox
    - After surgery for proximal Ulnar compression, the deformity gets worse initially
    - This is due to recovery of Extrinsic muscles overpowering still weak Intrinsics
    - As nerve recovers proximal to distal

Radial nerve

- Examination:
  - Look
    - Wrist drop.
    - Thumb held in adduction
    - Triceps and forearm muscle wasting
    - Compare with other side
    - Look for splint
    - Look for scars around humerus
  - Feel: Sensation in the 1st dorsal web space
  - Move
    - High injury: triceps
    - Low (PIN): EPL, EDC
      - o Differentiate from EDC rupture with tenodesis test
- Radial Nerve Anatomy:
  - Originates from the posterior cord – Root values C5, C6,C7,C8
  - Runs on the posterior wall of axilla
  - Runs through triangular interval with Profunda brachii Artery, between long head of triceps & humerus
  - Courses through the spiral groove between lateral and medial heads of triceps
  - Passes through lateral intermuscular septum 7.5 cm above the distal articular surface
  - Runs in the Anterior & lateral at cubital fossa.
  - Runs between brachialis and brachioradialis (anterior to lateral epicondyle).
  - Passes between 2 heads of supinator.
  - Divides into superficial branch & (PIN)
    - PIN:
      - o motor to long extensors of MCP joints and wrist except ECRL
      - o Sensory, superficial branch to dorsal radial side of hand and fingers (3 1/2);
      - o Autonomous zone = 1st web space dorsum.

PIN Compression

- PIN Anatomy
  - Originates from radial nerve at radiocapitellar joint line level
  - Dives under supinator at Arcade of Frohse
  - Passes between two heads of supinator
  - Reaches posteriorly to interosseous membrane of the forearm
  - Located on the floor of the 4th extensor compartment
  - Ends supplying sensation to the dorsal wrist capsule
  - Supplies:
    - EDC & EDM & ECU & EIP & EPL & EPB & APL & supinator & ECRB
    - All dorsal compartment except ECRL
- Causes of PIN compression
  - **F**ibrous tendinous band at origin of supinator (30% of people)
  - **R**adial recurrent vessels (the **leash of Henry**) (less convincing evidence)
  - **E**xtensor carpi radialis brevis
  - **A**rcade of Frohse (proximal edge of superficial head of supinator)
  - **S**upinator (the distal border).
  - RA of elbow (subluxated or dislocated radial head cause nerve compression)
  - dislocation of elbow, Monteggia fracture
  - surgical resection of radial head
  - mass lesions
- Presentation of PIN Compression: **(pain and paresis)**
  - Tenderness distal to lateral epicondylitis
  - Inability to extend fingers and thumb
  - Can extend wrist with radial deviation as ECRL working but ECU is not
  - Increased pain on resisted supination
  - Tenodesis test used to differentiate from extensor tendon rupture 2^{nd} to RA
- Treatment
  - Rest and activity modification
  - Lidocaine & Cortisone injection
  - Surgical decompression last resort

Radial tunnel syndrome (pain but no paresis)

- Mild compression of the post interosseous nerve without paresis
- Causes
  - As for posterior interosseus syndrome but not usually any mass lesions
- Symptoms
  - dull aching in extensor muscle mass
  - worse at the end of day
- Signs
  - local tenderness 5cm distal to lateral epicondyle
  - pain elicited by resisted active supination
  - Middle finger test.

- Each finger is tested under resisted extension. Testing the middle finger increases the pain. Due to ECRB inserting into base of the 3rd metacarpal.
- Performed with the elbow and middle finger completely extended with the wrist in neutral position.
- Firm pressure is applied by the examiner to the dorsum of the proximal phalanx of the middle finger.
- The test is positive if it produces pain at the edge of the ECRB in the proximal forearm.

➢ Differential diagnosis
  - Tennis elbow.

➢ Investigation
  - NCS.
  - Increased motor latency in active forceful supination.
  - Injection of local anaesthetic into radial tunnel.

➢ Management
  - Conservative: anti inflammatories,avoidance of repetitive provoking activities
  - Surgical: decompression (Thompson Approach). The internervous plane between ECRB and EDL developed. PIN found just proximal to arcade of Frohse

Wartenberg syndrome

➢ Greek for a painful hand
➢ Wristwatch neuropathy causing Superficial (sensory) radial nerve compressive neuropathy
➢ Sensory branch emerges from between brachioradialis and ECRL, 5-8 cm proximal to radial styloid
➢ Bifurcates proximal to wrist into dorsal and palmar branches
➢ Only sensory manifestations (No motor deficit).
➢ Tinel's sign positive
➢ Provocative test: wrist flexion & ulnar deviation
➢ Treatment
  - Symptomatic & splints
  - Steroid injections
  - Surgical decompression through anterior approach to forearm (Henry), distal to the site of Tinel 's sign

Median nerve

➢ History: Diffuse forearm pain in pronator syndrome
➢ Examination
  - Feel: 3 ½ radial fingers & Thenar sensation in high lesions
  - Move (See below Median N anatomy)
    - OK sign FPL & FDP: in high or AIN , Tip-to-tip pinch
    - Distinguish from FPL attrition rupture (seen in rheumatoid) by tenodesis effect in intact tendon
  - Tests: resisted pronation in 90o flexion for 60 sec reproduces symptoms for Pronator Syndrome

➢ Anatomy of the median nerve
  - From C5, C6 ,C7,C8,T1
  - No branches before elbow
  - Between 2 heads of pronator teres at the elbow
  - 5-6cm distal to the elbow gives off anterior interosseous branch (motor to FPL, FDP
  - Index finger & pronator quadratus)
  - Proceeds between FDS & FDP

- Palmar cutaneous branch (sensory to thenar skin) arises 5cm proximal to wrist joint & overlies flexor retinaculum
- Enters carpal tunnel between PL & FCR
- Recurrent motor branch to thenar muscles arises at distal end of carpal tunnel
- **Motor**
  - Supplies: Pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis and LOAF (radial two lumbricals, opponens pollicis, abductor pollicis, flexor pollicis brevis)
- **Anterior interosseous branch** supplies flexor pollicis longus, radial half of flexor digitorum profundus and pronator quadratus
- **Sensation**
  - Radial 3 and half digits
  - Autonomous zone (tip of index finger)

➢ Differential diagnoses
- Cervical radiculopathy
- Spinal cord lesions - tumour, MS, syrinx
- Peripheral neuropathy- Vit B12 and folate deficiency ,toxic, alcoholic, uraemia, diabetes mellitus

➢ **Median nerve compression test** – 86% sensitivity, 95% specificity
- Elbow extended, forearm in supination, wrist flexed to 60 degrees, even digital pressure applied with one thumb over the carpal tunnel. Test positive if paraesthesia or numbness within 60 sec

➢ **AIN**
- Comes off the median Nerve between two head of PT, 4cm distal to medial epicondyle
- Exits from anterolateral aspect of median nerve
- Runs along front of interosseous membrane of forearm in interval between FPL & FDP
- Terminates distally in pronator quadratus and wrist joint
- Potential sites of entrapment:
  - Deep head of pronator teres
  - FDS arcade
  - Edge of Lacertus fibrosus
  - Accessory head of FPL (Gantzer's muscle)
  - Thrombosed radial or ulnar artery
- Motor supply:
  - FDP (except the ulnar side FDP which is supplied by ulnar nerve)
  - FPL
  - PQ
- No sensory innervation
- Presentation:
  - Benediction hand due to paralysis of FDP to index finger
  - Pronator quadratus weakness
  - Weak pronation with elbow flexed to neutralize pronator teres
- Treatment
  - Splint in 90^{o} flexion
  - Surgical decompression

➢ **Martin Gruber anastomosis**
- Branches from median to ulnar nerve in forearm

- Results in the median nerve innervating number of intrinsic muscles in hand
- Disruption of the ulnar nerve above anatomises may not result in motor loss

➢ **Pronator Teres Syndrome**

- Compression of the median nerve at
  - Lacertus fibrosus (high origin of PT, test with resisted pronation with elbow flexed).
  - Pronator teres muscle (test with resisted pronation with elbow extended).
  - Fibrous arcade of FDS (resisted flexion of PIPJ of middle finger).
  - Ligament of Struthers: band from anterior supracondylar spur (present in 1.5 % of people).
- Symptoms
  - **Aching / fatigue of the forearm after heavy use**
  - Clumsiness
  - Vague, intermittent paraesthesia, but rarely numbness
- Signs
  - Local tenderness to a deep pressure and reproduction of symptoms
  - Tinels test
  - Pain on resisted pronation of the forearm with elbow extended = Pronator teres
  - Pain on resisted elbow flexion and supination= lacertus fibrosus.
  - Pain on resisted flexion of PIP joint middle finger = FDS arch.
- Investigations
  - NCS not much use, intermittent symptoms
  - EMG may show evidence of reduced innervation of muscles (may differentiate from CTS)
- Management
  - Conservative-avoidance of repetitive elbow movements, NSAIDS, Splint with elbow flexed with pronation
  - Surgical- Decompress all the structures

➢ **Anterior Interosseous Syndrome**

- Compression under the humeral part of pronator teres.
- Anterior interosseous nerve motor to FPL, radial side of FDP and pronator quadratus.
- Does not provides a skin sensation
- Afferent sensory fibres from capsular ligament structures of wrist and DRUJ.
- Clinical diagnosis
  - spontaneous vague forearm pain
  - reduced dexterity
  - weakness of the pinch
  - unable to make **'OK sign'** due to a weakness of FPL & FDP index finger (makes square instead of circle)
  - Weak pronation with elbow in full extension (isolates PQ).
  - Direct pressure over the nerve can elicit symptoms.
  - Tinel's sign usually negative.
- Investigations
  - NCS unhelpful
- Management
  - Conservative- NSAIDS, avoiding aggravating movements.
  - Surgical exploration- most common compressing structure is the deep head of pronator teres.

THORACIC OUTLET SYNDROME

- Rare condition seems more common in middle age female
- Presentation
  - Symptoms
    - Neurological symptoms: Lower trunk (C8 – T1)
    - Vascular symptoms
      - Subclavian artery aneurysm
      - Microemboli in hands
      - Upper limb claudication
    - Local symptoms: Hard lump
  - Adson test:
    - Arm abducted, and head extended & rotated towards the affected side
    - Radial pulse obliterated on deep inspiration (normal finding in 10% of populaion)
  - Roos overhead test:
    - Both shoulders in 90 deg of abduction and ER
    - Rapidly open and close hands for 2 min
    - Weakness, paraesthesia or loss of pulses
- Causes
  - Anatomical variation that causes compression of neurovascular structures in supraclavicular fossa as they pass over 1^{st} rib:
    - Musculotendonus anomalies
    - Cervical rib
  - Clavicle & 1^{st} rib malunion
  - hypertrophy in athletes
  - Pancoast (apical lung) tumour
- Imaging
  - X-rays: C Spine, CXR
  - Angiography
- Treatment
  - Physio: improve posture
  - Botox for scalene muscles
  - Surgical decompression
    - Trans-axillary 1^{st} rib resection
    - Release anterior and middle scalene muscles
  - Heparinization for hand emboli

RHEUMATOID ARTHRITIS OF THE SPINE

- Present in 90% of patients with RA
- Symptoms and physical exam findings similar to cervical myelopathy
- Occipital headaches due to lesser occipital nerve, which is branch of C2 nerve root
- Might need fibre optic aided intubation if undergoing GA to reduced need for neck extension

2010 ACR/EULAR Rheumatoid Arthritis Criteria

- Score based system, $\geq$ 6 – definite RA
  - **Joint involvement** (exclude 1st TMTJ, 1st CMCJ and DIPJ)
    - 1 joint 0
    - 2-10 large joints 1
    - 1-3 small joints 2
    - 4-10 small joints 3
    - > 10 joints (at least 1 small joint) 5
  - **Serology** (RF and anti-CCP Ab)
    - Negative 0
    - Low positive 2
    - High positive 3
  - **Acute Phase reactants** (CRP and ESR)
    - Normal 0
    - Abnormal 1
  - **Duration of symptoms**
    - < 6 weeks 0
    - >6 weeks 1

Medical management of RA – NICE guidelines 2018

- Offer first-line treatment with disease-modifying anti-rheumatic drug (DMARD) monotherapy – oral Methotrexate, Leflunomide or Sulfasalazine ideally within 3 months of onset
- Consider Hydroxychloroquine for mild or palindromic disease
- Short-term bridging with glucocorticoids when starting new cDMARD
- Step-down if remission or low disease activity achieved – stop multiple DMARD and switch to monotherapy

Sub-axial subluxation

- Posterior fusion if > 4mm subluxation with intractable pain or neurologic symptoms

Atlantoaxial subluxation

- Most common form of instability
- Most common is anterior subluxation of C1 on C2
- Pannus formation leading to destruction of transverse ligament and dens
- Inflammatory pannus behind odontoid peg
- **Causes**
  - Congenital - Down's syndrome, Os odontoideum
  - Degenerative - RA, JRA
  - Traumatic - odontoid and atlas fractures
- Normal anter

The Hand & Wrist

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CONTENTS

HAND EXAMINATION

History

Continuous practice is the key for taking structured and focused history.

- **Personal History:** Age, hand dominance, occupation, hobbies, smoking.
- **Trauma**
- **Pain:** (Full pain analysis as other joints)
  - Site & radiation: Radial/ulnar-sided & dorsal or palmar. Radiation up or down.
  - Time: night pain, pain at rest, aggravated with movements,
  - Severity: duration, relieving and aggravating factors
- **Other symptoms:**
  - Stiffness - morning/all day
  - Swelling
  - Loss of function
  - Deformity
- **ADL** (Activity of Daily Living):
  - Difficulty opening jars or doorknob in thumb CMCJ arthritis
  - Weak pinch & grip, dropping objects
  - Pain, clicking and giving way in instability
  - Pins and needles, hypoesthesia
  - Buttoning and knitting.
- **Medical History:** DM, RA, previous operations.

Examination

Patient sitting facing you, Hands on pillow
(Look-Feel-Move-Grip)

- **Look**
  - Both hands from front, back and sides & Bare above elbow
  - Describe surface and skin:
    - Scars either traumatic or surgical scars (know incisions e.g. CTS, Russe, dorsal universal approach & arthroscopic portals).
    - Skin changes e.g. psoriasis.
    - Discoloration (melanoma).
    - Dystrophy (pigmentation) from steroid injections.
  - Hand Shape:
    - Wasting of thenar, hypothenar, interossei and forearm muscles.
    - Clawing of finger due to weakness or paralysis of intrinsics (ulnar/median nerve injury) or over-activity or contraction of long flexors.
    - Pits, nodules, and Garrod's pads - if exist ask about similar nodules on penis and feet (Pyronie and Ledderhose's disease). Check progression rate.
    - Alignment, position and bone landmark of hand and wrist.
    - Deformity: Describe flexion attitude at MCPJ and PIPJ, Angular or rotational deformity
  - Clues: Futura splint or thermoplastic splints for Dupuytren's disease, tendon repair or nerve injury.
  - Nails:
    - Haematoma, mucous cyst, glomus tumour pitting.
    - Dystrophic nail changes in psoriasis and tips of fingers in CTS

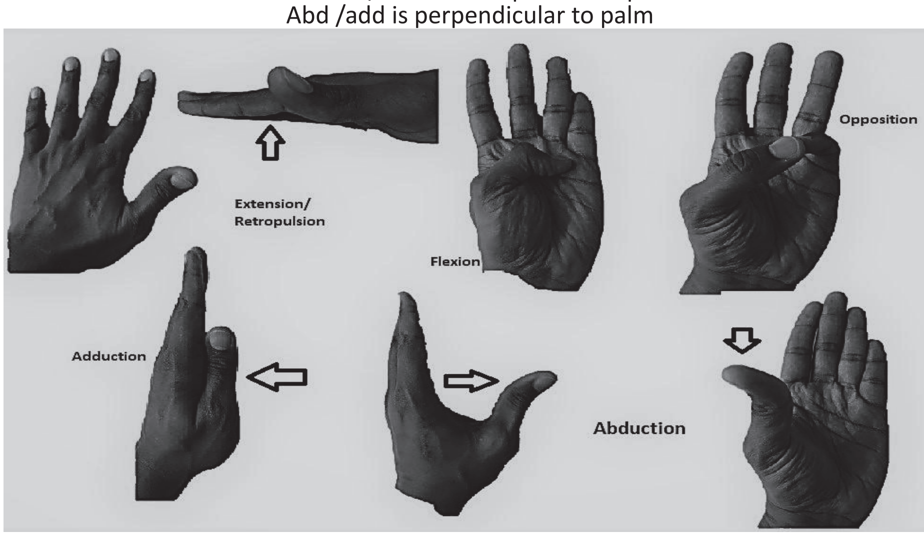
- Prominent ulna in Madelung's
- Swelling like ganglion on dorsum or volar wrist, giant cell tumour over tendons
- Heberden & Bouchard nodes
    - OA (PIPJ & DIPJ)
    - Psoriasis (DIPJ)
    - Rheumatoid (MCPJ)

➢ **Feel:**

- Ask your patient where the maximal pain is, to avoid starting with palpation over painful part.
- Keep a routine logical order of palpation to avoid missing any part. I suggest making it in clockwise manner.
- Feel bony landmarks, joints and tendons as you go along.
- Thickening over palm consistent with cord
- Thenar commissural cord due to thumb web space contracture
- Sensation on each side of digit in recurrent Dupuytren's
- Test sensation over:
    - Tip of index finger for median, base of thenar area for palmar cutaneous branch (runs above transverse carpal ligament as it branches off 3-5cm proximal to wrist)
    - Tip of little finger for ulnar (low ulnar nerve lesion), dorsum of 5th MC (high ulnar nerve lesion – dorsal cutaneous branch)
    - Dorsum 1st web space for radial

➢ **Move:**

- Start with quick screening of movements. Cock up your wrist, drop it down, and turn your hand around.
- Ask patient to make a fist in pronation and supination.
- At this stage probably you will pick up the pathology to start a DISEASE SPECIFIC HAND EXAMINATION.
- Ulnar and radial deviation
- Passive dorsiflexion and palmar flexion
- For thumb Flexion /extension is parallel to palm
  Abd /add is perpendicular to palm



(Courtesy of D Hughes)

- Quick screen of neck movements - flexion, extension, and rotation
- Use goniometer to measure joints range of motion.
    - MCPJ 0 – 90 deg
    - PIPJ 0 – 110 deg
    - DIPJ 0 – 90 deg

- **Grips** (5 grips)
  - Tripod (Pen).
  - Pinch (tip to tip) - thumb and index (Coin).
  - Key grip (tip to side) Key.
  - Power grip - ring and little (Grasp my fist/hand-shake)
  - Hook grip - hook my fingers
  - FDS - DIPJ flexion
  - FDP - PIPJ flexion

Special Tests

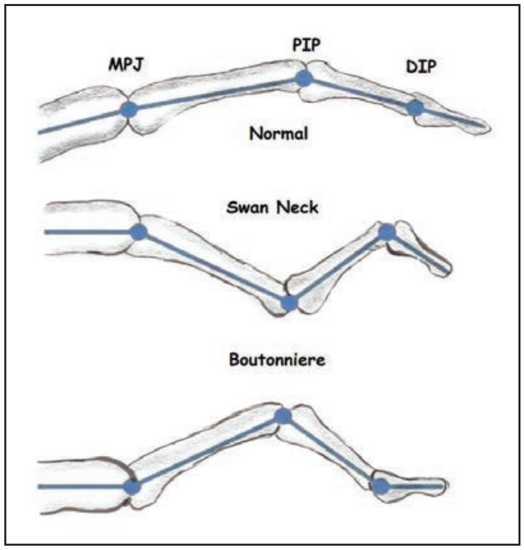
- **Allen test**
  - Occlude both radial and ulnar arteries - make fist several times finishing with fingers extended. Ulnar artery released - time to refill palm and digits measured.
  - Test is repeated for radial artery. Same test can be performed in digits called Digital-Allen test.

  (Always assess sensation and perform digital Allen test in Dupuytren's especially for recurrent disease)
- **Bunnel - Littler test:**
  - Differentiates intrinsic from capsular tightness.
  - MCPJ extension stretches intrinsic muscles causing reduced IPJ movement
  - Improved passive IPJ movements with MCPJ flexed
- **Elson test:**
  - Extension of PIP against resistance.
  - DIP goes rigid due to activation of lateral bands to help damaged central slip. Test for acute cases of central slip injury.
- **Finkelstein test:**
  - Ulnar deviated wrist with thumb clenched in fist. For DeQuervain's tenosynovitis
- **Piano key test:**
  - Elbow flexed and rested on table and forearm pronated, to check for DRUJ instability
- **Kirk Watson test:**
  - To check SLL instability
  - Thumb over scaphoid tuberosity, index on SLL
  - Deviate from ulnar to radial side.
  - Produce pain & clunk due to subluxation of scaphoid over dorsal rim of radius.
- **Valgus stress test:**
  - At neutral and 30°of flexion of 1st MCPJ
  - Instability in 30° of flexion indicates injury to proper UCL
  - Instability in neutral indicates injury to both proper as well as accessory UCL and/or volar plate. Compare to uninjured thumb MCP joint.

RHEUMATOID HAND

History

- Pain - due to synovitis or secondary OA
- Functional assessment
- ADL :
  - Dressing - bra, pulling up trousers / stockings, buttoning
  - Toothbrush, hairbrush, fork, knife use.
  - Knitting
- C-spine symptoms
- Previous treatment - details of previous surgery
- Disease modifying anti-rheumatic drugs (DMARD) or biologics



Examination

Expose to elbows as part of hand examination

- **Look:**
  - Scars/swelling Nodules over ulnar border of forearm.
  - Wrist: Caput ulnae & Radial deviation.
  - MCP: Ulnar deviation & Dropped fingers.
  - Fingers deformity: Swan-neck deformity & Boutonniere & Z-thumb
- **Feel:** Nodules, Synovial thickening
- **Move:**
  - Screening movements of fingers and thumb.
  - Triggering.
  - FPL (Mannerfelt lesion)
  - Extensors (Vaughan-Jackson lesion)
  - 5 Grips.
- **Neurological:** For myelopathy/CTS, Screen nerves

Say, I would like to examine neck, shoulders and elbow, but for this exam I will concentrate on hand.

(Courtesy of R Dhir)

Stages of RA

1) Synovitis without deformity.
2) Synovitis with passively correctable deformity.
3) Fixed deformity without joint changes.
4) Articular destruction:
   - **Nalebuff classification of MCPJ arthritis**
     - Stage I: Synovitis, joint effusions, and soft tissue swelling → Medical treatment (steroid injections)/synovectomy
     - Stage II: Narrowing of joint due to loss of articular cartilage
     - Stage III: Pannus of synovium, extensive cartilage loss and erosions around margins of joint
     - Stage IV: End stage disease, deformity, fibrous or bony ankylosis of joint

Soft tissue reconstruction not possible, arthroplasty or fusion

- **Nalebuff classification of thumb MCPJ**
  - Type I: Boutonniere: MCP flexion and compensatory IPJ hyperextension to increase thumb span
  - Type II: Boutonniere with CMCJ subluxation
  - Type III: Swan neck: MCPJ hyperextension and IPJ flexion
  - Type IV: Gamekeeper thumb due to synovitis and stretching of UCL
  - Type V: Swan neck with CMCJ disease
  - Type VI: Arthritis Mutilans; destruction and collapse

Management Principles

- Assess whole patient.
- MDT approach.
- Functional assessment Physio and OT assessment.
- Optimize medical care.
- Synovectomy for painful tenosynovitis.
- Wrist: Synovitis of extrinsic carpal ligaments – laxity
  Supination and radial deviation of carpus
- Caput ulnae: prominent distal ulna
  - Synovitis DRUJ - dorsal subluxation of ulna & ECU rupture
  - ECU sheath stretching - ECU sublux volarly causing supination of carpal bones away from ulnar head.
- MCPJ: Volar subluxation and ulnar drifting. Radial sagittal band stretching secondary to synovitis, extrinsic extensor tendons sublux ulnarly, stretching of radial collateral ligament.
- Wrist radial deviation generates ulnar deforming force through extrinsic extensors.
- Treatment:
  - Wrist arthrodesis.
  - Centralization procedure and sagittal band reconstruction.
  - MCPJ replacement.
  - PIPJ - Reconstruct central band.
  - Relocate lateral bands.

Causes of Dropped Fingers in RA

- Tendons rupture
  (Vaughan – Jackson syndrome: Ruptured EDM & EDC).
- EDM 1st tendon to rupture due to attrition over prominent ulnar head and tenosynovitis damaging tendon.
- PIN palsy due to elbow synovitis and in advanced RA secondary OA.
- Subluxed MCPJ.
- Subluxed extensor tendons: patient can maintain extension when passively extended.
- Locked trigger fingers.

FLEXOR TENDON INJURY

Physiology

- **Tendon healing** (occurs via 2 pathways):
    - Intrinsic
    - Extrinsic (healing in 3 phases):
        1- Inflammation
        2- Fibroblastic
        3- Remodelling
- **Nutrition**
    - Via bony insertion
    - Musculo-tendinous junction
    - Vincular arteries - derived from digital arteries
    - Synovial diffusion at zone 2
- **Tenodesis effect** (with passive wrist flexion and extension):
    - Extension at PIPJ or DIPJ with passive wrist extension indicates flexor.
    - Tendon discontinuity.
    - Differentiates between PIN/EDC and AIN/FPL.

Flexor tendon zones

Zone I:

- Distal to FDS insertion (on middle of middle phalanx)
- Treatment:
    - Mini anchor repair.
    - Or reattach through bone holes drilled with K wires and tied with suture over button on top of nail.

Zone II:

- From FDS insertion to distal palmar crease (A1 pulley) - No-man's land
- FDS & FDP in same tendon sheath (Risk of adhesion to pulleys).
- At level of proximal 3rd of proximal phalanx:
- FDS split into two slips (Camper chiasma) & divide around FDP and reunite on dorsal aspect of FDP, inserting into distal end of middle phalanx.
- Poor blood supply
- Direct repair with early ROM (Duran or Kleinert)

Zone III:

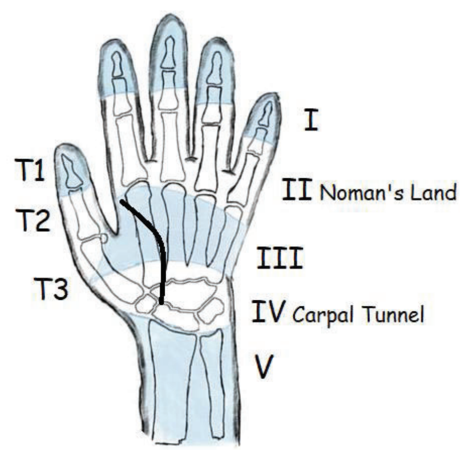
- Palm (A1 pulley to distal aspect of carpal tunnel).
- Often associated with neurovascular injury.
- Direct repair, may require A1 release to avoid impingement.

Zone IV:

- Carpal tunnel – repair complicated by postop adhesions.

Zone V :

- Tendons from wrist to forearm.
- Often associated with neurovascular injury.



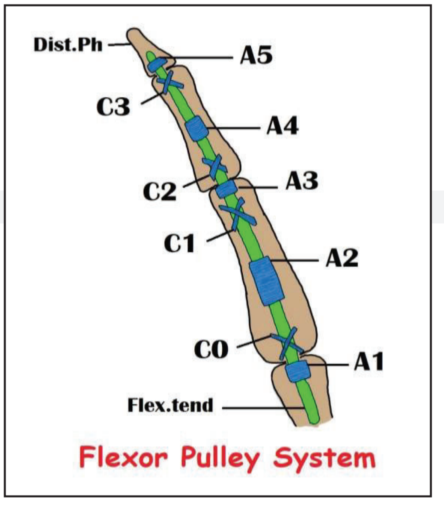
➢ **Thumb**:
- T1: FPL insertion to A2 (IPJ).
- T2: A2 to A1 (IPJ to MCPJ).
- T3: A1 to carpal tunnel.

Pulleys

Thickening of flexor sheath

➢ **Fingers**
- A-Annular:
  - A1 - A3 - A5 pulley overlies MCPJ – PIPJ – DIPJ (Arise from volar plate).
  - A2 and A4: prevent bowstringing, arise from periosteum (stronger) must be preserved.
- C-Cruciate: prevent sheath collapse during digital motion

➢ **Thumb**
- A1 -MCPJ.
- A2 - IPJ.
- Oblique - (most important) over PP, it prevents bowstringing of FPL



Management

➢ **How to retrieve FDP from palm?**
- Retrieve proximal tendon by milking or flexing wrist
- Tendon retriever can cause a lot of damage
- Skin hook
- Suture to infant catheter through proximal incision and pull distally

➢ **Principles of repair**
- Direct repair if >60%.
- Within 2 weeks to avoid pulleys collapse.
- 4-6 core strands provide adequate strength for early active ROM.
- Cross flexion crease transversely or obliquely to avoid contractures.
- Core suture to purchase 10mm from cut edge, minimum of 4 size 4/0. Biomechanically strong repair with TiCron (Polyester coated with Si), Fiber-wire, stainless steel suture.
- Move the repaired tendon at end of operation to make sure it is strong enough and doesn't catch on pulleys.
- Circumferential epitendonous suture to improve gliding and strengthen repair using 5/0 or 6/0 mono-filament.
- Preserve/reconstruct A2 & A4 & oblique pulleys to prevent bowstringing causing weakness of flexion.
- Mobilize early to prevent adhesions and allow increased tendon excursion.

Postoperative regimes

➢ RCT study from Washington by Trumble et al (JBJS Am 2010) showed active ROM after repair provides more flexibility without increasing risk of rupture, less flexion contractures or adhesions and better patient satisfaction scores.

➢ Even 2mm excursion of repair is sufficient to prevent adhesions.

➢ **Belfast protocol (active)**
- Early active ROM starts from day 4 every 2 hourly
- Dorsal blocking splint
- Postoperatively maintain wrist at 20 deg extensions and MCPJ at 40 deg of flexion.
- Don't bandage fingers to allow full early active and passive IP flexion
- First week : full passive flexion and full active extension

- Requires close supervision
- Splint discontinued at 4 – 6 weeks
- Better excursion and ROM but higher re-rupture
- Any residual flexion contractures are treated with dynamic extension splints

➢ **Duran protocol (patient-assisted passive movement)**
- Low force and low excursion
- Active finger extension with patient-assisted passive finger flexion and static splint

➢ **Kleinert protocol (splint-assisted passive movement)**
- Low force and low excursion
- Active finger extension with dynamic splint-assisted passive finger flexion

➢ **Thumb:**
- Early motion protocols do not improve long-term results
- Higher re-rupture rate than flexor tendon repair in fingers

➢ **Children:** Immobilize for 4 weeks

➢ **Neglected or chronic (>3-month) or failed primary repair**
- 2-stage tendon grafting could be 1-stage if sheath not collapsed
- Implant silicone rod in first stage for 3 months.
- Free tendon graft (palmaris longus or plantaris) through pseudo-sheath formed around silicone in 2nd stage
- In any chronic tendon injury, if joint mobile (reconstruction) & If not (joint procedure)
- Reconstruction of pulleys - A2 & A4
- Graft from portion of FDS
- Not to be undertaken at same time as tendon repair as active motion may stretch reconstruction

➢ **Complications**
- Adhesions & stiffness - tenolysis at 6 months
- Re-rupture weakest b/w post-op days 5 and 21
  If >1cm of scar is present, perform tendon graft
- Triggering
- Quadrigia

Flexor tendon injury

Intrinsic Vs extrinsic healing

➢ Intrinsic better to prevent scarring
➢ Intrinsic healing occurs with tenocytes and collagen
➢ Extrinsic healing causes adhesions
➢ Gelberman et al. historically mentioned of gap > 3mm may lead to failure of repair or reduced strength of repair.

Quadrigia effect

➢ FDPs of middle to little fingers work as one unit (multi-pennate muscle), share common muscle belly. Index finger has independent FDP
➢ Tethering causes flexion lag of normal FDP (limited flexion) by injured (and retracted) or repaired (shortened > 1cm advancement) FDP.
➢ Patient may complain of weak grip
➢ Release shortened FDP if severe symptoms limiting function.

Jersey finger

- FDP avulsion injury - zone I
- **Leddy & Packer classification**
  - Type I:
    - Retraction into palm
    - Disruption of entire vincular system
    - Repair within 10 days repair to restore vascularity
    - Chronic: DIPJ fusion
  - Type II:
    - Retraction to PIPJ
    - Within 6 weeks – repair
  - Type III:
    - Bony avulsion fracture blocked at A4 pulley.
    - Tendon repair with anchor or reinsertion with dorsal button
    - Graft or arthrodesis for chronic injury
  - Type IV:
    - Osseous fragment and simultaneous avulsion of tendon from fracture fragment.
    - Fix fracture fragment and repair as type I/II


(Courtesy of M Elgendy)

US to find where the proximal end has retracted to

Mannerfelt lesion

- FPL rupture due to tenosynovitis in RA or attrition over scaphoid prominence
- Fusion or tendon transfer from FDS

Spaghetti wrist

- Sharp volar wrist laceration in which at least 10 structures, including tendons, and at least one major nerve and usually one major vessel are divided

Intrinsic minus (Claw hand)

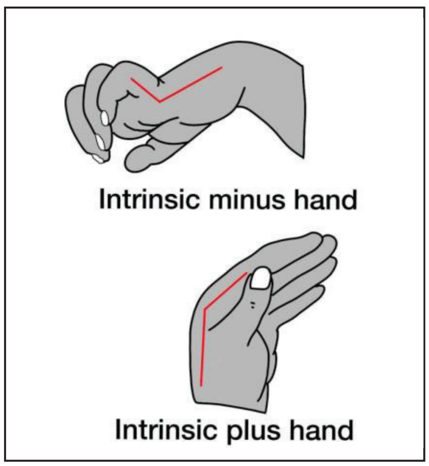
- Intrinsic weak – extrinsic dominant
- Hyperextension at MCPJ and flexion at IPJs
- Integrated flexion is lost in intrinsic minus hand. Normal MCPJ flexion cannot be initiated by intrinsic palsy and IPJ flexion occurs before MCPJ can flex (premature flexion of IPJ causes inability to grasp)
- **Causes**
  - Ulnar nerve palsy – ulnar two digits
  - Median N palsy – Radial 3 digits
  - Volkmann ischaemic contracture – compartment syndrome
  - Klumpke's paralysis
  - Charcot-Marie-Tooth
  - Polio
  - Syringomyelia
  - Failure to splint hand in intrinsic positive position


(Courtesy of M Elgawadi)

- **Edinburgh (intrinsic plus) position**
  - Immobilization of MCPJ in flexion to maintain collateral ligament at maximal length, avoiding scar contraction.
  - PIP joint extension in this position also maintains length of volar plate and collateral ligament
- **Treatment:** Capsulodesis, tenodesis, tendon transfers
- **Bouvier's test**
  - Used in claw hands to assess PIPJ capsule & integrity extensor mechanism
  - Patient is asked to extend PIP joint of the involved digit with MCPJ blocked in flexion:
    - Able to actively extend PIPJ and DIPJ – extensor mechanism intact
    - Unable to actively extend PIPJ and DIPJ – extensor mechanism disrupted
    - We then assess passive movements of PIPJ
  - Patients who are unable to actively extend and have stiff PIPJ are not candidates for tendon transfer
- **(**Differentiates simple from complex clawing)
  - This test checks the integrity of central slip and lateral band function
    - Simple: Able to extend IPJ with blocked MCPJ extension (intact long extensors)
    - Complex: Unable to extend IPJ even with MCPJ flexion

Intrinsic plus

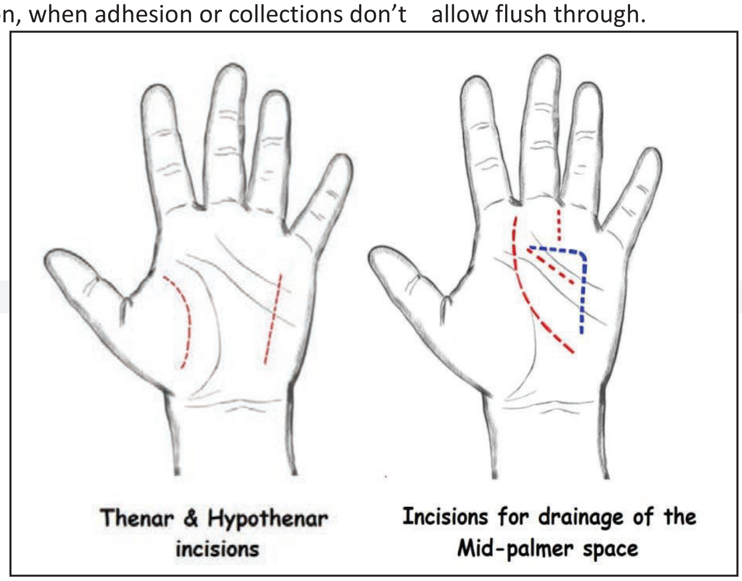
- Spastic intrinsic & weak extrinsic
- MCP flexion and PIP & DIP extension
- Causes : RA, CP, Parkinson's
- Treatment: stretching, muscle release.



HAND INFECTIONS

Pyogenic flexor tenosynovitis

- Infection of synovial sheath that surrounds flexor tendon
- **Horseshoe abscess**
  - Connection between sheaths of thumb (radial bursa) and little finger (ulnar bursa) at wrist.
  - Infection in one finger can lead to infection of sheath on opposite side of hand.
  - Flexor sheath of thumb communicates with radial bursa.
  - Flexor sheath of little finger communicates with ulnar bursa.
- **Kanavel signs**
  - Flexed posture
  - Fusiform (symmetric) swelling
  - Tenderness along the tendon sheath
  - Pain with passive extension
- **Treatment**
  - Urgent surgical drainage followed by intravenous antibiotics, elevation and Splint in Edinburgh position
  - Two incisions - over A1 and A5
  - 16G cannula and irrigate with at least 500 ml saline, washout from proximal to distal.
  - Or full open exposure using Brunner incision, when adhesion or collections don't allow flush through.
  - For radial bursa: mid-lateral incision
- **Complications**
  - Stiffness
  - Tendon rupture
  - Spread of infection
  - Osteomyelitis



Deep palmar space infection

- Results from penetrating injury
- Can have dorsal swelling due to lax tissues
- **3 spaces in hand**
  - Thenar: b/w index FDP and adductor
  - Hypothenar: b/w hypothenar and metacarpals
  - Mid-palmar: b/w interossei & FDP and thenar & hypothenar
- **Parona space**
  - In distal forearm between flexor tendons & pronator quadra
  - Continuous through carpal tunnel with central palmar space
  - Area of communication between thenar and hypothenar bur
- **Incisions**
  - Thenar incision along thenar palmar crease.
  - Hypothenar (Ulnar 4th ray).
  - Longitudinal incision in line with middle finger and proximal to distal palmar crease for mid-palmer

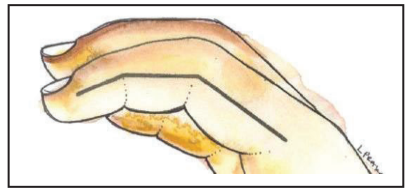
Fungal/mycobacterial/viral infections

- Common in macerated skin areas (skin folds)
- Marine workers, swimmers, dentists
- **Onychomycosis**
    - Fungal infection of nail plate
    - Organisms:
        - ✓ Trichophyton Rubrum destroys nail plate
        - ✓ Candida causes chronic infection of nail fold
    - Treatment: topic antifungals & nail plate removal
    - Systemic Griseofulvin or Ketoconazole for recalcitrant cases
- **Sporothrix Schenckii**
    - From rose thorn
    - Local papules and ulceration at site of penetration
    - Additional lesions form on lymphatic nodes and vessels
    - Cultures and sensitivities
    - Lowenstein-Jensen culture agar to rule out mycobacterium
    - Treatment: oral Itraconazole for 3 to 6 months
- **Mycobacterium Marinum**
    - **Most common** mycobacterial infection
    - Treatment: Oral antibiotics - Isoniazid, Pyrazinamide, Ethambutol, Tetracycline, Clarithromycin, Rifampicin
- **Blackthorn inflammation**
    - May lead to chronic tenosynovitis due to foreign body reaction
    - Swollen, indurated and tender without discharge
    - Thorns not radio-opaque
    - Subsides once thorn removed

Felon

- Subcutaneous abscess of fingertip pulp (Pulp fat separated by fibrous vertical septae running from distal phalanx bone to dermis)
- May lead to compartment syndrome, digital tip necrosis and osteomyelitis of distal phalanx, or may spread proximally to cause flexor tenosynovitis
- **Types:**
    - **Viral (whitlow) - herpes simplex**
        - Vesicular rash
        - Diagnosis confirmed by culture or Tzank smear
        - Self-limiting in 7-10 days
        - Acyclovir may shorten duration of symptoms
        - Antibiotics if superimposed bacterial infection
        - Surgical treatment associated with dissemination, super-infections, encephalitis, and death
    - **Bacterial:**
        - Staphylococcus Aureus, most common organism.
        - Gram negative organisms in immuno-suppressed patients.
        - Eikenella Corrodens in diabetics who bite their nails.

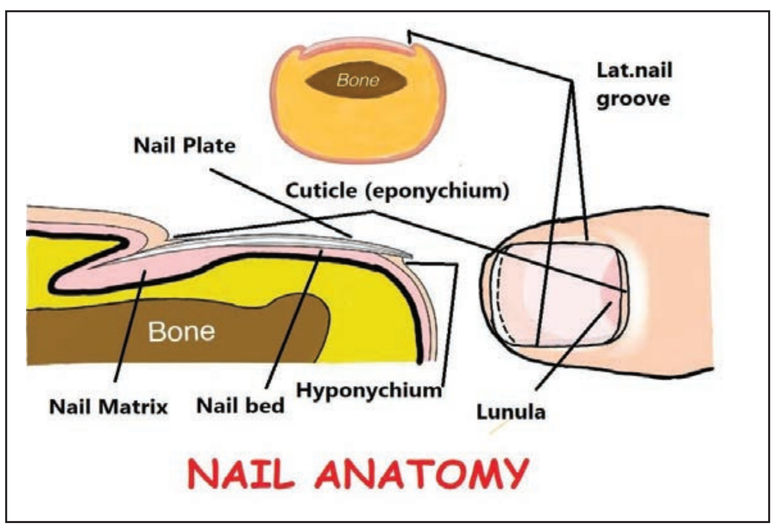
- **Treatment:**
  - Oral antibiotics and observation
  - I&D if not resolving, break up all septa
  - Avoid sides involved in pinch



  - Keep incision distal to DIP crease to prevent contracture and extension into flexor sheath and DIPJ"
    - Mid-lateral approach or volar longitudinal
    - Mid-lateral incision:
      - line connecting between ends of flexion creases
      - Preserve fat on volar flap to protect NV bundle.
      - Dorsal branch of digital N at radial side of index & Middle and ulnar side of ring & little

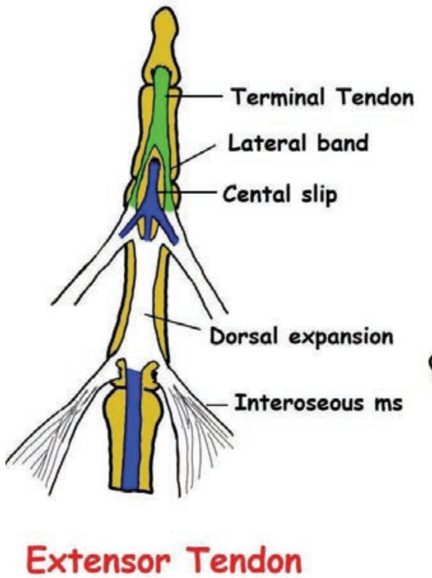
Eponychia/Paronychia

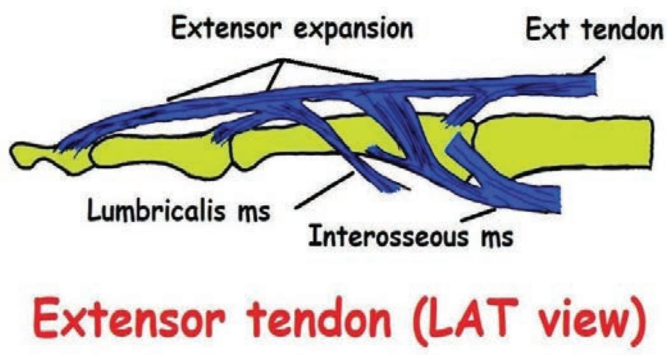
- Germinal matrix should be preserved
- Soft tissue infection of proximal or lateral nail fold
- Nail plate made of keratin - grows at 3mm/month
- Fingernails take 3-6 months to regrow; toenails take 12-18 months
- **Types:**
  - Acute: Staph Aureus (Green discoloration suggests pseudomonas)
  - Chronic: Candida, DM, occupations (prolonged exposure to water and irritant acid/alkali).
- **Treatment:**
  - I&D with partial or total nail bed removal followed by oral antibiotics
  - Nail bed mobility indicates abscess tracking under nail
  - Incision into sulcus between lateral nail plate and lateral nail fold
  - Preserve eponychial fold by placing materials (removed nail) between skin and germinal matrix of nail-bed
  - Marsupialisation in severe cases – excision of dorsal eponychium down to level of germinal matrix (leave it to heal by secondary intention).



EXTENSOR TENDONS

- EDC tendons are cross-connected by juncturae tendini – examine individual extension of MCPJ.
- Insert on extensor expansion (hood) of fingers at MCPJ level.
- Central portion of extensor hood forms central slip.
- Lateral portion of extensor hood forms lateral bands that form terminal slip.
- Blood supply: synovial diffusion under dorsal retinaculum and from paratenon distal to dorsal retinaculum





Zone 1 - Swan neck deformity

- Hyperextension of PIP & flexion of DIP
- Primary cause is lax volar plate at PIPJ that allows hyperextension at PIPJ
- Imbalance of forces at PIPJ: Laxity of transverse retinacular ligament cause dorsal subluxation of lateral bands which become dysfunctional & inefficient.
- Other causes:
  - Mallet injury, leads to transfer of DIP extension into PIP extension forces
  - FDS rupture, leads to unopposed PIPJ extension
    - Volar plate injury
    - Intrinsic contracture
- Management:
  - Conservative: Murphy (oval 8) splint
  - Surgery
    - For progressive deformity.
    - Address volar plate laxity with volar plate advancement.
    - FDS tenodesis indicated with FDS rupture.
    - Transverse & oblique retinacular ligament reconstruction.
    - Central slip tenotomy (Fowler).
    - For infection: approach on either side of terminal tendon.


(Courtesy of M Elgendy)

Zone 1: Mallet finger

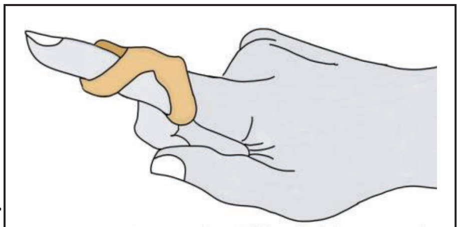
Type: tendinous or bony

- **Tendinous/un-displaced:**
  - Conservative**:** - splint in extension for 6 weeks, allow PIPJ to move.
  - Surgery for tendinous mallet can lead to loss of flexion
- **Bony:**
  - Splint in hyper-extension
  - Displaced/Subluxed or >50% of articular surface involved:Trans-articular wire, Dorsal blocking for displaced bony fragment
- **Chronic:**
  - Reconstruction of terminal tendon.
  - Fusion of DIPJ: Painful & stiff.
- **Complications:**
  - Extensor lag, little dysfunction.
  - Swan neck from overpowering of central slip - release central slip (Fowler's tenotomy)
  - Skin maceration
  - Flexion within splint as oedema settles

Zone 3 - Boutonniere deformity

Injury to central slip → PIP flexion and DIP extension

- **Causes:** Disruption to central slip e.g. trauma
  - PIPJ dislocation sequel.
  - Attenuation of triangular ligament.
  - Lateral bands slip volar to axis of rotation.
- **Acute:** consider re-inserting central slip with mini anchor
  - Surgery for avulsion fracture and open wounds requiring washout
  - Splint for 6/52 in extension then 3/52 in Coil extension (Capener) dynamic splint
  - Encourage DIPJ flexion.
- **Chronic**: lateral band relocation
  - Terminal tendon tenotomy.
  - Central slip reconstruction.
  - PIPJ arthroplasty for degenerative joint and correctable PIPJ.
  - PIPJ arthrodesis for degenerative joint and un-correctable PIPJ.



Static three points PIP splint to prevent hyperflexion (Boutonniere deformity)

Retinacular system

- **Function**: Maintain position of EDC during flexion
- **Sagittal bands** :
  - Originate from volar plate and insert on central slip
  - Primary stabilizer of extensor tendon at MCP joint
  - Rupture: traumatic (boxer knuckle)
    - Extension splint for 6 weeks
    - Direct repair
  - Attritional (RA) - Extensor centralization procedure

- **Oblique retinacular lig** prevents dorsal subluxation of lateral bands, lies volar to PIPJ and dorsal to DIPJ axes
- **Transverse retinacular ligament** from edge of flexor tendon sheath to lateral border of lateral bands

Attenuation leads to dorsal translation of lateral bands and result in swan neck deformity
Contracture leads to volar subluxation of lateral bands and result in boutonniere deformity

- **Triangular lig** counteracts oblique & transverse retinacular ligament to prevent volar subluxation of lateral bands

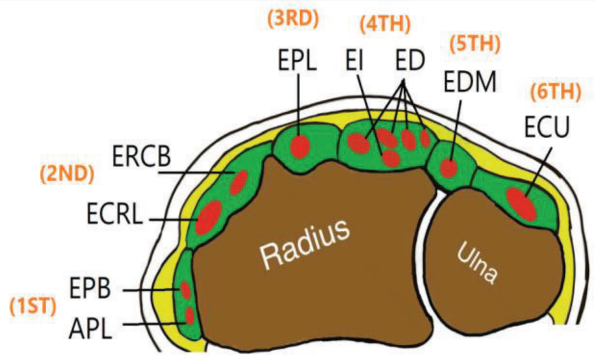
Zones 4 – 8

- EDM normally divides into two slips

Zone 5 - Fight bite at MCPJ

- Always X-ray to rule out any osteochondral lesion or foreign body.
- Repair with horizontal mattress where tendon is flat or Kessler - then continuous.
- Use 5/0 PDS
- Factors affecting strength of flexor/extensor tendon/any tendon repair:
  - Linear relationship with number of sutures crossing repair (core strands)
  - 4-6 strands provide adequate strength for early active ROM
  - Increasing number of strands & size of stitches, increase strength of repair but decrease surface area for healing
  - Locking of stitch
  - Repair usually fails at knots
- Tendon repairs are weakest at 7-10 days post-repair
- Most of strength is recovered by 21-28 days
- Maximum strength at 6 months
- Chronic > 3 weeks - use tendon graft (Palmaris longus or EIP or plantaris)
- Complications: adhesions require tenolysis

Dorsal extensor compartments



EXTENSOR COMPARTMENTS OF THE WRIST

EPL rupture

- 3rd extensor compartment
- Inserts on base of distal phalanx of thumb
- Tested by Retropulsion - table top test (EPB not enough to extend MCPJ by itself)
- **Causes :**
  - RA
  - Post Colle's fracture even if treated conservative (Attritional rupture secondary to increased intra-compartmental pressure)
- **Management:**
  - Direct repair not possible due to tendon degeneration
  - Free tendon graft from Palmaris longus
- **EIP to EPL transfer**
  - EIP ulnar to EDC
  - Check clinically with extension of index and little fingers with other fingers flexed (Horn test)
  - 3 incisions:
    - 1 cm transverse over index MCPJ proximal to extensor hood to harvest EIP
    - 3 cm transverse distal to extensor retinaculum to retrieve EIP
    - Oblique at base of thumb to identify EPL distal to rupture
    - Pulvertaft weave - 3 incisions at 90 degrees
  - Tenodesis effect to judge tension intra-operatively to avoid loss of IPJ flexion
  - Over-tighten slightly as tendon tends to stretch
  - Hand therapy:
    - Early active movements with static volar splint
    - Or early passive movements with dorsal split and elastic band

CONGENITAL HAND MALFORMATIONS

Camptodactyly

- Congenital PIPJ flexion deformity of little finger
- c**A**mpto – **A** for **A**ntero-posterior deviation
- Abnormal insertion of lumbricals, short FDS
- Flexible or fixed
- Usually affects little finger
- Progress with growth (can be infantile or adolescent)
- Painless
- Commonly bilateral
- Management:
  - Non operative: splint & stretch
  - Operative:
    - Progressive deformity leading to functional impairment
    - FDS tenotomy
    - FDS transfer to lateral band
    - Osteotomy/arthrodesis for severe fixed deformities

Clinodactyly

- Deviated little finger due to delta (trapezoid) middle phalanx
- c**L**ino – **L** for **L**ateral/radial deviation
- C-shaped physis
- Can be associated with trisomy 21 (Down syndrome)
- Treatment:
  - Surgery if functional deficit
    - Opening wedge osteotomy to preserve length & avoid risk to ulnar digital nerve
    - Resection of abnormal bracket of physis and fat graft

Kirner Deformity

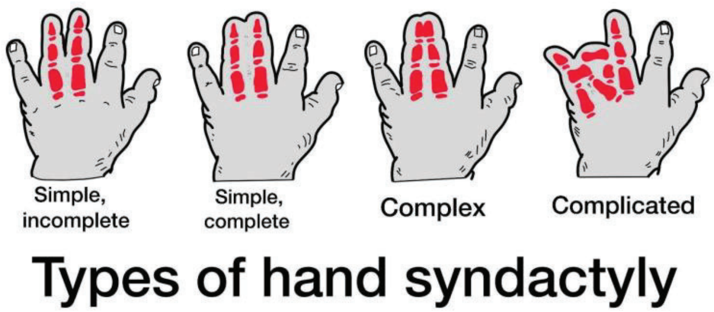
- May be mistaken for clinodactyly
- Volar and radial curvature at the distal phalanx of the little finger
- Usually autosomal dominant
- Frequently bilateral
- Management:
  - Surgery for cosmetic reasons only - Corrective osteotomy
  - Avoid when growth plate is open

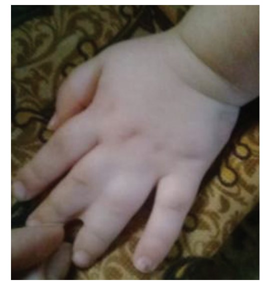
Symphalangism

- Failure of IP joint to differentiate during development - Ankylosis of PIPJs
- Absent of flexion and extension creases
- Capsulotomy/arthroplasty/osteotomy/fusion, limited success

Syndactyly

- Most common congenital malformation of limbs
- Common between middle and ring fingers
- Failure of apoptosis to separate digits
- Complicated syndactyly (joined digits with osseous or cartilaginous union) can happen with Apert and Poland syndrome




(Courtesy of M Shashoo)

- Release digits with significant length difference to avoid growth disturbances
- Zig-zag flaps to avoid longitudinal scarring
- Can produce skin deficiency that requires skin grafting
- Complication: web creep - ***most common*** complication of surgically treated syndactyly
  - Caused by abnormal scar tissue formation
  - Graft failure

Constriction ring (Amniotic band) syndrome

- Loose fibrous bands of ruptured amnion adhere to and entangle normal developing structures of foetus
- 90% in hand but can also affect foot and limbs


(Courtesy of L Prakash)

- Ranges from simple constriction to syndactyly to amputation
- Strong correlation with clubfoot
- Intrauterine diagnosis can be made with ultrasound at end of first trimester
- **Treatment**
  - Observation in simple constriction ring
  - Operative: excision or release of constriction band compromise of digital circulation
  - Circumferential Z-plasties if distal deformities present
  - Reconstruction of amputated parts to improve function

Polydactyly

- **Preaxial:** Thumb duplication **(Wassel classification)**
  Type IV is ***most common***.
  Wassel 7 associated with: Holt-Oram - Fanconi's anaemia - Black fan-Diamond Syndrome

  Management:
  - Aim to produce well aligned normally sized ,stable thumb before age of 2 while preserving epiphyseal plate
  - Asymmetrical: Resect smaller thumb (usually radial) & preserve ulnar thumb with the UCL
  - Symmetrical: Excise central composite and approximate outer halves
- **Postaxial** Small finger duplication
  - Most common type of polydactyly
  - Could be well formed digit or rudimentary skin tag
  - Excise and reconstruct UCL
- **Central:** Associated with syndactyly

Macrodactyly (Local gigantism)

- Congenital digit enlargement: affects fingers and toes
- Can be multiple
- Vessels not enlarged → relative ischaemia
- Can be static or progressive
- Index ***(most common)***
- Associated with neurofibromatosis and Klippel-Trenaunay-Weber syndrome
- In toes: cosmetic and shoe fitting problems
- **Treatment:**
  - Epiphysiodesis: perform once digit reaches adult length of same sex parent
  - Osteotomy and shortening
  - Amputation - in severe involvement of digit or toe or in non-reconstructable digit

Congenital thumb deformities

Congenital Trigger Thumb

- Increased FPL tendon diameter compared to A1 pulley causes disruption of normal tendon gliding
- Prominence of flexor tendon nodule, referred to as Notta node
- Begins with thumb triggering that progresses to fixed contracture
- Usually painless
- Spontaneous resolution unlikely after age of 2 years
- **Treatment:**
  - Passive extension exercises and observation, extension splinting (for flexible deformity)
  - A1 pulley release –
    - For fixed deformity and failed conservative treatment
    - Before age of 18 months to prevent FFD
    - Transverse incision in thumb MCP flexion proximal crease
    - Protect radial digital nerve
    - Watch nodule during passive IP extension to ensure smooth tendon gliding
- **Complications:** Bow-stringing of flexor tendon due to release of oblique pulley

Thumb Hypoplasia

- Frequently associated with partial or complete absence of radius
- **Associated anomalies**: VACTERL, Holt-Oram, TAR, Fanconi's anaemia
- Aim of treatment - stable, mobile and opposable thumb
- **Blauth classification**
  - **I:**
    - All musculoskeletal and neurovascular components of digit are present. Just small in size (hypoplasia) - not a clinical problem
  - **II:**
    - MCPJ unstable , adducted posture and thenar hypoplasia
    - Reconstruct UCL or MCPJ fusion
    - Opponensplasty (opposition transfer) using FDS or abductor digiti minimi
    - Release first web space
  - **III:**
    - Musculotendinous and osseous deficiencies hypoplastic extrinsic
    - **A** CMCJ intact – reconstructable: stabilization
    - **B** CMCJ deficient - not reconstructable: amputation/ablation & Pollicisation
    - Stability of CMCJ is essential for success of thumb reconstruction to provide resistance during grasp and pinch
  - **IV:**
    - Floating thumb - Attachment to hand by skin / neurovascular structures
    - Pollicisation of index finger
    - Also consider 2nd toes transfer
  - **V:**
    - Complete absence - Adactyly
    - Pollicisation of index
    - Can also consider 2nd toes transfer

Clasped Thumb

- Flexion-adduction deformity
- Weakness or deficiency of extensor pollicis longus or brevis, or both
- Associated conditions: congenital vertical talus, congenital talipes equinovarus and arthrogryposis
- **Treatment** Serial splinting and stretching for 3-6 months
  EIP to EPL tendon transfer and release adductor pollicis
  Arthrodesis

Cleft hand

- Absence of 1 or more central digits of hand
- Swanson type I failure of formation (central longitudinal deficiency)
- Could be simple or complex
- Familial
- Bilateral
- May have syndactyly of ulnar digits
- Associated with absent metacarpals
- Observe - if no functional impairment
- Reconstruct - close cleft or toes transfer

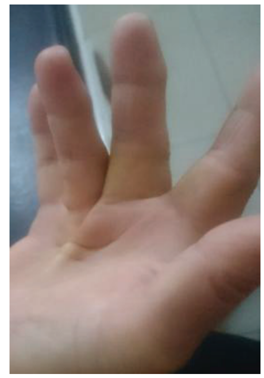
BLOOD SUPPLY TO HAND

1. **Radial artery**
   - Runs between brachioradialis and FCR
   - Enters dorsum of carpus by passing between FCR and APL/EPB (in snuffbox)
   - Gives superficial palmar branch (communicates with superficial arch)
   - Finally passes between 2 heads of 1st dorsal interosseous
   - Forms **deep palmar arch**, deep to flexor tendons - 1 cm proximal to superficial arch
   - Anatomical landmark – Kaplan's line
   - Supply thumb
2. **Ulnar artery**
   - Runs under flexor carpi ulnaris, lateral to ulnar nerve at wrist
   - Enters hand through Guyon's canal
   - Forms **superficial palmar arch** deep to palmar fascia
   - Supply digits
3. **Venae comitantes**
   - Pairs of veins that accompany an artery
   - Pulsations of artery aid venous return
4. **Digital arteries**
   - Common digital arteries arise from superficial palmar arch
   - Dominant arteries are found on medial side of digit (closer to midline)
   - Dorsal to nerves in digits but volar in palm

Traumatic injury can result in pseudoaneurysm that requires MRA and excision

DUPUYTREN'S DISEASE

- **Definition:**
  - Benign proliferative disorder characterized by fascial nodules and contractures of hand (metaplasia of normal fibro-fatty tissue)
  - Autosomal dominant inheritance



(Courtesy of S Chenow)

- **Epidemiology**
  - Northern Europeans, genetic inheritance
  - DM, alcoholic, HIV, smoking
  - M: F = 4:1
  - Associated with epilepsy and phenytoin
  - Family History: COPD
- **History**
  - Painless - look for synovial sarcoma if painful
  - How is this affecting you? ADLs
  - Medical History: DM, Epilepsy, Alcohol, Phenytoin
  - Family history
- **Examination**
  - **Look**
    - Contractures, pits, cords, nodules, scars, graft
    - Little finger abduction in abductor digiti mini cord
    - Garrod's pads at PIPJs - ask if similar pads elsewhere
    - Hueston table top test: inability to put hand flat on table - screening test
  - **Feel**
    - Nodules and cords
    - Test sensation - Digital sensation on each side
    - Commissural cord in thenar eminence
    - Lateral digital sheath
    - Abductor digiti mini cord in the palm
  - **Move** (ROM):
    - Assess MCPJ by flexing PIPJ ,and PIPJ by flexing MCPJ - cords can cross more than 1 joint
  - **Test:** Allen
  - **Assess grips and functional assessment of hand**
  - **Mention** about involvement of feet and penis

Luck Stages

1. **Proliferative:** Dysplasia of fibroblasts to myofibroblasts which produce type III collagen
2. **Involutional:** Myofibroblast & Type III collagen organised along lines of tension
3. **Residual:** Less cellular density

Pathoanatomy

Bands become pathological cords

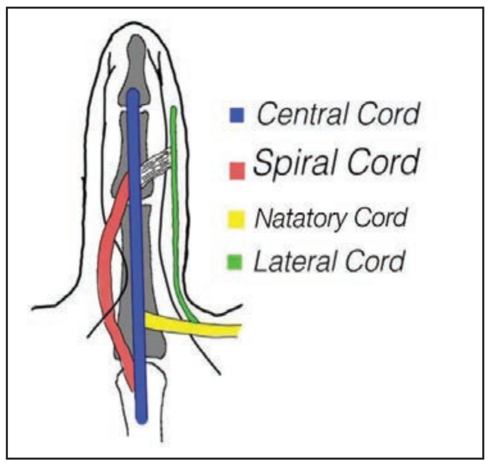
Normal bands

Anchor skin to prevent excessive mobility and improve grip

- **Pre-tendinous:** overlie flexors in palm, NV bundle lies lateral to it
- **Spiral:** from pre-tendinous band, lie deep to NV bundle
- **Lateral digital sheath:** NV bundle lies medial to it
- **Natatory ligament:**
  - Distal to superficial transverse metacarpal ligament
  - Lies immediately beneath volar skin
  - Beneath it passes the digital vessels and nerves
  - Limit abduction of MC
- **Deep Transverse Metacarpal Ligament** prevents metacarpal heads from splaying apart
- **Cleland & Grayson ligament** stabilize digital neurovascular bundle with finger flexion & extension *(Cleland spared in Dupuytren's)*

Pathological cords

- **Central:** from pre-tendinous band, causes contraction of **MCPJ**
- **Spiral**:
  - From pre-tendinous band + spiral band + lateral digital sheath + Grayson ligament
  - Displace NV bundle centrally (medially) and superficially as the spiral cord tightens its course becomes more straighter that displaces the NV bundle
  - Superficial to NV bundle proximal to MCPJ and deep to bundle distal to MCPJ
  - Causes contracture of **PIPJ**
- **Lateral** from lateral digital sheath – affects **MCP and PIPJ**
- **Retro-vascular cord** – affects DIPJ
- **Natatory** causes **(web space contracture)**
- **Abductor digiti minimi cord**
- **Proximal commissural ligament** – radial extension of superficial transverse palmar ligament (**thumb contractures**)



Woodruff classification

Stage I	Palmar	No contracture	Surveillance
Stage II	One finger	MCPJ contracture	Surgery
Stage III	One finger	MCPJ + PIPJ contracture	Surgery
Stage IV	> one finger		Surgery
Stage V	Severe	finger-in-palm	?amputation

Diathesis - aggressive form

Features:

- < 50 years old
- Family history
- Multi-digit involvement, bilateral
- Ectopic lesions Ledderhose disease (plantar fascia fibromatosis)
  Peyronie's disease (Dartos fascia of penis)

Garrod's pads on the knuckle

BSSH classification

I. **Mild**- no functional problem, MCPJ contracture < 30°
II. **Moderate**- Functional problems with, MCPJ contracture 30°-60° or PIPJ <30° or 1st web contracture
III. **Severe**- MCPJ >60°, PIPJ>30°

- **Indications** for surgical treatment:
  - BSSH recommends surgery for moderate or severe disease
  - Inability to put hand flat on table (Hueston Table top test)
  - Painful nodules are ***not*** indication for surgery

Treatment

- Spontaneous resolution does not occur
- No cure for Dupuytren's disease
- Aim: To correct deformity and restore movements - cannot cure
- Observe if good function

Collagenase Clostridium Histolyticum - Withdrawun from European market

- Into palpable cords - causes lysis & rupture
- Injection in 3 points along cord - Stretch after 1-2 days and Splint
- Contraindicated in Warfarin and Tetracycline and pregnancy
- Comparable deformity correction to surgery
- Reduced morbidity
- Quicker return to work
- Higher recurrence rate than surgery: 50 % recurrence in 5 years
- *RCT – Hurst – NEJM – 2009*
  Significantly improved extension.
  Most common adverse events reported were tendon ruptures, pruritic rash and axillary lymphadenopathy

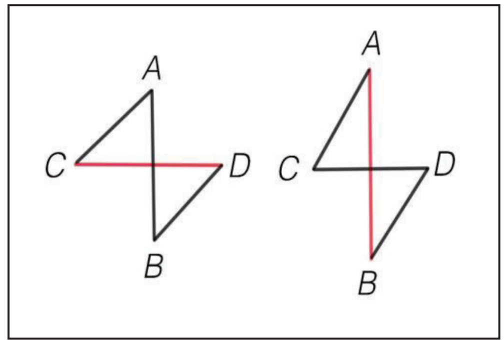
Percutaneous needle fasciotomy

- For MCPJ contractures
- NICE - Safe & efficacious
- Recurrence: 50% at 3–5 years

Partial fasciectomy

Gold standard

- Brunner zigzag incision -
  - Apex at finger flexion crease
  - Angle > 60 degrees to avoid apex necrosis
  - NV bundle vulnerable at apex
  - Full thickness skin flaps



- Z-plasty
  - 30 degrees (lengthen 25%)
  - 45 degrees (lengthen 50%)
  - 60 degrees (lengthen 75%)
  - Straight midline longitudinal incision
  - Transverse limb should lie in flexure crease
  - When flaps transposed – lengthening in longitudinal axis and shortening in transverse axis

Other rare options

- Amputation
- McCash open hand technique
- Dermofascectomy with skin graft
- Michigan USA study: A systematic review of outcomes of fasciotomy, aponeurotomy, and collagenase treatments for Dupuytren's contracture (Chen, Srinivasan et al. Hand J 2011) gave recurrence rates:
  - Collagenase injection 10-31% at mean follow up of 4 months-4 years
  - Needle aponeurotomy 50-58% at mean follow up of 3-5 years
  - Open partial fasciectomy 12-39% with mean follow up time of 1.5-7.3 years
  - Various studies have reported **Dermafasciectomy with fire-break grafts** having recurrence rates of 8% at 5-6 year follow-up

FINGER AMPUTATION

- Asses patient and resuscitate according to ATLS protocol
- Wrap amputate in sterile saline soaked gauze
- Place in sealed plastic bag
- Place in slush, but not in direct contact with ice
- Label it - name, time of injury, time placed in bag
- **Indications for replantation**
  - Clean sharp injury
  - Child
  - Thumb - thumb amputation causes 40-50% loss of hand function
  - Multiple fingers
  - Wrist level
- **Contraindications to replantation**
  - Zone II amputations in single digit
  - Crush injury
  - Mangled extremity
  - Prolonged ischaemia time
    - Maximum warm ischemia time for digit is 12 hrs, cold ischemia 24 hrs
    - Maximum warm ischemia time for wrist is 6 hrs, cold ischemia 12 hrs
- **Order of reconstruction**
  - Bone – Extensor – Flexor – Artery – Nerve – Vein – skin (BE a FAN of V)
  - Restore bony anatomy 1st to provide stability
  - Repair arteries first to force blood out to be able to see veins
  - Digit transposition - use salvageable digits to replant on functionally more important fingers (index for thumb)
- **Post op**
  - Keep patient in warm room
  - Avoid caffeine, chocolate, and nicotine
  - Adequate hydration
  - Anticoagulation
- **Failure**
  - <12 hrs: Arterial thrombosis (Prevent with Heparin)
  - >12 hrs:
    - Venous thrombosis (Prevent with Heparin)
    - Leeches suck blood

      Release Hirudin (powerful anticoagulant)

      Aeromonos hydrophila infection (prophylaxis with Bactrim or Cipro)
  - >5 days: infection (Prevent with Antibiotics)
- **Complications**
  - Patients tend to exclude implanted digit following single digit re-planation
  - Stiffness
  - Cold intolerance
  - Poor sensibility
  - Reperfusion injury

Ring avulsion injury

- Sudden pull on finger ring results in severe soft tissue injury
- Ranges from circumferential soft tissue laceration to complete amputation
- Skin, nerves, vessels are often damaged
- Require free skin flap

Thumb reconstruction

- Aim restore length
  Provide stability
  Adequate sensation
  Mobility
- Regions of thumb reconstruction:
  - A (through IPJ) - finger-tip injury management
  - B (through proximal phalanx) - Web deepening or MC lengthening
  - C (through MC) - 2nd toe to thumb
  - D (through trapezium) – pollicisation

Index:

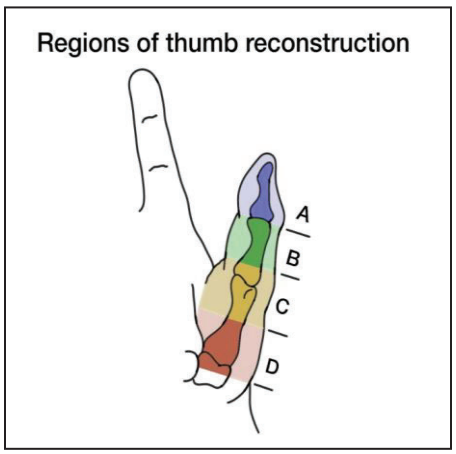
- Remove MC to allow middle finger to come across
- Preserve insertion of ECRL

Middle

- Remove MC to reduce space
- Preserve insertion of ECRB

Ring:

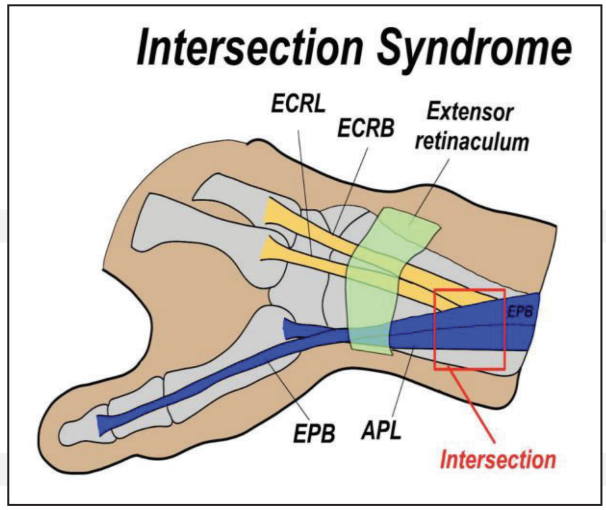
- Transfer 5th MC to close gap



RADIAL SIDED WRIST PAIN

De Quervain's syndrome

- Stenosing tenosynovitis of sheath of APL & EPB -1st dorsal compartment
- APL inserts on base of 1st metacarpal
- EPB inserts on base of proximal phalanx of thumb
- Associated with postpartum state
- Thumb spica
- Surgical release - transverse incision
- EPB and APL lie in separate sub-sheath



Intersection syndrome

- Tenosynovitis at crossing point of 1st and 2nd dorsal compartments
- Splint, steroid injection
- Surgical release of 2nd compartment

Thumb CMCJ arthritis

- Saddle joint
- Anterior oblique ligament (Beak ligament) **primary stabilizing** restraint to subluxation of CMC joint
- Robert view - true AP of thumb CMCJ: forearm pronated and thumb abducted

Clinical assessment

- **Look**:
  - Swelling, Prominence (squaring) of base of thumb (also called shoulder sign)
  - Patient avoids painful thumb abduction & progressive 1st CMC stiffness - adduction deformity develops
  - Hyperextension of MCPJ to compensate (Z deformity)
  - Look for concomitant carpal tunnel
- **Feel**: Tenderness
- **Move**: Axial grind test, combined axial compression and circumduction with stabilized carpus (Reduce joint 1st).
- **Functional grip assessment**

Eaton & littler classification

I	Widening from effusion, synovitis & joint laxity
II	Slight narrowing, sclerosis, small osteophytes < 2mm
III	Marked narrowing, large osteophytes > 2mm, subluxation > 3rd
IV	Pan-trapezial arthritis

Management

- **Non-operative:**
  - Thumb spica splint. Physio, activity modification.
  - Injection of corticosteroid/Hylan
  - Heyworth (RCT comparing Hylan, steroid or placebo injection, J Hand Surgery 2008) equally effective at reducing pain and increasing thumb function at 3 months
- **Operative**

- Trapeziectomy (excision arthroplasty) leads to weak pinch from shortening
- Interposition arthroplasty with PL
- Ligament recon & tendon interposition (**LRTI**)
- Reconstruct volar oblique ligament using distally based radial half of FCR
- MCPJ arthrodesis if >40 degree hyper-extension deformity

➢ Cochrane:
  - No one procedure produced greater strength and pain reduction and physical function than any other.
  - If associated with STTJ arthritis – consider excision of proximal trapezoid

➢ RCT (Dias – J hand surgery, 2004)
  At 3 month & 1 year - all procedures had same improvement in pain and grip strength
  - Approach: 5 cm incision over APL & Between EPB & EPL
  - Risks: Superficial radial nerve & Radial artery

➢ **Other surgical options:**
  - **Arthrodesis**
    - Young manual worker, improved grip
    - Aim: pain relief, stability and maintenance of length
    - Clenched fist (cup holding) position
    - Small area for bony union – non-union 20%
    - Decreased ROM
  - **Joint replacement**
    - Better strength at 1 year than LRTI
    - Risk of loosening and dislocation
    - PyroDisc - from Pyrocarbon
  - **Abduction osteotomy -** for stage I & II

STT arthritis

➢ Volar /dorsal movements – painful
➢ Ulnar/radial deviation cause pain
➢ Consider distal scaphoid excision, small amount to prevent DISI
➢ Or STT fusion - technically demanding

Wartenberg's neuritis

➢ Compressive neuropathy of superficial sensory radial nerve

Scaphoid non-union and scapho-lunate injury

➢ SNAC/SLAC wrist

Scaphoid AVN (Preiser's disease)

➢ Sclerosis and fragmentation of proximal pole
➢ Treatment: microfracture, vascularized graft ,PRC

FCR tendonitis

➢ Inserts on 2nd MC
➢ Resisted wrist flexion triggers pain
➢ Causes: primary stenosing tenosynovitis

- Secondary to trauma and fractures
- Immobilization, steroid injection, surgical release

ULNAR SIDED WRIST PAIN

TFCC tear

- Fibrocartilage at distal aspect of ulna
- Attaches to base of ulnar styloid
- Meniscus-like structure
- Made of
  - Dorsal and volar radioulnar ligaments
  - Central articular disc
  - Meniscus homologue
  - ECU sheath
  - Ulnar collateral ligament
- Periphery well vascularized, central portion avascular
- Contributes to stability of DRUJ
- **Classification**
  - Traumatic
  - Degenerative
    - Associated with ulna positive variance
    - Usually central perforation
- Arthroscopy - most accurate method of diagnosis
- **Treatment**:
  - Immobilize arthroscopic debridement (central perforation)/repair (ulnar sided tear). Ulna shortening osteotomy works for positive ulnar variance and degenerative tear. There are no RCT data on efficacy.

Snapping ECU

- Secondary to attenuation and rupture of ECU sheath in 6th dorsal compartment
- Subluxates in volar and ulnar direction leading to ECU tendonitis
- ECU sheath repair/reconstruction

Pisio-triqutral OA

DRUJ

- Trochoid (pivot) joint → allows for rotation parallel to long axis of bone
- Primary stabilizers: Volar and dorsal radioulnar ligaments & TFCC
- Instability present when ulnar head subluxed from sigmoid notch by its full width with arm in neutral rotation
- Consequences of instability:
  - Decreased grip strength
  - Limited pronation and supination
  - On-going pain
  - DRUJ arthritis
- Corrective osteotomy of distal radius if DRUJ instability is caused by radius mal-union

(Courtesy of M Elgendy)

In the presence of arthrosis

- **Darrach procedure:**
  - Resection arthroplasty of ulna head can be used for caput ulnae or positive ulna variance.
  - Ulnar head resection 1-2 cm
  - For low demand patients
  - Risk of ulna stump instability
- **Sauve-Kapandji:**
  - DRUJ fusion with ulnar neck resection to create pseudoarthrosis
  - Good option for manual labourers
  - Contraindicated in advanced OA of wrist
- **Ulna head replacement:** early results are promising but long-term results pending

Hamate fracture

- Racket sports
- Triangular shaped carpal bone, composed of hook and body
- Can cause ulnar nerve compression
- Carpal tunnel view
- Oblique view
- Hook Non-union: excision
- Body: inter-fragmentary screw

Pisiform fracture

- Located within FCU tendon
- Contributes to stability of ulnar column by preventing triquetral subluxation
- Immobilize in 30 degree of wrist flexion
- Excision: for painful non-union

Ulnar Styloid Impaction Syndrome

- Impaction between ulnar styloid tip and triquetrum
- Patients with excessively long ulnar styloid or ulna positive wrists
- Treatment: same as for abutment

Ulnocarpal Abutment Syndrome

- Excessive impact between ulna and lunate
- **Associated conditions with positive ulnar variance:**
  - Scapholunate dissociation
  - TFCC tears
  - DRUJ injuries
  - Lunotriquetral tears
  - Shortening from previous Colle’s fracture
  - Madelung deformity
  - Gymnast's Wrist:
    - Premature closure of distal radial physis
    - Resect physeal bridge or ulna epiphysiodesis
  - Neutral ulnar variance

- **X rays**:
  - PA view with forearm in mid-pronation, shoulder abducted and elbow flexed to 90°
  - Ulnar variance: Describes cranio-caudal position of distal ulna in relation to distal radius
  - 2 lines tangential to articular surface of ulna and perpendicular to shaft & Line tangential to lunate fossa of radius and perpendicular to shaft
    - If ulnar tangent is distal to radial tangent = positive UV
    - If ulnar tangent is proximal to radial tangent = negative UV
  - 80% of compressive load across wrist accepted by distal radius
  - 20% accepted by distal ulna
  - -2.5mm of ulnar variance: 5% of wrist load accepted by distal ulna
  - +2.5mm of ulnar variance: 40% of wrist load accepted by distal ulna
- **Treatment:**
  - Ulnar shortening osteotomy **(gold standard).**
  - Wafer procedure- 2 - 4mm of cartilage and bone removed from under TFCC arthroscopically
  - Partial ulnar styloidectomy
  - Darrach procedure
  - Sauvé-Kapandji procedure
  - Ulnar head replacement

CENTRAL WRIST PAIN

- Osteoarthritis
- Rheumatoid arthritis
- Kienbock's disease
- SLAC
- SNAC

WRIST PROCEDURES

Wrist replacement

- NICE evidence that total wrist replacement relieves pain and improves ROM
- Need adequate bone stock
- Distal fixation in carpus
- Uncemented, with screws to augment initial fixation
- Minimal bone resection of distal radius enables preservation of carpal ligament attachments, enhancing both wrist proprioception and stability.

(Courtesy of K Memon)

Wrist fusion

- Splint 1st to see if they like it
- OA - secondary to Keinbock
- Decorticate, bone graft and fix
- Pre-contoured dorsal wrist plates allow 10 – 20 deg extension to preserve grip strength
- Steinman pin
- Radius in line with 3rd MC
- RA: Slight flexion to improve extensor tenodesis effect at MCPJ
- For bilateral – fuse contra-lateral in 10 deg flexion.
- Difficulty with working in confined spaces where shoulder and elbow can't compensate.

Wrist arthroscopy

- 2.7 mm, 30° arthroscope
- **Radiocarpal portals**
  - 1 - 2 portal risk to radial artery & superficial radial nerve
  - 3 - 4 portal 1 cm distal to Lister tubercle primary viewing
  - 4 – 5portal for TFCC instrumentation
  - 6U/R portal at level of ulnar styloid risk to dorsal sensory branch of ulnar nerve
- **Mid-carpal**
  - MCR (1 cm distal to 3-4 portal): Allows visualization of scapho-lunate, scapho-capitate, and scapho-trapezoid joints
  - MCU (1 cm distal to 4-5 portal): Allows visualization of luno-capitate, luno-triquetral, and triquetro-hamate joints

SWELLINGS OF HAND

Ganglion

- History
- Examination:
    - Look: Increase size in flexion
    - Feel: Mobile skin.
    - Tests: Trans illuminates (transmits light through fluid filled lump)
    - Cyst attached to synovial joint or tendon sheath
    - Wall made of compressed collage fibres, no synovial cells
    - Contains: Mucin, glucosamine, albumin, Globulin & Hyaluronic acid
- **Dorsal:** from SL joint
- **Volar:** from STT or radiocarpal joint or from herniated tendon sheath fluid
- Allen test
- US or MRI to show relation with radial artery to differentiate cyst from vascular aneurysm
- Dias et al. J Hand Surg (Euro Vol), 2007 (Leicester study):
    - 58% resolve with observation
    - Recurrence rate 58% with aspiration
    - Recurrence rate 39% with excision
- BMJ best practice
    - 13% success with single puncture and drainage
    - 40% success if wrist splinted for 3/52 after aspiration
    - 85% success with up to 3 aspirations

Mucous cyst

- Ganglion at DIPJ level, dorsally
- From joint capsule
- Can cause nail damage, present with grooved nail
- X ray joint: requires fusion if OA
- Treatment:
    - Observe (33% of dorsal and 45% of volar ganglia will resolve spontaneously)
    - Aspiration - 50% recurrence (BSSH-no evidence for steroid injection)
    - Excision: 10% recurrence
    - Transverse incision: Langer lines – cosmetic
    - Longitudinal incision: extensile
    - Requires adequate exposure to identify origin and allow resection of stalk
    - 50 % resolve spontaneously 40 % recurrence with aspiration.
    - Simple closure if small
    - Excision with reverse Mercedes incision
    - Or rotational rhomboid flap closure if large
    - Or hatchet flap
    - Must resect underlying osteophyte
- **DD**
    - Synovial cell carcinoma
    - Giant cell tumour of tendon sheath
    - Epidermal inclusion cyst

- CMC bossing - bony mass due to trauma (boxing), degeneration or congenital Carpal boss view difficult to see on standard lateral due to carpal curvature Excise
- Anomalous extensor tendon

Epidermal Inclusion Cyst

- Painless, benign, slow-growing soft tissue tumour
- From penetrating injury that drives keratinizing epithelium into subcutaneous tissues
- Most commonly occur in fingertip, superficial and tethered to overlying skin
- Punctum at tip
- X rays: Lytic lesion of distal phalanx if cyst erodes into bone
- Biopsy to rule out neoplasm or infection if lytic bony lesion present in distal phalanx
- Differential diagnosis
  - Enchondroma
  - Glomus tumours
  - Giant cell tumour of tendon sheath
- Treatment - marginal excision, low recurrence rate

Giant Cell Tumour of Tendon Sheath

- Also known as **pigmented Villo-nodular tumour** of tendon sheath of hands and feet
- 2nd most common tumour of hand after ganglion
- Benign nodular tumour
- Most common on palmar surface of radial three digits near DIPJ
- Painful enlarging mass
- **Investigation**: X-rays can cause bone erosion, US, MRI
- **Treatment**: Locally aggressive, marginal excision


(Courtesy of H Hermina)

Subungual exostosis

- Bony diverticulum from terminal phalanx - causes distortion of nail bed
- Cartilaginous cap
- Can also affect toes
- Differential Diagnosis Glomus tumour
  Enchondroma
  Subungual inclusion dermoid cyst
  Amelanotic melanoma
- Postpone surgery until physis closes

Glomus tumour

- Occur in subungual region
- Benign
- Glomus body regulates blood flow and temp
- Pain - reduced on exsanguination
- Blue nodule
- Tenderness, cold intolerance (put finger on ice)
- Bone erosion (on X-rays)
- Treatment: excision

INTRINSICS

Interosseous muscles

- 4 dorsal interossei, 3 volar/palmar interossei
  - *DAB* (dorsal *abd*uct Bi-pennate)
  - *PAD* (palmar *add*uct Uni-pennate)
- Flex MCPJ and Extend PIPJ (same as lumbricals)
- Origin: MC shaft
- Insertion: Extensor expansion (hood) & base of proximal phalanx
- Innervation: Ulnar nerve (C8/T1)

Lumbricals

- From FDP to radial side of extensor expansion/lateral band
- Extend PIP & DIP and Flex MCP
- Pass volar to deep transverse MC ligament whereas interossei pass dorsal to it
- 1st and 2nd lumbricals – uni-pennate innervated by median nerve
- 3rd and 4th lumbricals – bi-pennate innervated by ulnar nerve
- **Lumbrical plus finger**
  - Intrinsic plus attitude in involved finger on attempted flexion
  - When FDP is divided distal to lumbrical origin, paradoxical PIPJ & DIPJ extension with attempted fingers flexion
  - Treatment: Tenodesis of FDP or reinsertion to distal phalanx
Lumbrical release

TRIGGER FINGER

Stenosing Tenosynovitis due to hypertrophy of A1 pulley

History: catching, locking

Examination: Look partially flexed finger

Feel nodule

Move Slowly open fingers

4 stages I- Occasional triggering
II- Triggering on every excursion
III- Occasional locking but passively correctable
IV- Locked finger

Trigger finger in child may be caused by - nodules in either the FDS or FDP tendon

Thickened and tightness of A2 or A3 pulley

Treatment: Steroid injection If there are no response to 2 injections, may proceed to open or percutaneous trigger release
Surgical division of A1 pulley

RA - synovectomy and not division of A1

Complications :

Bow stringing if oblique pulley of thumb or A2 pulley damaged

HAND INJURIES

Carpometacarpal Joint Dislocations

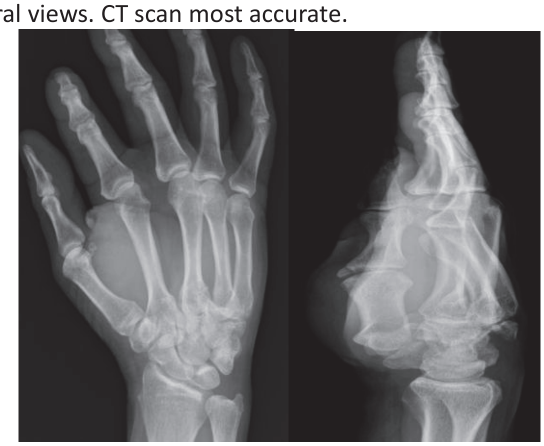
Most common in fourth and fifth fingers.
The central digits are more protected from deformity secondary to the stabilizing effect of the deep transverse inter-metacarpal ligaments and bony architecture of CMCJ.
In higher-energy injuries, a fracture of the base of the small finger metacarpal (reverse Bennett's fracture) or of the hamate articular surface may occur.

Assessment

History	Axial loading trauma with clenched fist.
Examine for	Swelling, ecchymosis and tenderness over metacarpal bases.
	Palpable step-off.
	Malrotation and shortening of the digit.
	Loss of knuckle height, excessive CMC extrusion, or scissoring.
	Check motor branch of the ulnar nerve
	Compartment syndrome.

Imaging

Posteroanterior, Oblique, and true lateral views. CT scan most accurate.



(Courtesy of H Hermina)

Management

Non operative	MUA and ulnar gutter for 4 weeks.
Operative	Closed/open reduction and K wire fixation into Hamate and next uninjured metacarpal.
	Keep POP and K wires for 4 weeks.

Metacarpal fractures

- Border metacarpals are not supported and less stable. However, they are more mobile & can accept more deformity.
- Index MC is the most firmly fixed
- Thumb MC articulates with trapezium and acts independently from others
- Look for rotational deformity
- Don't want prominent MC head in palm

1st MC

- Deforming forces lateral retraction of 1st MC shaft by APL (insert o base of 1st MC) and adductor pollicis.
- Volar lip of MC base attached to volar oblique ligament
  - Extra-articular
  - Intra-articular
    - **Bennett** - fracture dislocation
    - **Rolando** - comminuted Y fracture
- Treatment Moulded Bennett cast
  Stabilize to trapezium or 2nd MC with K wires if displaced
- Baby/reverse Bennett fracture/dislocation of 5th MC base - Displaced by ECU

(Courtesy of H Salame)

Boxer fracture- 5th Metacarpal neck

- Operative treatment indications
  - Displaced intra-articular fractures
  - Rotational mal-alignment of digit
  - Multiple metacarpal shaft fractures
- **ORIF**
  - Dorsal plating - tension band effect
  - Pre-bend to avoid volar fracture opening
  - Avoid dorsal cutaneous branch of ulnar nerve
  - Through juncturae tendinum interconnecting EDC tendons
  - Wagner approach for 1st MC
    Between glabrous and unglabrous skin
  - Mini-fragment 2 mm DCP for transverse fractures
  - T-plate for base of thumb MC fracture
  - Multiple lag screws for spiral fractures
  - Evaluate rotation before closure
- **K wire:**
  - Extramedullary or intramedullary with blunt ended wire in chuck key and T-handle.
  - Difficult in ring finger as it is the narrowest MC
- **Postoperative:**
  - Early motion critical to avoid finger stiffness and tendons adhesions to plate
  - Immobilize MCPJ at 70 -90 degree of flexion
  - Remove pins/cast at 4 weeks
  - Stable – mobilize
- **Complications**
  - Extensor lag due to shortening - with each 2 mm of shortening comes 7 degrees extensor lag at MCPJ

MCP joint

- Sagittal band keep extensor mechanism tracking in midline during flexion of MCPJ
- Collateral ligaments taut in flexion and lax in extension
- Dorsal approach - split extensor tendon
- **Principles of MCPJ replacement**
  - Results better than fusion
  - Problem with instability in RA - use constrained prosthesis
  - Types:
    - Rigid hinged causes early loosening
    - Flexible hinged (Silicon) in RA
  - Resurfacing
    - Prerequisite is intact tendons and ligaments
    - Better ROM
  - Pyro-carbon
    - Biocompatible
    - Uncemented
    - Elastic modulus matches cortical bone
    - Excellent incorporation
    - Can squeak
  - Silicon (Swanson) - Constrained
    - Poor wear characteristics, synovitis
  - **Complications**
    - In RA - recurrence of ulnar drift
    - Lack of metacarpophalangeal joint extension
    - Prosthesis fracture
    - Persistent volar subluxation of proximal phalanx
    - Infection
    - Later rupture of extensors

MCPJ dislocation

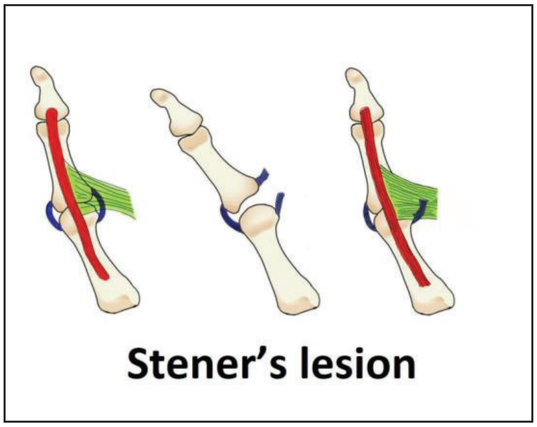
- **Kaplan lesion** (complex dislocations)
  - Interposition of volar plate between MC head and base of proximal phalanx button-hole between superficial transverse ligament proximally and Natatory ligament – volar plate distally.
  - Lumbricals and flexor tendons get displaced with NV bundle)
  - Skin dimpling.
  - Open volar - be aware of nerves stretched anteriorly.
- **Noose (loop) effect** (Thumb)
  - Complex dislocation from hyperextension with rupture of volar plate
  - Sesamoid intra-articular position
  - FPL displace to ulnar side of MC Head
  - Volar approach if irreducible

UCL injury

- **Type**:
  - Acute: gamekeeper thumb
  - Chronic: skier/goal keeper thumb
- Usually separates from base of proximal phalanx.
- Stress radiograph to look for opening at ulnar aspect of joint
- **Stener's lesion**
  - Interposition of adductor pollicis aponeurosis between torn ends of UCL
  - Avulsed ligament displaced above & proximal to adductor aponeurosis
  - Will not heal without surgical repair
  - Diagnosis Ultrasound (operator dependent)
    MRI

Adductor pollicis:

- Origin:
  - Transverse head → from volar 3^{rd} MC
  - Oblique head from base of 2^{nd}, 3^{rd} MC & capitate
- Insertion:
  - Ulnar aspect of base of thumb PP
  - Ulnar sesamoid
  - EPL
- Function:
  - 1^{st} MC adduction
  - MCPJ flexion
  - IPJ extension
- Innervation: motor branch of ulnar nerve



- **Treatment**
  - Direct repair or fix avulsion or suture anchors >35° of opening
  - Chronic:
    - Reconstruction with tendon graft Palmaris longus or FCR, or adductor advancement
    - MCP fusion for arthritis
    - RCL – immobilization

Phalanx fracture

- All phalanges and MC have their secondary ossification centre at their base
- Check for rotation, assess scissoring
- **Proximal phalanx:**
  - Deformity is apex volar due to proximal fragment in flexion (from interossei)
  - Distal fragment in extension (from central slip)
  - If allowed to heal with apex palmar deformity, an extensor lag will result
- **Middle phalanx:**
  - Deformity apex dorsal if fracture proximal to FDS insertion (from pull of central slip)
  - Apex volar if fracture distal to FDS insertion.
- **Treatment:**
  - ORIF for transverse or spiral rotated fractures
  - Crossed K wires or mini-fragment plate/lag screws
  - Side of extensor expansion to prevent adhesion of plate to tendon

PIPJ


(Courtesy of M Elgendy)

- OA - Bouchard nodes
- **Volar plate injury**
    - Found at MCP & PIP joints
    - Fibrocartilaginous structure
    - Reinforce joint capsule, enhance joint stability, and limit hyperextension.
- **Dislocation**
    - **Dorsal (More common):**
        - Can lead to swan neck deformity due to volar plate injury
        - Dorsal blocking splint with PIPJ in 90 degree, reduce weekly
    - **Volar:**
        - Risk of central slip disruption, immobilize in extension for 6 weeks.
        - Irreducible – head of PP protrudes b/w central slip and lateral band
        - Extract interposed volar plate
        - Dorsal approach with incision between central slip and lateral band
- **ORIF** if fracture > 50% of articular surface involvement
- **Suzuki /Giddins frame**
    - Dynamic distraction external fixation
    - Named after its Japanese inventor, first described in 1994
    - For comminuted pilon phalangeal fracture
    - Allows early ROM
- Dorsal blocking wire and splint for dorsal fracture.
- Or distraction bridge plating (removed at 6 weeks)
- **Arthrodesis**
    - Gold standard for OA.
    - Also for RA
    - Reduce function by 50%
    - Recreate normal cascade of fingers: Index -20°, middle -30°, ring -40°, and little -50°
    - Compression screws
    - Arthrodesis of index and middle for pinch and arthroplasty of ring and little for grip
    - Approach between central slip and lateral band

DIPJ

OA	Heberden nodes (caused by osteophyte) Most common hand joint affected in OA, followed by PIPJ Nail deformity Joint replacements do badly
Dorsal dislocation	Dorsal splint Open reduction for volar plate interposition DIPJ fusion, as main function of DIPJ is to assist with pinch
Chronic mallet deformity	

HIGH PRESSURE INJECTION INJURIES

- Prognosis of injury dependent on:
  - Time from injury to treatment
  - Force of injection
  - Volume injected
  - Composition of material:
    - Grease, latex, chlorofluorocarbon & water based are less destructive
    - Industrial solvents & oil based paints cause more soft tissue necrosis requiring amputation in 50%
- Treatment: Irrigation & debridement, foreign body removal and broad-spectrum antibiotics

HAND COMPARTMENTS

10 compartments (without carpal tunnel)

- **Hypothenar**: abductor digiti minimi, flexor digiti minimi, opponens digiti minimi
- **Thenar** : abductor pollicis brevis, flexor pollicis brevis, opponens pollicis
- 4 dorsal interosseous
- 3 volar interosseous
- Adductor
- Carpal tunnel

Opponens pollicis

- Origin: Flexor retinaculum and tubercles of scaphoid and trapezium
- Insertion: Lateral side of 1st metacarpal
- Innervation: recurrent Br of median N
- Function: flexion of thumb CMCJ

- **Indications for fasciotomies** Crush injury

- **Approach**
  - 2 longitudinal incisions over 2nd & 4th metacarpals
    Decompress volar/dorsal interossei & adductor
  - 1 longitudinal incision radial side of 1st metacarpal
    Decompresses thenar compartment.
  - 1 longitudinal incision ulnar side of 5th metacarpal
    Decompresses hypothenar compartment.

SKIN CANCER

Important to recognise, pigmented lesion with recent change in shape or size

Malignant melanoma

- Aggressive skin malignancy of melanocytic origin
- UV radiation suppresses skin immunity
- Induces melanocyte cell division
- Produces free radicals that damage melanocyte DNA
- Melanocytes are derived from neural crest cells
- Found in deepest layer of epidermis, separated from dermis by basement membrane
- Often on thumb
- Types: Amelanotic melanoma & Subungual
- Poor prognostic factors: deep lesion. Depth is the ***most important*** prognostic factor.
- Male sex
- Lesion on neck or scalp
- Positive lymph nodes and metastases, lungs are often first site of metastases
- Ulceration
- Subungual melanoma
- Bone scan – cold
- Treatment:
  - local resection
  - Sentinel node biopsy (if positive perform radical node dissection)
  - Chemotherapy (if evidence of metastasis)
  - Amputation (for subungual melanoma)

Squamous cell Carcinoma

- **Most common malignant** tumour of hand
- Risk factors: exposure to UV light
- High metastatic potential
- Back of hand
- Lytic bone lesion
- Marjolin ulcer result of chronic drainage from sinus tracts or burn scar
- Treatment Excision & skin graft
  Radiotherapy
  Amputation of finger

Epithelioid sarcoma

- Malignant, slow growing on hands and feet
- Painless
- Multi-nodular firm mass with areas of ulceration
- Most common soft tissue sarcoma of hand
- Erosion of bone
- Treatment Wide excision, adjuvant radiotherapy
  Amputation, for multiple recurrences

TENDON TRANSFER

Transfer of functioning musculotendinous unit to tendon of paralysed muscles

- **Indications**
  - Irreparable nerve injury
  - Rupture due to RA
  - Congenital disorders e.g. thumb hypoplasia
- **Selection** Determine what function missing
  Determine what muscle-tendon units available.

Principles

- Receiver: **S**ensate and **S**car free tissue
- Donor:
  - **S**upple joint - full passive ROM
  - **S**acrifiable (expendable) donor
  - **S**ynergistic action and **S**traight line of pull
  - **S**ynergistic transfers are easier to rehabilitate(Occurs together in normal function, e.g. finger flexion and wrist extension)
  - Grade 5 power
  - Appropriate amplitude of power to function being restored
  - **S**ufficient excursion to provide reasonable ROM
- **Outcome**
  - One grade of MRC motor strength lost following transfer
  - Worse after age 30, age is the leading prognostic factor
  - Distal better than proximal

	Recipient Muscle	**Donor muscle**
Musculocutaneous nerve	Biceps	Pec major or lat dorsi
Radial nerve		
- Elbow	Triceps	Pec major or lat dorsi
-Thumb	EPL	PL or FCR or 4th FDS
-Fingers	EDC	FCU or FCR (need ulnar deviation for good grip)
-Wrist	ECRB	PT
Ulnar nerve		
- Interossei	Adductor pollicis	FDS of middle finger or ECRL
	Dorsal interossei	EIP, ECRL, or APL
-Fingers	-FDP	Suture to functioning FDP
Median nerve		
-Thenar	OP and APB	EIP or FDP to ring
-Thumb	FPL	BR
-Fingers	FDP	Side to side tenodesis to functioning FDP

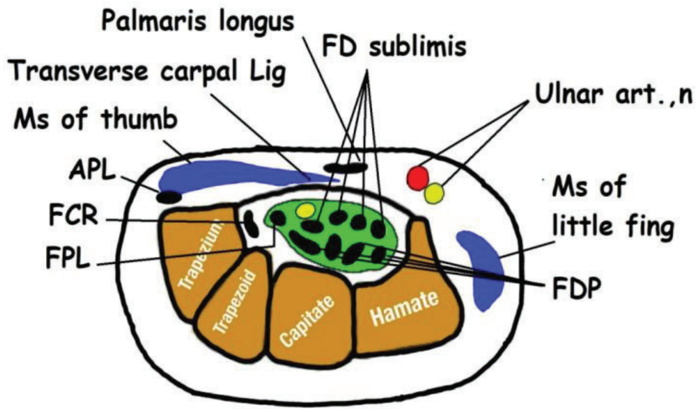
CARPAL TUNNEL SYNDROME

- Most sensitive sensory test for early CTS is *Semmes-Weinstein test.* Measures single nerve fiber innervating single or group of receptors
- **History** - Night/daytime symptoms
  - Weakness of grip and pinch
  - ADLs affected (Buttoning of clothes, opening of jars, driving car, reading book)
- **Examination**
  - Look: thenar muscle wasting, scar
  - Feel: sensation on tip of index finger, decreased sweating
  - Move: APB (point to ceiling) and OP (Press on proximal phalanx of thumb to isolate from APL)
  - High lesion: OK sign (FPL, 1st & 2nd FDP) weak & Sensation over thenar area
  - Special tests: Tinel's, Phalen's

Diagnostic tests

- **Tinel's sign:**
  - 74% sensitivity, 91 % specificity
  - Gentle tapping over median nerve at the wrist in a neutral position
  - Positive if this produces paraesthesia or dysaesthesia in the distribution of the median nerve
  - Progressive Tinel sign used to monitor recovery
- **Phalen's sign:**
  - 61% sensitivity, 83% specificity
  - Elbows on the table allowing the wrists to passively flex
  - If symptoms provoked within 60 sec then positive
- **Durkan's test** - (**Most sensitive)** (direct compression test)
  - Elbow extended, forearm supinated and wrist flexed
  - Pressure over carpal tunnel
  - Anaesthesia or paraesthesia within 30 sec
- **Examine** neck and shoulder and elbow to complete examination.
- **Incidence:** 1:1000 / year
- Regular and prolonged use of hand-held vibratory tools increases risk of CTS 2 folds.
- Evidence on keyboard and computer work did not indicate association with CTS.
- Carpal tunnel pressure in neutral 2.5 mmHg and in extension 30 mmHg
- Assess for any acute trauma, fractures, rheumatologic conditions, secondary to pregnancy, hypothyroidism, DM, peripheral neuropathy, cervical spine symptoms
- Non-op treatment (as suggested by AAOS, 2016):
  - Lifestyle modification
  - Night splint
  - Corticosteroid
  - *Do not prescribe NASIADs / diuretics*
- Mild CTS should improve in 6 weeks of non-op treatment, if not patient should be referred for seeking alternative diagnosis or CTS release **(RCS, 2013)**
- Middleton and Anakwe **(Br Medical Journal 2014)** suggested wrist splint or CTS injection

- **INDICATE Trial (Injection or Decompression in Carpal Tunnel Syndrome**) results presented at BSSH meeting 2017
  - Steroid injection 70-90% good response at 6 months, but only 34% at 18 months post-injection
  - CTS release 90-95% effective in permanent relief of symptoms. But at 2 years, only 75% considered release successful and 8% even got worse.
- Carpal Tunnel is a fibro-osseous tunnel with following boundaries and contents:
  - Roof: Transverse carpal ligament
  - Floor: Proximally pisiform and scaphoid tubercle, distally trapezium hook of hamate
  - Contents: 9 tendons – 4 FDS (3+4 lie over 2+5) + 4 FDP + FPL and median nerve
  - Function:
    - Support carpus - pain on press up when divided (pillar pain)
    - Increases efficiency of flexor tendons - reduced grip when divided
    - Also acts as muscle attachment site – reduced pinch when divided



CARPAL TUNNEL C.S

- Stay ulnar to radial border of ring finger to prevent damage to recurrent motor branch of median nerve that supplies thenar muscles.
- Landmark: Intersection b/w flexed ring and Kaplan
- Anatomical variation in course of recurrent motor branch of median nerve:
  - Extra-ligamentous 75%
  - Sub-ligamentous 13%
  - Intra-ligamentous 12%
- Supply superficial head of FPB, Abductor PB, and OP
- Deep head of FPB supplied by ulnar Nerve
- **Kaplan line:** (marks deep palmar arch, superficial arch 1 cm distal to it)
  - From apex of 1st web space to hook of hamate
  - Parallel with proximal palmar crease
- Branch of median nerve proximal to carpal tunnel:
  - Palmar cutaneous branch - 5 cm proximal to wrist crease
  - Between PL and FCR at level of wrist flexion crease
  - Superficial to TCL
  - Supply sensation to thenar eminence

Causes

- Idiopathic
- Congenital - thrombosis of persistent median artery
- Inflammatory - RA, gout
- Fluid retention - heart failure, pregnancy, DM
- Traumatic
- **Differential diagnosis:** DM & Radiculopathy

Indications for NCS/EMG - BSSH

- Recurrent/persistent symptoms after surgery
- ? Peripheral neuropathy, bilateral symptoms
- Neck pain, double crush - examine C6
- Unclear diagnosis
- Medico-legal or occupational indication
- Can be false negative in 10 % (sensitivity of 90%)
- Specificity 95%
- Increased latency and reduced velocity in early stages when myelin layer compressed
- Amplitude is reduced when axon compressed
- **Boston Carpal Tunnel questionnaire (BCTQ):** patient-based outcome measure that is specifically for patients with CTS. It has two scales, the Symptom Severity Scale and the Functional Status. Each scale generates a final score which ranges from 1 to 5, with a higher score indicating greater disability.
  Has also undergone extensive testing for validity, reliability and responsiveness.

How to do CTD?

- Longitudinal incision in skin crease where possible in line with radial border of ring finger, from beyond distal palmar crease up towards Kaplan's cardinal line.
- Incise superficial palmar fascia
- Use self retainer to clear palmar fat exposing flexor retinaculum
- Divide this carefully over MacDonald elevator gently inserted
- Underneath transverse carpal ligament
- Cut transverse ligament ulnar to avoid cutting recurrent motor branch
- Decompress proximally up to proximal flexor crease and distally until fully released
- Avoid injury to superficial palmar arch by cutting retinaculum under direct vision
- Document appearance of nerve
- Neurolysis - no difference in outcome (perform if nerve adherent to adjacent structures)
- Space occupying lesion of nerve - close and refer to microscopic skilled surgeon
- Pinch strength return in 6 week
- Grip strength expected to return to 100% preoperative levels by 12 weeks
- **Endoscopic release** to avoid scar pain (less in 3 months but no difference at 1 year)
  - Same complications & return of hand function
  - Slower technique, more expensive
- Associated Guyon canal compression – enlarges following release of TCL

Consent

- Hypertrophic scar (10%)
- Trigger finger (10%)
- Scar tenderness (5%) - also called pillar pain, treat with massage
- Reflex sympathetic dystrophy (5%)
- Persisting symptoms and signs (4%)
- Injury to palmar cutaneous branch of median nerve (4%).
- Wound infection (2%)
- Recurrence

- *Desensitisation program*: (aim to re-educate nerve endings)
  - Pressure massage - moisturising cream
  - Texture massage - from soft to rough
  - Immersion massage - containers with different particles
- Revision of carpal tunnel release following previous incomplete relief:
  - 25 % of patients - no relief
  - 25% of patients - complete relief
  - 50% of patients - partial relief
  - Chronic - might require tendon transfer

NCS/EMG

- How are nerve conduction studies done?
  - No lotion
  - Uncomfortable but not painful
  - Stimulating electrode placed over nerve
- Measure latency, velocity and amplitude of impulse in recording electrode following initiation of action potential by stimulating electrode

NCS

- Test conduction of action potential along nerve
- Test large diameter myelinated motor and sensory nerves
- **Recording electrode** placed over sensory nerve when testing sensation and over muscle when testing motor
- **Ground electrode**
- **Stimulator electrode** placed over nerve
- **Reference electord** to remove background interference activity
- Compressive neuropathy starts with demyelination – reduced velocity & increased latency. Then axonal damage – reduced amplitude
- Latency
  - Time from stimulation to response (in Milliseconds)
  - Provides estimate of how well functioning axons are
  - Prolonged in demylinating injuries
  - **Distal sensory latency of > 3.5 ms** are abnormal for CTS
  - **Motor latencies > 4.5 ms** are abnormal for CTS
- Velocity
  - Speed = distance/latency, Meter/Sec
  - **Sensory - normal > 35 m/s**
  - **Motor - normal > 45 m/s**
  - **Reduced in demyelination**
  - Factors affecting the NCS velocity
    - ✓ Temperature: reduced by 1 m/s per˚C temperature fall
    - ✓ Age: motor slows by 1 m/s per decade after 20 years and sensory by 3 m/s
- Amplitude
  - Size of response
  - Motor amplitudes measured in millivolts (mV)
  - Sensory amplitudes much smaller than motor amplitudes, usually in microvolt range
  - Provides **estimate of number of functioning axons**
  - Decrease indicate loss of axons (chronic condition)
- **Voltage** Measured in volts or joules
- **Amp** Measure of electrical current
- **F wave**
  - Supramaximal stimulation of motor nerve
  - Measure the **antidormic** conduction of an impulse to the ant horn cell and then **orthodormic** conduction down the nerve
  - Sensitive for **early proximal lesions** (absent)
  - Useful when there are root or proximal injuries that we can't get above

- **M wave:**
  - Muscle contracture in response to supra-maximal stimulation
  - Orthodromic going in the right direction
  - Early response
- **H response**
  - Analogous to stretch reflex
  - Reflectory reaction of muscles after electrical stimulation of sensory fibres
  - Orthodromic and Late response
- **Motor nerve conduction studies**
  - Electrical stimulation of a nerve and recording the compound muscle action potential (CMAP) from surface electrodes overlying a muscle supplied by that nerve.
  - The median motor study might involve stimulation at the wrist, the elbow
  - Orthodromic impulse transmission
- **Sensory conduction studies**
  - Electrically stimulating sensory fibres and recording the nerve action potential at a point further along that nerve.
  - The stimulus must be supramaximal.
  - Anti-dromic impulse transmission

EMG

- Records muscle electrical activity /action potential, look for denervation changes
- Study electrical activity of individual muscle fibres and motor units
- Patient provided the stimulus ,so no stimulating electrode
- Needle is active electrode
- Insertional activity shows resting state of muscle and innervating nerve & Abnormal in early denervation (polymyositis, myopathies)
- Contraction activity - patient is asked to contract muscle and EMGs are recorded

➢ Spontaneous activity	Flat line at rest
➢ Fibrillations	Single muscle fibres From 5 weeks of injury Sign of denervation
➢ Fasciculation	Group of muscle fibres Visible twitching of muscle Occur in disease of anterior horn cell
➢ End-plate activity	Only activity in healthy muscle at rest

What do you tell the patient about the tests?

NCS involve activating nerves electrically with small safe pulses over several points on the skin of the limbs and measuring the responses obtained.

KIENBOCK'S DISEASE

- **History:** Pain & Function
- **Examination:** Mid-dorsal wrist tenderness
- AVN of lunate
- Natural history not clear and symptoms don't correlate well with radiographic appearance
- **Causes**
  - Repetitive micro-trauma
  - Ulnar negative variance exposes lunate to greater loading
  - Intraosseous blood supply to lunate
    - Y-pattern (**most common** pattern)
    - X-pattern
    - I-pattern (**highest risk** for avascular necrosis)
- Wrist PA radiograph, ulna styloid prominent
- Lunate Blood supply:
  - In >80% cases lunate has rich palmar and dorsal vascular supply
  - <20% cases single palmar vessel - hyperextension injury can disrupt the supply

Lichtman classification

- **Treatment**
- I – IIIA:
  - Treatment symptomatically
  - Injection
  - Cast immobilization for 3 months
  - PIN neurectomy in 4th dorsal compartment
  - Temporary scaphotrapeziotrapezoidal pinning for adolescent
  - Distal radius core decompression creates local vascular healing response
  - Levelling procedure - Radial wedge shortening or ulna lengthening if ulna negative variance
  - Vascularised bone graft: 4, 5 ICSRA
  - STTJ fusion - unload lunate & transfer load to scaphoid & maintain carpal height
  - None proven to be universally successful
- IIIB – IV:
  - Proximal row carpectomy - if capitate preserved
  - Preserves movements compared to fusion
  - STT Fusion
  - Replacement

I	Pre-radiographic (seen on MRI)
II	Sclerosis
IIIa IIIb	Lunate collapse/fragmentation Lunate collapse with scaphoid rotation, carpus shortening (measure carpus height ratio)
IV	OA (pan-carpal arthrosis)

FINGERTIP INJURIES

- Perionychium
    - Eponychium: soft tissue on dorsal surface just proximal to nail
    - Paronychium: lateral nail folds
    - Hyponychium: Plug of keratinous material situated beneath distal edge of nail where nail bed meets skin
- Lunula: white portion of proximal nail & Transition from germinal to sterile matrix
- Germinal matrix: responsible for 90% of nail growth
- Sterile matrix: distal to lunula, adheres to nail
- Goals of treatment
    - Sensate tip
    - Bone support for nail growth
    - Maintain length
    - Maintain mobility
- **Treatment**
    - Bone is not satisfactory bed for healing – skin will break down
    - Bone not exposed & < 2 cm: Leave to heal by secondary intention or primary closure, takes up to 5 weeks
    - Bone not exposed & > 2cm: Flap/graft
    - Bone exposed & adequate nail-bed support - Revision amputation/terminalisation by...
        - Bone shortening
        - Bone exposed & inadequate nail-bed support - Tissue cover needed
        - Dorsal Oblique laceration-V – Y advancement, rapid healing and maintain sensation
        - Volar oblique laceration - Thenar flap for age <30, Cross finger flap - suitable at all ages
        - Reverse cross finger flap - for dorsal tissue loss
        - Homo-digital island flap - for volar oblique lesions
    - V-Y technique:
        - Free skin from septae
        - Retain nerves and blood vessels.
        - Can also do double
    - Cross fingers flaps
        - For exposed tendons
        - Rectangular
        - Raised from 3 sides of dorsal aspect of middle phalanx of adjacent digit
        - Swung on its pedicle
        - Flap is detached at three weeks
        - Donor site is covered by full thickness graft
    - Full thickness thenar flap - well tolerated in children & PIPJ stiffness in adults
    - Avoid thumb shortening - first dorsal metacarpal artery (FDMA) flap for >2cm loss
    - Moberg volar advancement flap for <2cm loss, move entire volar skin
    - Terminalisation
        - For severely crushed distal phalanx
        - Through DIPJ
        - Tension free primary closure - Close wound dorsally
        - Preserve FDS
        - Transect digital nerves as proximally as possible

- **Complications**
  - Hook nail deformity - cut nail-bed back to level of bone support to avoid it
  - Avoid tight wound closure that draw nail bed over tip
  - Split nail, caused by scaring of matrix. Excise scar
  - Cold intolerance and hypersensitivity

Nail bed injury

Subungual haematoma	<50%	Drainage by perforation
	>50%	Remove nail & nail bed repair

- Consider K-wire fixation if associated with distal phalanx fractures
- Nail matrix may be incarcerated in fracture and block reduction
- Glue (dermabond) or 6/0 absorbable
- Put nail back as eponychial splint, or use aluminium or non-adherent gauze and stitch to hold in place
- Trephining a nail to drain subungual haematoma
- **NINJA RCT** (Oxford Study) – Nailbed injury Analysis, whether to replace nail plate after repairing nail bed injury

Seymour fracture

- Injury to physis of distal phalanx
- Lies under nail fold casing nail-bed avulsion
- Reduce to prevent growth disturbance of bone and nail bed
- Very often it is open, treat as open fracture, commonly missed injury
- Treatment:
  - Unstable - closed reduction and pinning across DIPJ
  - Open fracture: Antibiotic, explore, retrieve and repair nail-bed, DIPJ pinning

(Courtesy of Suddhajit Sen)

PERIPHERAL VASCULAR DISEASE

Thromboangiitis Obliterans (Buerger's disease)

- Inflammatory disease in small and medium-sized vessels of hands and feet
- Occurs predominantly in smokers
- Intermittent claudication of feet, legs, hands or arms
- Ulceration, necrotic distal digits
- MRI angiogram: cork screw vessels
- Treatment:
  - Smoking cessation
  - Avoid exposure to cold
  - Daily aspirin, vasodilators
  - Amputation for gangrene

Reynaud syndrome

- Vasospastic disease
- Periodic digital ischemia induced by cold temperature or sympathetic stimuli including pain or emotional stress.
- Triphasic colour change:
  - Digits turn white from vasospasm.
  - Blue discoloration follows from venous stasis
  - Finally digits turn red as result of rebound hyperaemia

A- Idiopathic: Reynaud disease

B- Associated with another condition (Reynaud phenomenon)

- Associated conditions connective-tissue disease: scleroderma, SLE, dermatomyositis,RA
- CREST syndrome: Calcinosis, Reynaud's phenomenon, oEsophageal dysmotility,Scleroderma, Telangiectasia.
- Trophic skin changes – ulceration and gangrene

- **Treatment:**
  - Smoking cessation and avoidance of cold exposure
  - Calcium channel blockers
  - Aspirin
  - Digital sympathectomy - severe cases that fail conservative treatment
  - Excise segment and graft if causing ischaemia
- **Differential Diagnosis:**
  - Ulnar artery aneurysm, hypothenar hammer syndrome
    - From using vibrating tools
    - Does not affect thumb
    - Can cause distal embolic events

BITES

Human

- Alpha-haemolytic streptococcus, Staphylococcus Aureus, Eikenella Corrodens in 7-29%
- Augmentin
- **Fight bite**
  - Wound of 5th MC head is fight bite until proven otherwise
  - Assess extensor tendon
  - X ray to look for foreign body such as piece of tooth
  - Tetanus prophylaxis
  - Approach through extensor tendon not through sagittal band
  - Recreate fist by flexing MCPJ to look for tendon damage
  - Wash joint
  - Leave wound open, non-adhesive dressing and relook after 48 hrs

Cats & dogs

- Alpha-haemolytic strep, Pasteurella Multocida, Staph Aureus, Anaerobes
- Dog bites can cause rabies - caused by Rhabdovirus
- Suspect if unprovoked attack by animal with bizarre behaviour
- Cats can cause cat scratch disease infection of lymphatic system by Bartonella Henselae
- Azithromycin

Rat

- Strep. Moniliformis

Treatment

- Irrigation
- Augmentin
- I & D
- Tetanus prophylaxis

CARPAL HEIGHT RATIO

- Helpful in assessment of severity and progression of carpal collapse – SNAC, Kienbock’s disease
- Distance from base of 3rd MC to cortex of distal radius
- Influenced by differences in body habitus. Therefore, it is more appropriate to use carpal height ratio (Divide carpal height by length of 3rd metacarpal)
- When radiograph doesn’t fully include 3rd MC, alternative ratio by dividing carpal height by capitate length.
- Mean carpal height ratio is 0.5 and alternative ratio is 1.5

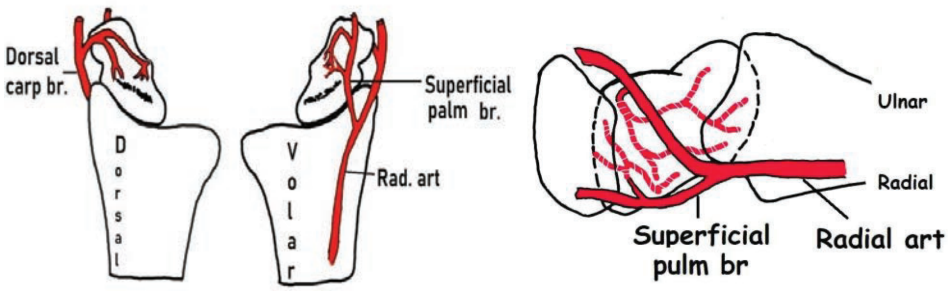
CARPAL INJERIES

SCAPHOID FRACTURES

- With wrist in neutral force is transferred across via lunate fossa and scaphoid fossa equally. With wrist extended force transmission shifted to scaphoid fossa
- **Mechanism:** Falls on outstretched hand with wrist extended and radially deviated

Blood supply

- Retrograde
- 80% from dorsal carpal branch of radial artery
- 20% from volar branch of radial artery
- 80% covered with cartilage – minimal periosteal blood supply
- Sequence of ossification: Distal pole last most common fracture in children



Herbert classification

A (STABLE)	-Tuberosity -Waist undisplaced
B (UNSTABLE)	-Waist displaced -Proximal pole -Trans-scaphoid perilunate fracture dislocation -Cominuted
C (DELAYED UNION)	-widening of fracture line, cyst development
D (NON-UNION)	-Sclerotic, pseudoarthrosis

Imaging

- Scaphoid views:
  - AP, lateral
  - 30 deg wrist extension, 20 deg ulnar deviation
  - 45° pronation view
- Bone scan (positive at 72 hrs)
- MRI (positive at 24 hr) first-line imaging in people with suspected scaphoid fractures - NICE guidelines
- Cochrane review Bone scan has equal-to-higher sensitivity
  specificity lower than MRI Bone scans may be positive in ST arthritis

Management

- Suspected scaphoid fracture: Immobilize and bring back in 2 weeks to see fracture sclerosis. Can do MRI or CT
- No difference in outcome of scaphoid Vs Colle's cast

Indications for internal fixation

- > 3 mm displacement/fracture separation
- Delayed union beyond 12 weeks
- Proximal pole fractures
- 15° scaphoid humpback flexion deformity, CT to assess
- Radio-lunate angle > 60 deg (DISI)
- Scaphoid fractures associated with perilunate dislocation
- Comminuted fractures
- Delay presentation > 4 weeks

Dorsal approach

- For proximal pole non-union
- Screw from proximal to distal (antegrade)
- Between 3rd and 4th compartment
- EPL retracted radially and EDC ulnarly
- Scaphoid in-line with 5th MC
- Risk to dorsal carpal artery

Volar approach

- All except proximal pole
- Uses interval between FCR and radial artery
- Thenar muscles elevated to expose capsule
- Preserves dorsal blood supply and helps create hump-back deformity

Percutaneous fixation

- Up to 3 months unless there are cystic changes
- Risk of screw prominence
- Prospective randomized study – McQueen (Edinburgh) 2008 BJJ: Acutrak screw v/s cast. Quicker return to work/union/sports (9 weeks with screws v/s 14 weeks with cast)
- Dutch study by David Rang et al (JBJS Am, 2010) meta-analysis studied acute undisplaced waist fractures
- Patients treated surgically had more rapid return of function and to sport and full work compared with those managed conservatively, but surgery has more complications with no long-term benefits in terms of union rate or final grip strength or range of motion

Headless compression screw (Acutrak)

- Variable thread pitch: wider thread pitch at tip to penetrate bone faster than finer trailing threads.
- Compressing two fragments as screw advanced
- Longer central screws biomechanically stronger
- Hand and wrist physiotherapy

Complications

- **Non-union** (Increases with degree of displacement)
  - 80 - 100 % in proximal 3rd
  - MRI with gadolinium - Need vascularized bone graft if not vascular
  - Punctate bleeding at proximal pole fracture site is ***most reliable*** prognostic indicator of vascularity
  - Inlay (Russe) bone graft
  - Interposition (Fisk) bone graft when there is humpback (flexion) deformity
  - Restore scaphoid length and angulation

- **AVN**: Increases with more proximal fractures
- **SNAC:**
  - Scaphoid Non-union Advanced Collapse
  - Advanced collapse and progressive arthritis of wrist that result from chronic scaphoid non-union
  - Degenerative changes first occur at radio-scaphoid area and progress to pancarpal arthritis
  - Distal pole flex – incongruity with radial styloid
  - Proximal pole remains attached to lunate through SL ligament unlike SLAC
  - Staging - same as SLAC
- Vascularised bone graft, from dorsal distal radius
  - 1-2 inter-compartmental supraretinacular Ar (Branch of radial A)
  - For AVN or revision
  - Theoretical advantage over non vascularized free cancellous graft
  - Cortico-cancellous wedge graft from iliac crest
  - Prepare fracture surfaces with curette
  - Or Scapho-luno-capitate fusion

(Courtesy of M Elgendy)

EBM for scaphoid fractures

- **Scaphoid Fracture: waist, non-displaced**
  - Dias et al. (SWIFFT trial – Scaphoid waist internal fixation for fracture trial) from Leicester – RCT evaluating cast v/s surgical fixation for scaphoid waist fractures with < 2mm displacement.
  - Cast treatment preferred for minimally displaced waist fractures and suspected non-unions should be urgently fixed. No benefit of keeping wrist immobilized > 10-12 weeks

Scaphoid Waist Internal Fixation for Fractures Trial (SWIFFT) protocol: pragmatic multi-centre RCT of cast treatment versus surgical fixation for the treatment of bi-cortical, minimally displaced fractures

- **Scaphoid fracture non-union, choice of bone-graft**
  1. Systemic review by Munk et al. Acta Orthop Scand (2004) from Denmark
     - Non-vascularized graft without fixation 80% success
     - Nonvascular with internal fixation 84% success
     - Vascular bone graft - 91% success
  2. Meta-analysis: AVN cases treated with grafting
     - A comparison of the rates of union after cancellous iliac crest bone graft and K-wire fixation in the treatment of stable and unstable scaphoid non-union BJJ, 2013 (Korean study by Park et al.)
     - Vascular 88% union rate
     - Nonvascular 47% union rate

SCAPHOLUNATE LIGAMENT INJURY

- **History:** Clicking & Pain & weakness
- **Examination:** Kirk Watson scaphoid shift test
- SLL is formed from volar and dorsal (greatest constraint to translation) and interosseous ligaments
- **DISI**
- (dorsal intercalated segment instability)
  - Intercalated movements depend on proximal and distal structures
  - Scaphoid flex palmar and lunate dorsi-flex
  - Scaphoid normally flexes in radial deviation and extends in ulnar deviation
  - Progressive instability causes arthritis of radio-carpal and mid-carpal joints
  - Lead to SLAC (most common form of wrist arthritis)
- **Causes:**
  - Acute: trauma, forced wrist dorsiflexion
  - Chronic: degenerative
- **Watson classification of SLAC**

Describes progression of degenerative changes:
  - Stage I :arthritis between scaphoid & radial styloid
  - Stage II: arthritis between scaphoid & entire radius
  - Stage III: arthritis between capitate & lunate with proximal migration of capitate into SL interval
  - Stage IV: generalized pancarpal OA
- **X-rays:** (Clenched fist radiograph for early stages)
  - SL diastases/gap > 3mm compared to other side (Terry Thomas sign, British comedian)
  - Scapholunate angle > 70 deg
  - Lunate extended > 10 deg past neutral
  - Scaphoid ring sign - indicate scaphoid flexion
- Arthroscopy is **gold standard** for diagnosis especially if early dynamic instability

Management
- **Non-operative**
- **Operative**
  - *Acute:* Open repair /anchors protected with K wires
  - *Chronic:*
    - Brunelli ligament reconstruction
    - Irreparable ligament
    - Reducible mal-alignment of scaphoid & lunate
    - Without arthritic changes
    - utilizes a strip of FCR to reconstruct the SL ligament
    - Arthrosis - rigid deformity
  - **Stage I** - radial styloidectomy
    PIN and AIN denervation

- **Stage II** -
    - PRC: Good movements & Loss of grip – better in older patient
    - Scaphoid excision and 4 corner fusion:
        - Main indication is STTJ OA
        - Better pain relief
        - 4-corner fusion: Capitate/hamate/lunate/triquetrum
        - Need to have good radio-lunate joint as fusion will be resting there
        - Dorsal circular plate
    - Dorsal approach for both
    - Preserve volar radio-carpal ligaments to prevent ulnar translation of carpus
- **Stage III**:
    - Scaphoid excision and 4 corner fusion
    - PRC contraindicated
    - Wrist fusion - Better pain relief and grip strength
    - Worse motion
    - Contoured plate or Stanley pin
- **Stage IV**
    - Wrist fusion
    - Wrist replacement
    - 4-Corner fusion contraindicated if there is radio-lunate OA

➢ **Proximal row carpectomy vs. four corner fusion for Scapholunate (SLAC) or scaphoid non-union advanced collapse (SNAC) wrists: a systematic review of outcomes**

Mulford et al. **J Hand Surg Euro Vol. 2009**

- PRC : motion-preserving, salvage procedure for SNAC or SLAC
- Both procedures give improvements in pain and subjective outcome measures for patients with symptomatic and appropriately staged SLAC or SNAC wrists.
- There was reduced need for immobilisation and earlier recovery with PRC
- Tendency towards increased grip strength with 4CF, but increased chances of non-union and metalwork related complications

➢ **Scapholunate advanced collapse wrist: proximal row carpectomy or limited wrist arthrodesis with scaphoid excision?**

Tomaino USA, J Hand Surg Am (1994)

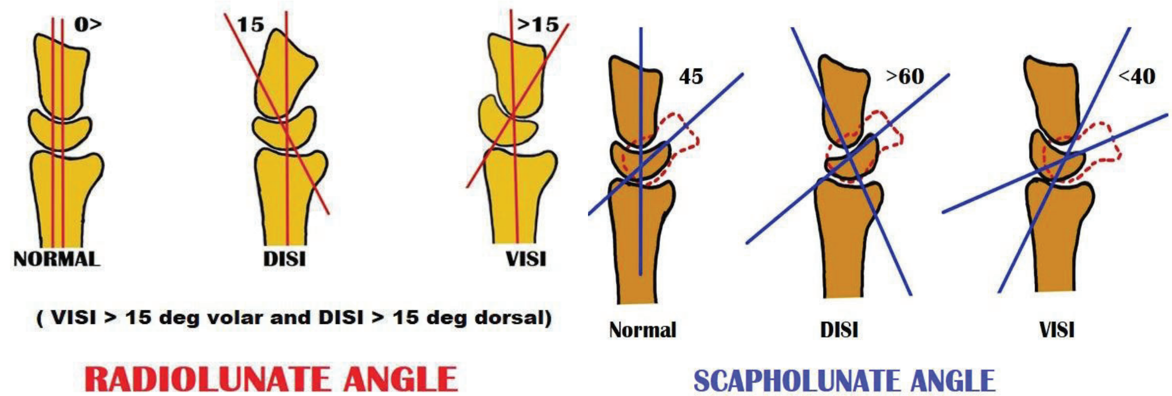
- For wrists without capito-lunate arthritis, PRC avoids the technical demands
- Lengthy postoperative immobilization and risk of non-union associated with limited inter-carpal arthrodesis with scaphoid excision, but for stage III disease (capito-lunate arthritis) limited wrist arthrodesis with scaphoid excision is recommended

SLAC & SNAC

CARPAL INSTABILITY

- Means **mal-alignment**
- **Extrinsic ligaments:**
  - Bridge carpal bones to radius or metacarpals
  - Include volar and dorsal ligaments
  - Volar: Long radiolunate and Radio-scapho-capitate are the **most important** ligaments
  - Dorsal: Dorsal intercarpal and Radio-triquetral are the **most important** ligaments
- **Intrinsic ligaments**
  - Originate and insert on carpal bones
  - **Most important** are scapholunate and lunotriquetral ligaments

- **Dissociative (CID)**
  - Between bones in same row
  - DISI & VISI – X ray appearance secondary to other pathology
  - DISI- Most common cause is Scapho-lunate ligament injury causing dissociation
  - Scapho-Lunate angle on lateral view >70°
  - VISI- Most common cause is Luno-Triquetral ligament injury



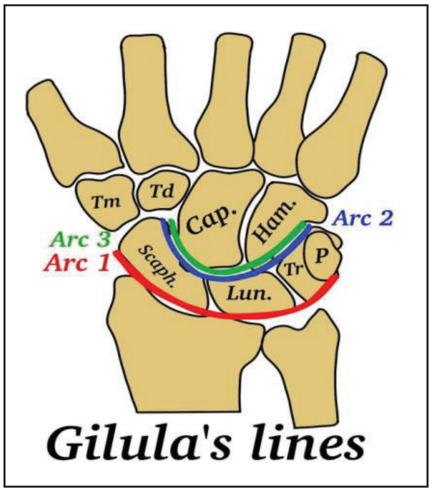
- **Non-dissociative (CIND)**
  - Between different rows or radiocarpal
  - RA

- **Adaptive (CIA)**
  - Post distal radius fractures
  - Causes carpus to be misaligned

- **Combined /complex (CIC)**
  - Perilunate dislocation

LUNATE TRAUMA

- **Gilula's lines:** 3 smooth curvilinear lines
    - Proximal: at radiocarpal joint, proximal convexities of scaphoid, lunate, and triquetrum
    - Middle: Distal concave surface of proximal carpal row
    - Distal: Proximal curvature of capitate and hamate



- **Greater and lesser arc injuries:**

Greater arc – injuries through carpal bones (scaphoid, capitate, hamate, triquetral, pisiform)
Lesser arc – purely ligamentous (scapholunate, capitolunate, lunotriquetral ligaments)

- **Space of Poirier**
    - Central triangular weak area of wrist in floor of carpal tunnel
    - Between volar radioscaphocapitate and volar radiolunotriquetral ligaments
    - Wrist dorsiflexion - area of weakness increases

Mayfield classification

- Progressive failure of ligamentous structures across the carpus produces a sequence of dissociation through to lunate dislocation
    - Stage I: SL dissociation
    - Stage II: above + lunocapitate
    - Stage III: above + lunotriquetral leading to perilunate dislocation
    - Stage IV: lunate dislocated volarly

Perilunate dislocation

- High energy dorsiflexion injury
- Lunate stays in position while carpus dislocate dorsally
- Greater arch - bony and ligamentous 4tyeps:
    - Perilunate
    - Transradial-styloid
    - Transcaphoid-perilunate
    - Transcaphoid-trans-capitate-perilunate

(Courtesy of L Prakash)

Lunate dislocation

- Lunate escapes into space of Poirier
- Lesser arch - ligamentous
  - Lunate dislocates volarly and capitate sits in lunate fossa.
  - Lateral view: Spilt tea cup. Loss of co-linearity of radius, lunate and capitate
  - AP view: Disruption of alignment of proximal carpal row,
    - lunate appears triangular
    - Lunate superimposed over capitate
    - Blood supply from intact volar radiolunate ligament
- **Treatment:**
  - High energy –ATLS protocol
  - Emergent reduction: wrist dorsiflexion – palmar pressure on lunate – volar flexion
  - ORIF: fractured bones (through dorsal approach centred on Lister tubercle)
  - Radial based dorsal flap of capsule (Berger's flap)
  - Stabilize with 2 K wires and repair SL and LT ligaments
  - Spanning ex-fix if unstable
  - Volar approach for carpal tunnel release and to reduce lunate
  - Dorsal approach for perilunate dislocation
  - Missed > 6 weeks - PRC


(Courtesy of S Sen)

Lunate and perilunate dislocation

Volar intercalated segment instability (VISI)

- **Caused** by lunotriquetral ligament as well as dorsal & volar radiotriquetral ligament injury
- **LTL**: dorsal and volar (strongest) portions
- ***Reagan ballottement test***:
  - Grasp triquetrum with thumb & index of one hand and lunate with other hand
  - Anterior and posterior stresses are placed on the LT joint
  - Triquetrum is 1s bone distal to ulna head
  - Positive finding is increased laxity and accompanying pain
- **Imaging**: SL angle < 30 deg
- **Treatment:**
  - A- Acute: Reduction and K wire fixation and ligament repair
  - B- Chronic: LT fusion & Scapho-luno-capitate fusion

COMPLEX REGIONAL PAIN SYNDROME (CRPS)

- Pain out of proportion following painful stimulus due to sustained sympathetic activity
- May last up to 18 months
- **Types:**
    - I: following injury (Trauma, Surgery, Infection)
    - II:following specific peripheral nerve injury
- Commonly affected joints - Wrist & ankle
- **Allodynia** - pain from non-painful stimulation of skin, such as light touch
- **Hyperalgesia/hyperpathia** - abnormally heightened sensitivity to pain
- **Examination:**
    - Look: Trophic changes (dryness), oedema, discoloration, hyperhidrosis
    - Feel: Warmth
    - Move Stiffness

International Association for Study of Pain diagnostic criteria for CRPS type I

1. Presence of initiating event
2. Continuing pain (allodynia)
3. Evidence of oedema, sweating, reduced movements or temperature changes
4. Absence of condition that would otherwise account for degree of pain and dysfunction

Budapest Criteria for CRPS

- At least one symptom in 3 of the 4 categories, at least 1 sign in 2 or more categories and absence of any other possible diagnosis for these signs and symptoms.
- Symptoms and Signs categories
    - **Sensory**- Hyperaesthesia, Allodynia
    - **Vasomotor**- Skin colour or temperature change/difference from the other limb
    - **Sudomotor**- Oedema ,sweating , sweating difference between the limbs
    - **Motor**- Decreased ROM, weakness, wasting, trophic changes, tremor, dystonia

Investigations

- X-rays disuse osteopenia
- Triple phase bone scan:
    - Very high sensitivity & specificity
    - Increased uptake in stage I, II & III
- Thermography: (Measures heat emitted from body)
    - Difference of 1.0°C between two symmetrical body parts considered significant
    - Affected limb may be warmer or cooler than unaffected

Management

- Prevention:
  - Vit C 500mg for 50 days after injury/surgery
  - Analgesia to allow early physiotherapy
- Physiotherapy
  - Gradual desensitization by increasing sensory stimuli
  - Active compression and distraction exercises
  - Counter-stimulation - acupuncture, TENS
- Cognitive -
  - mirror box
  - Hypnosis
- Medications
  - Alpha blocking agents
  - Antidepressants, anticonvulsants
  - Bisphosphonates
  - Chemical or surgical ganglionic sympathectomy
- Amputation will exacerbate the problem
- If you have to operate on same site then consider doing under regional block

LOWER LIMB

AUTHORS

Firas Arnaout ,Jikku Haniball, Rohan Bidwai and Sameer Mansukhani

CONTENTS

HIP EXAMINATION

History

1. Listen to the examiner/ read the GP notes thoroughly for clues
2. Hand rub
3. Concentrate on the patient
4. Develop rapport
5. Good morning Mr. /Ms. /Mrs. X, I am Dr Y, sit down with the patient to take history
6. I understand you have a problem with your Hips. How long it has been going on?
7. Age, occupation

➢ **Pain**
- With one finger point to the site of pain, do you have pain in the groin, does this pain go down the front of the thigh or to the buttock demonstrating a 'C' sign
- How long (duration - keep it the shortest/ recent possible)
- Onset - when did the pain start/ date of any trauma
- Progression of pain over time
- Continuous/ intermittent
- Rest/ night pain that wakes you up from sleep
- Aggravating factors/ relieving factors
- Sitting and getting up, standing, walking
- When you walk, after how many minutes, does the pain in hips stops you
- Climbing up/ down stairs
- Taking shower by yourself
- Does putting on socks/ shoes trouble you?
- Getting in and out of cars or shopping cause pain
- Pain killers - which one, how frequent
- Other Symptoms: Stiffness/ Limping/ shortening/ Clicking

➢ **What has been done so far?**
- Seeing GP, Specialist
- Investigations- X-rays, MRI scan
- Medications
- Walking aids/footwear adjustments- what/ which side
- Physiotherapy - are you doing it regularly, what was advised
- Injections
- Any previous surgery: date, what was it done for, post-op rehabilitation

➢ **Childhood hip problems**
- At which age, management conservative/Surgery, hospital admissions, follow up, any further treatment as adult

➢ **Other joints pain**
- Which joints, hips, knees, foot, hands, spine
- Any surgeries done on them
- How is that getting treated- physiotherapy, meds
- How is it now?

➢ **Medical history**
- (DM, HT, Recent Heart attack/ Stroke, breathlessness, Chest pain)

- **Medication history**
  - (Blood thinners, Steroids, Drugs for RA), allergic history, surgical history)
- **Social history**
  - Married, staying with partner, house with stairs, smoking/ drinking, how the disease is affecting occupation, any activity or hobbies you have stopped because of pain
- **Family History** of disease
- **Birth History, Developmental History**
- **Expectations**
  - What the patient expects from the consultation and what kind of treatment are you expecting, what level of activity you would be happy to sustain, open to surgical options
- **Summarize history to patient**
  - Ask if any other things you would like to add on to the history

Examination

Expose adequately

Walking aids/ footwear adjustment, moving comfortably/ restricted, rheumatoid hands

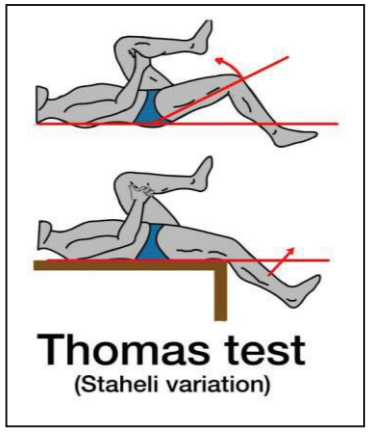
- **Inspection standing from front**
  - Attitude & Alignment of lower limb (pelvis, hip, knee, foot) [one limb long or short]
  - Pelvis asymmetrical/obliquity
  - Quads muscle wasting
  - General skin condition around hip - scars, swelling
  - General skin condition rest of lower limb, any evidence of limb ischemia distally, varicose veins, scars, swelling
  - Are the shoulders level?
  - ASIS – Any pelvic obliquity?
- **Inspection standing from side**
  - Lumbar lordosis
  - Scars, swelling, abductor wasting
  - Knee straight or bent
- **Inspection standing from behind**
  - Attitude (iliac crest, spine, shoulder)
  - Scoliosis - whether it corrects on sitting down
  - Gluteal or hamstring muscle wasting, surgical scars
  - SIJ palpation could be done now
- **Trendelenburg test**
  - Should be able to communicate the test to patient and demonstrate to examiner or you can show the patient how to do the test by performing it on yourself and asking patient to copy you.
  - ‘I am going do a test to examine muscles of your hips and will ask you to stand on one leg’
  - Stand in front of patient and ask him/her to hold your arms for balance
  - One foot off the floor backwards
  - Start by lifting painful side 1st and stand on normal side
  - Wait 30 sec
  - **Positive:**
    - Pelvis tilts down on lifted leg (Sound side sags or normal side dips). Patient puts pressure on normal side for balance.
    - Neuromuscular, Superior gluteal nerve injury, OA, Coxa vara

- **Negative:**
  - Patient does not put pressure on examiner arms for balance.
  - Normal or hip arthrodesis

➢ **<u>Gait</u>**
- Symmetrical gait,
- Trendelenburg:
  - Move centre of gravity to affected side to reduce moment arm.
  - Affected shoulder sways to opposite side
  - Due to weak abductors or neuromuscular conditions or short lever arm (coxa vara, DDH).
- Short limb:
  - Shift of centre of gravity towards short side.
  - Shoulder on affected side dips during stance. Stance phase is equal.
  - Circumduction of longer leg
- Antalgic
  - Flexors & adductors stronger than extensors & abductors
  - Attitude of painful hip flexion & adduction.
  - Short stance phase of affected leg to protect painful leg
  - Patient leans to the painful side
- Waddling: in bilateral DDH
- Foot and patella progression angle

➢ **<u>Supine inspection</u>**
- Pelvis square or not, the anterior superior iliac spines are at the same / different level and the legs appears equal length or not
- Any additional finding on closer inspection

➢ **<u>Palpation</u>**
- Enquire where the pain is
- Palpate joint line, GT tenderness



➢ **<u>Thomas test</u>**
- For revealing FFD
- Hugh Owen Thomas (1834-1891), British orthopaedic surgeon
- Normal hip flexed to eliminate lumbar lordosis
- Avoid in patient with THR due to risk of dislocation
- Keep a hand below the lumbar spine to demonstrate that lumbar spine is flat
- Ask patient to press knee against table or press it yourself
- Angle between long axis of thigh and couch
- Excessive flexion of normal hip can cause flexion of pelvis and false FFD
- Check for knee extension for FFD - **Staheli variation**
- If knee has fixed flexion deformity - hang knee on edge of table to assess hip FFD

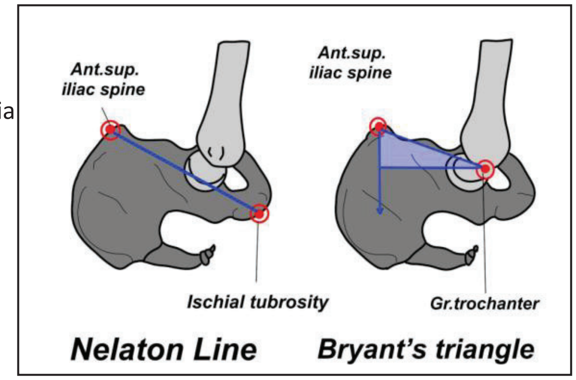
➢ **<u>ROM:</u>** Flexion, Abduction / Adduction / IR & ER in flexion & extension

➢ **<u>Leg Length measurement</u>**: Apparent / true shortening
- Ask if from childhood or adulthood
- It is apparent leg length that matters to patient - from tilted pelvis or flexion deformity of hip or knee or adduction deformity
- **True leg length** ASIS to medial malleolus
  Make sure pelvis is square and legs are in identical positions

- **Apparent leg length**: Xiphisternum to medial malleolus
- True = apparent refers to no compensation
- Difference in both the length measurement could be due to pelvic tilt or flexion contractures or compensation from adduction / abduction deformities

➢ **Tests for measuring leg length**

- **Galeazzi sign:**
  - Whether shortening is above / below knee
  - Hips 45^{o}, Knees 90^{o}, malleoli together
  - Check knee projection for femur and knee height for tibia
- **Digital Bryant's triangle:**
  - For supra-trochanteric shortening
  - Do only if Galeazzi positive
  - Thumb at ASIS to index finger to tip of GT
  - Perpendicular distance with index finger
  - Do simultaneously with both hands to compare
- **Nelaton's line**:
  - Hip 90^{o}, Patient on side
  - ASIS to ischial tuberosity
  - Tip of GT should be distal to the line normally



Special Tests

➢ **Tests for impingement:**

- Anterior Impingement: Flexion, Adduction, IR
- Posterior Impingement: patient at edge of table, Extension, Abduction, ER
- Patrick / FABER test: SI joint
- Ischio-femoral Impingement: Hip Extension, Adduction, ER

➢ **Tests for Hip Contractures:**

- **Ely's test**:
  - Prone, for Rectus Femoris. Flex knee to touch the heel to gluteal region.
  - Hip will get flexed if rectus femoris is contracted
- **Ober's test**:
  - Lateral position, for IT band. Hip to be tested is flexed, abducted to 45 ^{o} & extended.
  - In case of tight IT band, leg remains abducted instead of adducting
- **Phelps test**:
  - For gracilis. Hip to be tested is abducted. The knee is flexed off the table.
  - If abduction is more on flexing the knee suggests gracilis tightness.
- **Other Tests:**
  - **Straight leg raise test:**
    - Leg is raised against resistance.
    - Tests iliopsoas strength & intra-articular pathology

➢ **NV Examination:**

- Sensation on dorsum and plantar foot
- Motor power of toe dorsiflexors and plantar flexors
- Pulses - dorsalis pedis and posterior tibial, capillary filling

➢ **Don't forget:** Examine knee, spine and opposite hip

SURGICAL APPROACHES

Iliac crest

- **Anterior**
  - **Indication**
    - Harvest iliac crest bone graft (ICBG)
  - **Superficial Interval (Nerve)**
    - TFL / gluteal muscles (superior / inferior gluteal) & external oblique (segmental)
  - **Structures at Risk**
    - Lateral femoral cutaneous nerve (LFCN)
- **Posterior**
  - **Indication**
    - ICBG
  - **Superficial Interval (Nerve)**
    - Gluteus Maximus (inferior gluteal) & Latissimus dorsi (thoracodorsal), spinal erector muscles
  - **Structures at Risk**
    - Superior gluteal artery
    - Sciatic nerve
    - Superior gluteal nerves

Pelvic and acetabulum

- **Anterior (ilioinguinal)**
  - **Indication**
    - Fractures of acetabulum, iliac fossa, SI joint and pubic diastases
  - **Superficial Interval (Nerve)**
    - External oblique (segmental) and inguinal ligament
  - **Deep Interval (Nerve)**
    - Divide internal oblique (segmental)
  - **Structures at Risk**
    - LFCN
    - Spermatic cord
    - Inferior epigastric artery
  - **Additional Points**
    - 3 windows:
      - **1st (Lateral)** - lateral to iliopsoas/ iliopectineal fascia.
      - **2nd (middle)** window between iliopectineal fascia & external iliac vessels.
      - **3rd (medial)** window below the vessels & spermatic cord.
    - **Stoppa modification**
      - Uses a more extensive medial window & provides access to pelvic brim & quadrilateral plate.
- **Posterior (Kocher Langenback):**
  - **Indication**
    - Fractures of posterior wall, posterior column, posterior wall & column. Simple transverse fractures.
    - Transverse fractures associated with posterior wall.
  - **Superficial Interval (Nerve)**
    - Divide gluteus maximus (inferior gluteal), IT band

- **Deep Interval (Nerve)**
  - Piriformis (nerve to piriformis) and gluteus medius (superior gluteal)
- **Structures at Risk**
  - Sciatic nerve.
  - Superior &inferior gluteal nerve & artery.
  - MFCA

Hip

➢ **Anterior (Smith-Peterson)**

- **Indication**
  - Open reduction of DDH, neck fractures, Synovial biopsies,
  - Intra-articular fusions, THR, hemi, excision of tumours especially of the pelvis.
- **Incision:**
  - Start 1 inch lateral and 1 inch distal to ASIS anterior to greater trochanter. Proceeds over bulge of tensor fascia lata longitudinal incision to the patella
- **Superficial Interval (Nerve)**
  - Sartorius (Femoral) & TFL (superior gluteal)
- **Deep Interval (Nerve)**
  - Rectus Femoris (femoral) & gluteus medius (superior gluteal)
- **Structures at Risk**
  - LFCN
  - Femoral nerve & artery.
  - Superficial iliac circumflex artery
  - LFCA(ascending branch)
- **Additional Points**
  - **Advantages:**
    - Easy to determine leg length
    - Reduced blood loss
    - No muscle splitting (earlier recovery).
  - **Disadvantage:** difficult femur exposure (risk of fracture).

➢ **Antero-lateral (Watson-Jones)**

- **Indication**
  - THR, Hemi, ORIF of neck fracture, Synovial biopsy of hip.
- **Incision:**
  - Centered on GT.
- **Superficial Interval (Nerve)**
  - TFL (superior gluteal) & gluteus medius (superior gluteal)
- **Deep Interval (Nerve)**
  - Split gluteus medius (Superior gluteal)
- **Structures at Risk**
  - Femoral nerve & artery.
  - Superior gluteal nerve
  - LFCA (descending branch)
- **Additional Points**
  - **Advantage:** stability

- **Disadvantage:**
    - o Denervation or damage to abductors
    - o Difficult acetabular exposure.

➢ **<u>Lateral (Hardinge) (Transgluteal)</u>**

- **Indication**
    - THR, hemi, drainage of hip sepsis
- **Superficial Interval (Nerve)**
    - Split IT band
- **Deep Interval (Nerve)**
    - Divide gluteus medius (superior gluteal), divide vastus lateralis (femoral)
- **Structures at Risk**
    - Superior gluteal nerve
    - LFCA (transverse branch)
- **Additional Points**
    - **Advantage:** improved exposure of femur as compared to anterior & anterolateral approach.
    - **Disadvantage:** heterotopic ossification

➢ **<u>Posterior</u>**

<u>Limited approach (Moore or Southern)</u>
<u>Extensive approach (Kocher-Langenbeck)</u>

- **Indication**
    - THR, hemi, ORIF of posterior acetabular fractures, drainage of hip sepsis, pedicle bone grafting, open reduction of posterior hip dislocations
- **Patient position:** Lateral position- pelvic support to keep pelvis vertical
- **Incision:**
    - Lateral position- pelvic support to keep pelvis vertical
    - Curved incision centred on posterior half of GT
    - No internervous plane
    - Split : Fascia lata
    - <u>Gluteus Maximus</u>:
        - o Nerve supply: Inferior gluteal nerve
        - o Origin: ilium, iliac crest, sacrum, coccyx, and sacrotuberous ligament
        - o Insert: Deep (on gluteal tuberosity of femur) & Superficial (on ITB of fascia lata)
    - Tension the short external rotators by IR the hip
    - Feel but not expose for sciatic nerve unless doing revision
    - Stay suture in piriformis and obturator internus
    - Detach short extensors close to femoral insertion and reflect backwards to protect sciatic nerve
    - Peroneal component more lateral and commonly injured
    - In Kocher Langenbach Approach exposure is facilitated by
        - o Proximally extending the dissection till branches of Inferior Gluteal N is identified
        - o Distally incising the Gluteus Maximus insertion on femur
        - o Identifying the sciatic nerve and placement of Hoffman's in the notch
        - o Stienmann pin into the ileum for retracting the Gluteus medius
        - o Performing a trochanteric flip
    - Longitudinal or T capsulotomy and dislocate the hip
    - Closure of capsule and external rotators- enhanced repair reduces risk of dislocation

- **Superficial Interval (Nerve)**
  - Divide Gluteus Maximus (inferior gluteal), IT band
- **Deep Interval (Nerve)**
  - Piriformis, short external rotators and femur
- **Structures at Risk**
  - Sciatic nerve
  - Inferior gluteal artery (tie off internal iliac artery)
  - MFCA (AVN).
  - Superior gluteal art., nerve (limits upward retraction of gluteus medius and blocks from reaching iliac crest)
- **Additional Points**
  - **Advantages:** extensile approach, quick recover, low rate of complications. Preserve abductors, good acetabular exposure.
  - **Disadvantage:** slightly higher rate of dislocations.

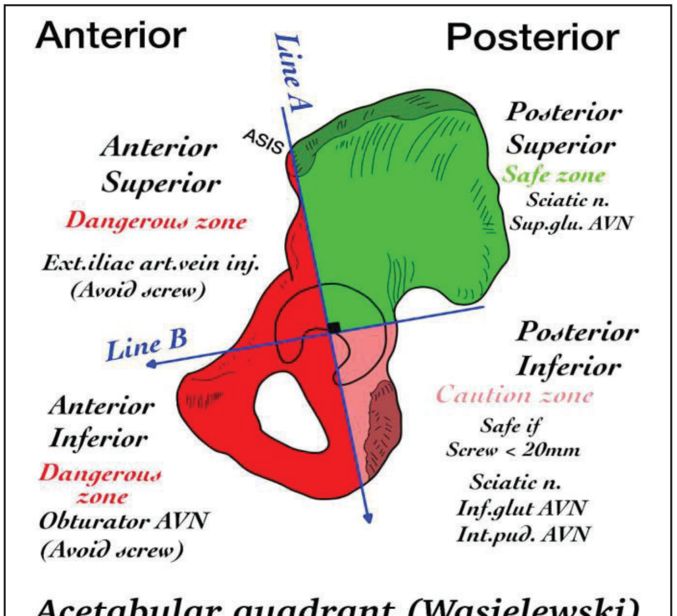
➢ **<u>Medial (Ludloff)</u>**

- **Indication**
  - Open reduction of DDH (<18 month), biopsy & treatment of tumours of inferior portion of femoral neck & medial aspect of proximal shaft, psoas release, obturator neurectomy
- **Position:** figure of 4
- **Incision**: - distal to the pubic tubercle over the adductor longus tendon, feel the LT on floor of the wound.
- **Superficial Interval (Nerve)**
  - Adductor Longus (Femoral N) and Vastus Medialis (Femoral N)
- **Deep Interval (Nerve)**
  - Adductor brevis (anterior division of obturator) and Adductor Magnus (obturator or tibial)
- **Structures at Risk**
  - Obturator nerve
  - MFCA
  - Deep external pudendal artery

➢ **<u>Trochanteric osteotomy (Charnley):</u>**

- Excellent exposure
- **Indications**: Hip replacement, Acetabular fractures
- Trochanteric non-union

<u>**Acetabulum quadrants**</u> (Wasielewski)
Line from ASIS to centre of acetabulum
and another line perpendicular
To determine safe quadrant for placement of screws



Acetabular quadrant (Wasielewski)

HIP ARTHROSCOPY

- Lower morbidity than open arthrotomy with easier post-operative course
- Supine on traction table, 50lbs distraction with well-padded perineal post with joint distension with saline
- Needle – Nitrinol (Nickel & Titanium) guide wire – capsular dilators – 70 deg arthroscope
- Fluid management system with pressure of 50-60 mmHg

Indications

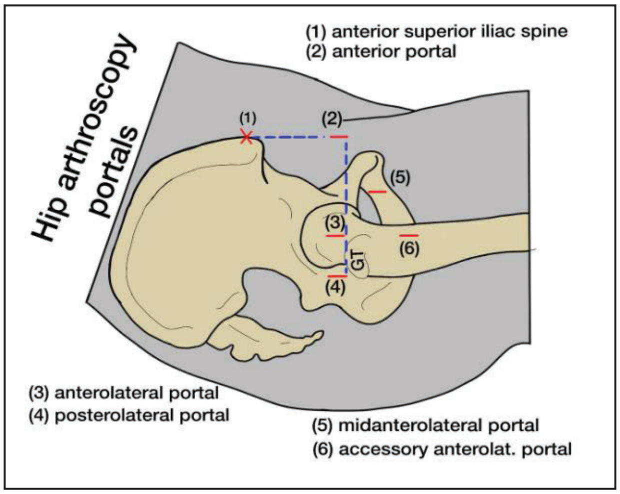
- FAI - labral tears, chondral injuries, impinging osteophytes
- AVN (diagnosis and staging)
- Loose bodies
- Synovial disease

Contraindications

- Advanced DJD
- Hip ankylosis
- Joint contracture
- Severe osteoporotic bone
- Significant protrusio acetabulum

Portals

1. **Proximal anterolateral portal:**
    - 2 cm anterior and 2 cm superior to antero-superior border of GT
    - Risks: superior gluteal nerve
    - To access peripheral compartment
2. **Anterolateral portal:**
    - 2 cm anterior to tip of GT
    - Primary viewing portal
3. **Posterolateral portal:**
    - 2 cm posterior to tip of greater trochanter
    - Risks sciatic nerve
4. **Anterior portal**:
    - Intersection between superior ridge of greater trochanter and ASIS
    - Risks:
        - LCFN (use nick and spread technique Don't cross ASIS)
        - Femoral N & A
        - Ascending Br of LCFA
5. **Mid anterior portal**



- **NAHR** (Non-arthroplasty Hip registry)
- Zona orbicularis - Annular ligament of neck of femur, formed by circular fibers of articular capsule of hip joint (Thicker anterior to joint, where greatest resistance is required. Identification can guide surgeon to iliopsoas tendon immediately medial)
- **Compartments:**
  - Intra-articular central - chondral lesions debride to stable margins
  - Intra- articular peripheral - cam lesions
  - Extra-articular

Rehabilitation

- NWB or PWB for about one week, with gradual progression to full weight bearing, strengthening is started after full ROM is achieved
- Return to full activities at approximately 3 months

Complications

- Chondral injury - direct injury from scope or cannula
- Pudendal nerve injury due to traction against perineal post used to distract hip

TOTAL HIP REPLACEMENT

- Primary aim of THR:
  - Restore center of rotation
  - Correct leg length
  - Correct offset and abductor tension
  - Proper component positioning

Implant of choice

- I would use **Exeter cemented stem** 13A*
- It is a hip system that provides me with ability to deal with anatomical variants and also achieve all the primary aims of THR.
- Allow good initial fixation and good long-term survival according to NJR data.
- My training has been with Exeter and I am familiar with instruments

- **Exeter contemporary flanged cemented cup** or **Trident uncemented** 13A*
  - Good survival: These combinations give best results in term of revision rate in NJR
  - NICE guidelines - Feb 2014 bench-mark is revision rate of < 5 % in 10 years
- **CORR (2008) Lewthwaite:**
  - Exeter Hip in Patients < 50 Years at 10–17 Years' Follow up; Survivorship of stem from all causes was 99%; no stem was revised for aseptic loosening
- **BJJ (2006) independent centre review**
  - Revision of Exeter hip at 10 years was 2.2%
- **<u>ODEP (Orthopaedic Data Evaluation Panel)</u>**
  - Initiated in response to request by NICE
  - Pre-entry, 3, 5, 7, 10 and 13 years
  - 13A* rating the highest score possible – represents 13 year evidence
  - A: strong evidence B: reasonable C: weak
  - Minimum cohort of 500 hips/knees
  - Data from beyond developing centre and from > 3 centres/surgeons
  - Revision rate at minimum 10 year follow up of < 5% for A*; < 10 % for A
  - Maximum of 20% loss to follow-up is permitted
  - Surgeons can make an informed choice about which implants to use
- **<u>Beyond Compliance</u>**
  - Service to support the safe and stepwise introduction of new or modified implantable medical devices
  - Independent panel of experts, known as the Beyond Compliance Advisory Group, work with the implant manufacturer to assess the relative risk of any new product, and the rate at which it should be introduced to the market
  - The service collects data about patients who receive these implants and about their recovery following surgery.
  - This data is made available to clinicians using the implant, to the manufacturer, and to independent assessors from the Beyond Compliance Advisory Group, to provide real-time monitoring of the implant's performance

Chronology of Total Hip Joint Replacement and Materials Development)

Biomechanics

- **Biomechanics of Charnley Vs Exeter**
  - Both are cemented stems but have a different design philosophy.

Charnley (Depuy) 10A*

John Charnley (1960s)

- Mono-block stainless steel stem with 22.2 mm head
- **Composite or shape closed beam design**
- **Rough surface (matt-finish)** to prevent subsidence
- Considered a **rod within two tubes**, an inner cement tube and an outer bone tube
- Once inserted the stem should not move and is expected to behave as a single unit. **Stability depends on strong cement bonds between bone and implant**
- Any subsidence, at the implant–cement or bone–cement interface represents loosening and failure
- Shear forces can cause cement fracture
- Generates greater wear debris when loose
- Acts on the principles of single unit, and three-point fixation
- The load is transmitted from the prosthetic femoral head via the stem to its tip, to the distal bone cement and subsequently to the host bone **by-passing the proximal femur leading on to stress shielding**
- As the proximal bone is not loaded according to Wolff's law, it will lead to osteolysis
- Addition of collar will provide for some amount of calcar- loading and protects from stress shielding

(The principle of Charnley THR – Wroblewski)

Exeter (Stryker)

- Double tapered, Stainless Steel (Designed by Ling &Lee: 1st implanted in 1970)
- Modular
- **Self-locking sliding taper or force-closed design**
- Intended to subside to a stable position, 1.5 mm in 12 months
- The hoop stresses provide circumferential compression around the stem
- **Polished stem with controlled-subsidence** as cement undergoes creep and stress relaxation. This transfers load to cement evenly
- Cement bonds to bone and not to implant
- No collar; neck cut level & orientation not critical
- V40 trunnion
- Avoid gaps in cement mantle
- Cement strongest under compression
- Viscoelastic properties of Poly-Methyl MethAcrylate (PMMA) will result in radial forces being generated as a result of axial loading and wedging of the stem within the mantle. These are transferred to bone as **hoop stresses**, which enhance fixation and stability of the stem

- Sliding matt finish was designed in 1980, as the importance of polished surface in preventing osteolysis and loosening was not well-appreciated
- **Centralizer** allows subsidence without point loading on cement and keeps stem central within mantle.
  Cement mantle is only as good as its thinnest portion (like a chain is as strong as its weakest link). Centralizer help obtain uniform cement mantle to ensure minimum 2 mm cement surrounding implant to minimize risk of cement fracture.

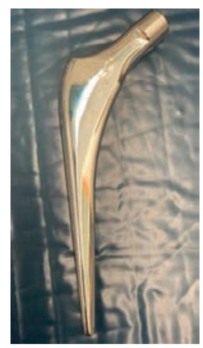
CPT stem (Zimmer)

- Introduced in 1990
- Similar to Exeter; made of stainless steel or Cobalt-Chrome
- 13A* ODP rating

(Courtesy of H Farid)

C-stem (Depuy)

- Launched in 2005
- Triple taper- thicker laterally than medially
- Loads medial cement mantle
- Produces proximal bone remodelling due to anatomic stress distribution
- 13A* ODP rating given in 2018



(Courtesy of N Walsh)

Stanmore (Zimmer)

- Similar design to Charnley
- 13A* ODP rating

When asked to talk about a stem discuss

- Shape: straight or curved
- Tip: tapered or blunt
- Surface finish: Smooth or rough
- Modular or mono-block
- Collar or collarless
- Neck, Morse taper (trunnion)
- Offset

Templating

- Aids selection of favourable implant size to restore anatomy & biomechanics
- Help to reduce LLD
- Estimate position and insertion depth of both components
- Facilitate operating room preparation and assure availability of appropriate size selection
- Predict potential complications and detect anatomic anomalies
- Help to guide neck cut to restore length

- Mental practice enhances surgical technique
- **Tear drop**
  - Develops at 18 months of age
  - Radiographic landmark created by superimposition of the most distal part of medial wall of the acetabulum and, tip of anterior and posterior horn of articular surface comprised of the quadrilateral surface and cotyloid fossa
- Get **low AP pelvic radiograph**
  - X-ray beam centered on pubis & coccyx pointing to symphysis
  - Symmetrical obturator foramina
- **AP hip:**
  - Radiographers use trapezium wedge on floor between feet in a standing X ray
  - 10-15^{o} of internal rotation - places femoral neck parallel to cassette
  - External rotation - falsely decreases offset
  - Create valgus appearing femoral neck
  - Falsely decrease femoral canal diameter
- Establish LLD by the distance between the two parallel lines drawn on AP pelvis X-ray. Inter-ischial line (lowest point of ischial tuberosities) and inter lesser tuberosity line (most proximal part of LT)

Templating the Acetabulum

- Draw horizontal line connecting tear drops
- Template acetabular component first to determine center of rotation of new hip with inclination of 40 deg and adequate cup coverage
- Medial border of cup should approximate ilioischial line close to tear drop
- Inferior border of cup should be at level of inferior teardrop line

Templating the Femur

- Appropriately sized femoral stem to fill medullary canal
- Insertion depth is determined to optimize limb length inequality

	Acetabular COR medial to Femur COR	Acetabular COR = Femur COR	Acetabular COR lateral to Femur COR
Acetabular COR superior to femur COR	Leg shortened Decreased offset	Leg shortened	Leg shortened Increased offset
Acetabular COR = femur COR	Decreased offset	No changes	Increased offset
Acetabular COR inferior to femur COR	Leg lengthened Decreased offset	Leg lengthened	Leg lengthened Increased offset

COR: Center Of Rotation

- **Calibration tools**
  - Digital software; TraumaCad
  - Ball (25mm)
  - Kingmark calibration device: Double marker better than single marker

Navigation

- Computer-assisted surgery
- Accuracy may be adversely affected in larger patients
- Little evidence that patient outcomes are improved through use of navigation techniques

Minimally invasive THR

- Benefits have not been reproduced in RCT
- Advantages: Cosmesis, Reduced blood loss
- No difference in early gait kinematics
- Concerns about increased complication rates (malposition, fracture)
- Technically demanding and high learning curve
- Techniques: 2 incision
- **Mini stems**
  - Preservation of proximal bone stock
  - Less stress shielding of proximal femur
  - Ease of revision
  - Reduction of risk of thigh pain
  - Soft tissue sparing procedure, ideal implant for use with direct anterior approach
  - Do not have long-term results
- **Bilateral THA**
  - Increased infection from pressure in lateral position
  - GA
  - Catheter
  - Increased bleeding - Tranexamic acid

Head

- **Head skirted or non-skirted**: skirts are attachments used to extend the length of the femoral neck. Skirts decrease the head-neck ratio
- **Small vs. Large heads**
  - Volumetric wear proportional to the square of radial diameter of femoral head
  - Trade off – 22.2 mm vs. 32mm vs. compromise 28mm
  - **Small heads** (22.2 mm):
    - Low torque, low friction and less volumetric wear; increased linear wear and dislocation
    - Linear wear is more with smaller heads because of small contact area.
  - **Large heads (36mm):**
    - Greater ROM and decreased dislocation rates due to increased head-neck ratio.
    - But greater torque, friction and volumetric wear and decreased poly thickness

Rheumatoid hip

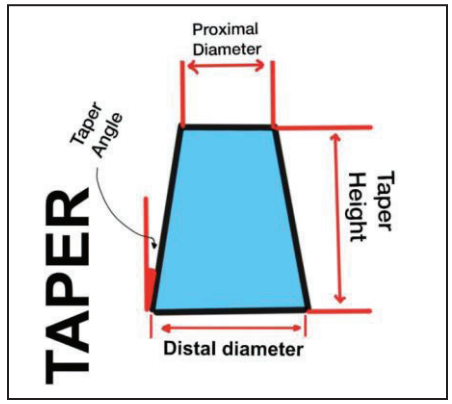
- Osteopaenic bone, fracture: better to use cemented implants
- Protrusio: bone graft
- Double rate of infection

THR in Tubercular arthritis

- **Kim SJ et al, BJJ (2013)** – Systematic review of THR in active TB
- THR is safe with extensive debridement and anti-tubercular treatment for 3 months before surgery and 9 months post-surgery

Trunnion (Morse Taper)

- Cone within a cone
- Trunnion is the male portion and the bore is the female portion
- Stresses created by compression of wall of bore by trunnion causes interference fit
- Contact is side to side – The Morse taper is **NOT end-loading**
- 12/14 is the difference of diameters between each end
- **Head locking mechanism:**
  - Conical femoral taper compresses walls of bore
  - Tapers of angle <7° will result in self-locking
  - The smaller the taper angle, more rigid the locking
  - Van Der Waals forces and Cold welding may occur
  - Deformation of ridges
- **Trunnionosis:**
  - Wear at the femoral head-neck interface
  - Mechanism - fretting
  - Mode 4 of wear
  - Produce metal debris
  - Morse taper wear implicated in Adverse Reaction to Metal Debris
  - Protect and dry trunnion
- **Taper:** uniform change in diameter of cylindrical object measured along its axis



Uncemented Stem

- Saves intra-op time
- High cost
- Difficult to control version
- Calcar fracture
- Needs rigid fit to reduce micro-motion to < 50 µM to prevent formation of fibrous tissue at implant-bone interface
- **Two methods**
  - **Press-fit technique**: slightly larger implant than what was reamed/broached is wedged into position, relies on hoop stresses for initial stability (4 – 6 weeks) then on bone in/on-growth
  - **Line-to-line technique**: size of implant is the same as what was reamed/broached, screws often **placed** in acetabulum if reamed line-to-line
- **Osseo-integration:**
  - Attachment of lamellar bone to implant without intervening fibrous tissue
  - Must have viable bone
  - Avoid in prior irradiation
  - Implants manufactured from titanium alloy
- **Porous coated: Bone in-growth**
  - Titanium plasma spray
  - Thickness of coating (50 – 100 uM)
  - Pore size (ideally 50-150 uM)
  - 40 - 50% porosity
    - Too little – weak fixation
    - Too much – shearing of metal
  - Extent of coating:
    - Proximal
    - Extensive - Better initial fixation
    - Stress-shielding of proximal bone (Furlong, Corail)

(Courtesy of M Zekry)

- **Uncemented stem Loosening**
  - Well fixed (with bone in-growth): no radiolucent line, proximal stress shielding
  - Stable (with fibrous in-growth): uniform radiolucent <1mm line, no surrounding sclerosis, no subsidence
  - Unstable (loose): irregular wide radiolucent lines
- **Spot welding**
  - Small areas of sclerosis originating from endosteal surface and abutting femoral stem. They are strong indicators of stability
- **Bone pedestal**
  - Transverse sclerotic line below the tip of cementless stem, sometimes but not always associated with loosening

Uncemented Stems commonly used

- Accolade (Stryker): proximally coated, collarless, flat tapered wedge design
- Corail (Depuy): most commonly used cementless stem in UK
- Taperloc (Biomet): Proximally porous coated, flat taper

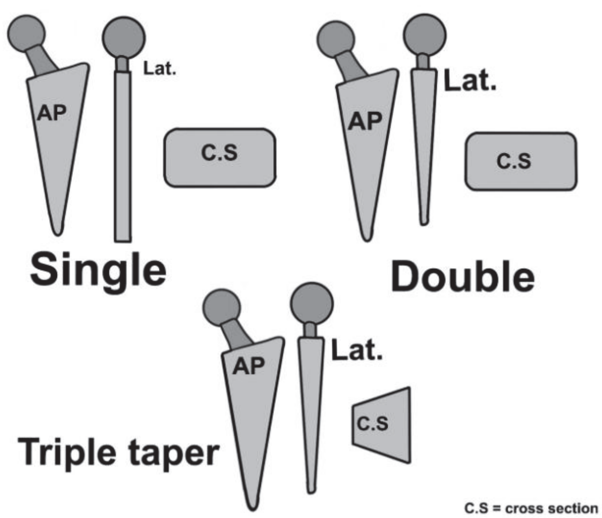
(Courtesy of H Hermina)

Bonding to bone

- **Bone on-growth**
  - Divots not pores
  - Grit-blasting of Aluminum Oxide to create a surface roughness, Ra = 4-7 uM or plasma spraying of molten metal
  - Extensively coated: fixation strength is less than porous coated
- **Plasma spray of Calcium HydroxyApatite**
  - Osteo-conductive, shorter time to biologic fixation
- **Bone in-growth:** Extensively porous stem with fiber mesh

Stem Geometry

- **Flat-tapered**
  - Achieve early fixation by wedging a rectangle into a circular hole. Mismatch of geometry achieves good torsional stability. Fixation occurs by medial-lateral engagement
- **Dual taper**
  - Achieve fixation by completely filling metaphyseal canal and circumferentially engages the femoral cortex proximally



Cemented Stem

- Made of stainless steel or Cobalt Chrome
- Increased risk of cement fracture if mantle is < 2mm
- French paradox (line to line stem insertion with thin cement mantle)
- Round corners and stiff stem to reduce stress on cement mantle
- Thompson & Muller have narrow medial border- increase load on cement
- Titanium less stiff leading to cement fatigue and prosthesis cement failure
- Square cross-sectional stems are limited in size due to their contact against inner cortex
- Oval cross-sectional stems have good fit
- Avoid varus placement of stem by starting at the lateral-most entry point
- Useful in abnormal anatomy
- Better in osteoporotic and irradiated bone
- Antibiotics in cement reduce deep infection, reduce mechanical strength
- Cemented stems are smaller than press-fit stems and unable to tolerate as much cantilever bending
- Mantle defect is area where prosthesis touches cortical bone with no cement in between
- Failure of high-profile **3M capital THR** led to establishment of NJR in England
- Based on Charnley design but was made of Titanium and had flanged proximal part. Wear particles of titanium initiated inflammatory reaction leading to loosening and failure
- **BHS & MHRA:**
    - Hydrogen peroxide promotes haemostasis and allows strong cement-bone interface but is used as "off-label" indication in arthroplasty
    - Injecting it in closed cavity risks gas embolism – use suction catheter attached to vacuum; Use only less than 1.5 % strength.

Cementing technique generations of development

- **1st generation**: hand mixing, finger packing
- **2nd generation**: cement gun, pressurization with cement restrictor, pulse lavage, femoral brushing. Biodegradable cement restrictors can cause inflammatory reaction and cortical thinning


(Courtesy of N Walsh)

(Courtesy of F Arnaout)

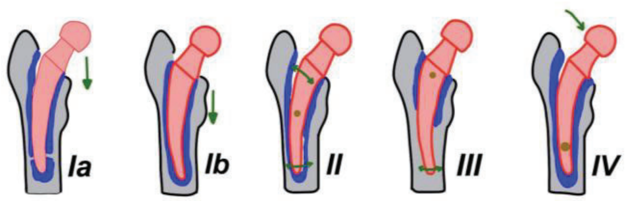
- **3rd generation**: vacuum to reduce porosity, distal centralizer
- **4th generation**: proximal centralizer

Gruen modes of cemented femoral stem failure

1) **Pistoning**
   - A: subsidence of stem within cement
   - B: subsidence of stem & cement within bone, lucency in all zones
2) **Medial mid-stem pivot**
   - Fixed in middle, proximal part tilts medially and distal part laterally, fracture mid stem

(Courtesy: H Hermina)

3) **Calcar pivot**
   - Fixed proximally; toggling of distal stem, lucency zone 4 & 5
4) **Bending cantilever**
   - Loss of proximal fixation leaving distal end fixed (distal pivot), likely cause of fractured stem, lucency 1, 7, 2 & 6



Gruen modes of radiographic failure of cemented femoral THA

Grading of cement technique (Barrack and Harris)

- A: White out
- B: Near complete filling with slight lucency
- C1: Lucency more than 50%
- C2: Cement mantle less than 1mm in some areas
- D: Lucency more than 100% or absence of cement distal to tip

Dorr femoral bone classification

- A: Narrow canal with thick cortices (Champagne flute canal)
- B: Moderate cortical wall thickness
- C: Wide canal with thin cortical walls (Stove pipe canal)

Bearing Surfaces

MoP

- Metal (cobalt-chrome) femoral head on polyethylene acetabular liner
- Longest track record, Lowest cost, most modularity
- Higher wear rate and osteolysis compared to MOM and ceramics
- Smaller heads when compared to MoM
- 4.63% (in males) and 2.99% (in females) revision rates at 15 years in 75+ age group, but 5.10-11.82% revision rates in younger age groups (**16th NJR data 2019**)

CoC:

- Best wear properties of all bearing surfaces
- Lowest coefficient of friction of all bearing surfaces
- Inert particles
- More expensive than MoP
- Alumina is brittle, low fracture toughness
- Squeaking
- Less modularity with fewer neck length options
- Lowest revision rates in <55 age group with hybrid THR, 5.6% (in males) and 4.3% (in females) revision rates at 15 years in <55 years age group
- In age group 55-74 years, reduced rates of revision are noted too (4 % in males, 3 % in females) **16th NJR data 2019**

CoP

- Reduced fracture and squeaking risks
- Revision rates 2.4 % (in males) and 2.9% (in females) at 15 year follow up in 75+ age group, but 4.3-8.3% revision rates in <55, 55-64, 65-74 age groups (16th NJR data 2019)

MoM

- Cobalt Chrome alloys
- Better wear properties than MoP
- Larger head improves stability
- More expensive than MoP
- Increased metal ions in serum and urine
- No proven cancer link
- Pseudotumor formation
- Type IV delayed type hypersensitivity
- **Contraindications**
  - Child-bearing age women, renal disease, metal hypersensitivity due to metal ions
- **Disadvantages or reasons of failure**
  - Edge loading leading to ALVAL (aseptic lymphocyte dominated vasculitis associated lesion), ARMD (Adverse reaction to metallic debris) and Pseudotumor
- **Nickel allergy:**
  - Type IV hypersensitivity – confirm by patch testing
  - No staples
  - Use uncemeted hip

- Use coated femoral component

Cup fixation

Cemented Cup

- All poly rather than metal-backed to allow use of thicker poly
- 3 holes with Charnley drill to encourage intrusion of cement into bone
- Trial flange rim should fit within rim of acetabulum
- Minimum of 2 mm cement mantle - cement spacers to help maintain a uniform cement mantle
- Cement at 2 min and insert cup at 4 min
- 40 deg abduction & 20 deg anteversion
- Use Transverse Acetabular Ligament for version:
  Archbold & Beverland paper – BJJ – 2006
  Reamer should be just deep to rim of TAL
- Thicker poly reduces stresses transmitted to cement mantle
- **Ogee (Depuy)** 13A* ODEP rating
  Flange for better pressurisation


(Courtesy of N Walsh)

- **Exeter Rimfit/contemporary (Stryker) –** most common cemented cup used in UK
- **ZCA (Zimmer)**
- **Mararthon (Depuy)**


(Courtesy of N Walsh)

Uncemented Cup

- **Trident (Stryker):** 13A*
  - Two types
    - PSL shell with oversized periphery
    - Hemispherical shell, under-reaming of acetabulum
- **Trilogy (Zimmer)** 13A*
  - Porous coated with titanium
- **Exceed (Biomet)** 13A*
  - Porous coated
  - Hemispherical
  - Line to line fixation
- **Pinnacle (Depuy)**
  - Most commonly used cementless cup in UK
- **Risk of intra-operative fracture:**
  - Under-reaming <2 mm
  - Elliptical cup

- Poor bone quality
- In instances of suboptimal coverage with trial component, check for insufficient reaming of medial osteophyte up to tear drop
- Minimal thickness of poly insert is 6 mm
- Screw holes may act as passage route for wear debris to bone
- **To test primary fixation**
    - Move handle of introducer between index and thumb in supero-inferior direction- because component squeezed between anterior & posterior columns
- Look for stress shielding in postoperative X-rays

Consent for THR

- What type of THR? Cemented / cementless implants; bearing surface
- Aim: relieve discomfort & disability
- Alternative treatment; including what if we do nothing
- Break reaction time takes 6 weeks to return to normal
- **Risks**
    - VTE:
        - Clinical DVT With prophylaxis 3 %
          Without prophylaxis 10%
        - PE with prophylaxis: fatal 0.1 % & Non-fatal 1%

      NICE & BOA good clinical practice:
        - Mechanical & chemical prophylaxis for 4 weeks post-op
        - Foot pump in hospital & Below knee TEDS
    - Heart attack: 1-300
    - Death: 1 – 300 (NJR 90-day mortality)
    - Loosening: NJR - inverse relationship between ago of patient and survivorship
    - Nerve injury: 0.5%
        - Sciatic nerve from hematoma, traction and direct surgical injury or screws
        - Peroneal fibers of sciatic N are closer to acetabulum (**Farrell et al JBJS Am 2005** – higher risk for sciatic nerve palsy with lengthening, DDH, post-traumatic THR, uncemented implants and posterior approach)
        - **What would you do in case of neurological injury?**
            - Depends on whether I think it was damaged intra-operatively or not
            - Early exploration
            - CT/US for hematoma or protruding screws
            - Full recovery in 50% - can take 1.5 years
            - Sural nerve graft
    - Vascular injury from acetabular screws
        - Damage to obturator A from placement of retractor inferior to TAL
    - Fracture: 1-4 %: higher in uncemented
    - Iliopsoas tendonitis/impingement
    - Trochanteric bursitis
    - LLD
    - HO: Symptomatic in 5%
    - Infection 1%

(Adult hip reconstruction)

Infected THR

- When presented with a case of possible infection say 'I am concerned about infection and would take history and examine wound and investigate further'
- 0.5 % in OA and 1 % in RA, double the risk in revision surgery
- **ROH, Prospective study (BJJ, 2006)**: Deep infection developed in 0.57% hip replacements and 0.86% knee replacement
- Most common infecting micro-organism was coagulase-negative staphylococcus, followed by Staph. Aureus, Enterococci and Streptococci

Prevention

1. **Pre-op** (Same day admission):
   - Separation of elective from trauma patients, ring-fencing of beds (GIRFT)
   - Treat septic lesions (feet, urinary, dental, and respiratory)
   - Shave in anaesthetic room
   - Nasal decolonisation
   - Avoid intra-articular corticosteroids
   - Glycaemia control
2. **Intra-op**
   - Antibiotic-loaded cement
   - Broad spectrum Antibiotic on induction
   - Ultraclean air & laminar flow
   - Body exhaust suit
   - Avoid unnecessary movement of theatre personnel
   - Surgical Technique -
     - gentle handling of tissues, length of surgery, wound lavage, careful haemostasis, avoid tissue necrosis, prevent hematoma,
   - Face masks, modern weaved gowns, sterile disposable non-woven drapes.
   - Catheterization covered with Antibiotic (Incidence of bacteremia increases from 0.5% to 1.0% with single catheterization to 10-30% for catheters left for 4 days)
3. **Post-op**
   - Antibiotic for 24 hours
   - Minimise dressing changes
   - Early but safe discharge

History and examination:

1. **History**
   - Date of the index operation, revision surgery, any signs/symptoms of delayed wound healing, hematoma, persistent discharge after the index procedure, any hip debridement and washout following the index procedure, prolonged antibiotics usage
   - Or if the patient had a pain-free period and recurrence of pain following recent insertion, indwelling urinary catheter and any recent history of UTI, dental extraction or URTI

2. **Pain**
   - Site, duration and progression of pain
   - Septic osteolysis, where the pain has persisted from the time of operation, is continuous, relentlessly progressive and presents with rest pain or night pain, or
   - It can occur in a well-functioning arthroplasty from a distant source of infection usually from dental, respiratory, or urinary tract infection through the haematogenous route
3. **Risk factors**
   - Skin conditions increasing permeability of bacteria - Psoriasis, venous disease
   - Co-morbidities reducing immunity - DM, CKD, Liver failure, malnutrition, HIV
   - Inflammatory arthroplasty (RA, Psoriasis, AS)
   - Life style: Morbid obesity (BMI >50 has 18.3% increased risk of PJI – **Parvizi JBJS Am 2010**), smoking, excessive alcohol consumption, IV drug abuse, and poor oral hygiene
   - Can do serum Cotinine test for smokers
   - Recent bacteremia
4. **Examination**
   - Gait, hip kept in a position of ease, previous surgical scar, circumferentially look for signs of inflammation, induration, fluctuance and sinuses, ROM and any associated deformity of contractures

Classification

- **Coventry/Fitzgerald classification**
  - **Acute**
    - Post-operative - within 3 weeks
    - Superficial infection / infected hematoma
    - Not invaded bone prosthesis interface
    - Haematogenous - Secondary to another infection
  - **Chronic**
    - Has been present for > 3 weeks
    - Low-grade intraoperative infection
    - Biofilm
- **Musculoskeletal Infection Society (MSIS) criteria 2018, Parvizi et.al**
  - *Major criteria*
    - Presence of sinus tract is diagnostic
    - 2 positive cultures from separate samples
  - *Minor criteria* (≥6 infected, 2-5 inconclusive, 0-1 not infected)
    - Serum
      - CRP >10mg/L or D-dimer >860ng/mL – 2 points
      - ESR > 30mm/hr – 1 point
    - Synovial
      - WBC >3000 cells/uL – 3 points
      - Positive alpha-defensin – 3 points
      - Synovial PMN > 80% - 2 points
      - Synovial CRP > 6.9mg/L – 1 point

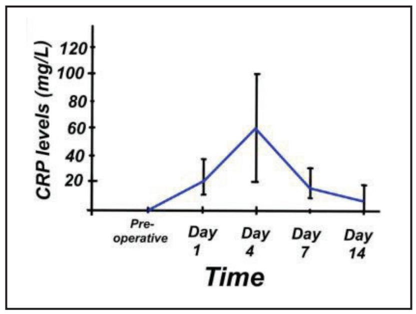
- **<u>Intra-operative diagnosis</u>** (≥6 infected, 5 inconclusive, ≤3 not infected)
  - Positive histology – 3 points
  - Positive purulence – 3points
  - 1 positive culture – 2 points

Biofilm

- Produced by bacteria (staph) formed on implant within 3 weeks of infection
- Polysaccharide (Glycocalyx) layer protects bacteria from host immune system (WBC and Abx)
- Adhere to foreign material, inhibit antimicrobial activity & reduce ABx penetration
- Anti-biofilm agents: Rifampicin for Gram +ve and Ciprofloxacin for Gram –ve

Organisms:

- Staphylococcus Aureus - 20%
- Staphylococcus Epidermidis - 30%
- Coagulase-negative Staphylococcus
- Peptostreptococcus: following dental procedure
- Most common fungal organism is Candida
  Requires antifungal drugs for 6-12 months



Investigations

- **<u>Blood tests</u>: Berbari (JBJS, 2010 – meta-analysis)**
  1. **CRP:**
     - Normally as high as 250 in 1st week post THR
     - Peaks at day 3; normalize in 2 weeks
     - Sensitivity 88 % and specificity 74%
  2. **ESR**:
     - Takes up to 6 months to go back to normal
     - Sensitivity 75 % and specificity 70%
  3. **IL 6**:
     - Produced by stimulated monocytes and macrophages
     - Peaks at 2 days and rapidly return to normal value. Sensitivity 97% and specificity 91%
     - Expensive

     (**Berbari et al JBJS Am 2010** – IL-6 more accurate than ESR, CRP, or WBC count)
  4. **Pro-calcitonin**
  5. **Synovasure (Zimmer Biomet):** Biomarker
     - Alpha Defensin test for peri-prosthetic joint infection
     - 97% sensitivity and 96% specificity & Only 62% in low grade infection
     - Antimicrobial peptide released by neutrophils in response to pathogens
     - False +ve with metallosis

(Courtesy of F Arnaout)

  6. **Polymerase chain reaction (PCR)** of aspirate, amplifies bacterial DNA

- Contamination leads to false-positive result

7. **Synovial fluid WBC**
    - > 3000 cell/uL
    - >80% PMN
    - Saline injection & Re-aspiration provides accurate diagnostic information in event of dry tap
    - AAOS guidelines:
        - Aspirated fluid for microbiologic culture & synovial fluid WBC
        - Patients should be off-antibiotics for minimum of 2 weeks prior to obtaining intra-articular culture

- **<u>Histopathology</u>**
    - **Intraoperative tissue culture**
        - 7 samples (2 or more should grow same organism)
    - **Intra operative frozen section**
        - 10 WBC/high power field
- **<u>Radiology</u>**
    - **X-rays:**
        - Osteolysis (focal), cortical destruction, new bone formation (periosteal reaction) in chronic infection
    - **Tech bone scan**
        - Sensitive, useful if –ve
        - Can remain +ve 2 years following THA
    - **White cells scan**
        - High specificity (100%) but low sensitivity (45%)
    - **Positron Emission Tomography**
        - PET identifies areas of high metabolic activity
        - Sensitivity & specificity 98%

Management

- Can use Ethylene blue to delineate area of infection in soft tissue in presence of sinus
- Poly exchange & Abx for 6 weeks (Debridement, antibiotic, Implant retention (**DAIR)**
    - Early post-op or acute haematogenous (less than 3 weeks) –If implants are stable, change modular components
    - No communicating sinus or purulence in joint
    - Low virulence and known micro-organism
    - Patient not immunocompromised
    - Success rate 16-89%
- Prosthesis removal & Abx spacer
    - Abx for 6 weeks for chronic infection
    - Aim of inserting spacer
        - Maintenance of joint space and limb length
        - Stabilization of the joint to allow some mobilization
        - Reduce dead space
        - In-situ release of high local antibiotic dosage with reduced systemic effects
    - Increase porosity by hand mixing
    - <u>Heat stable Abx for spacer</u>
        - Gentamycin Maximum 10 g (6 weeks elution time)
        - Tobramycin 2.4 - 3.6 g /40 g package of cement 2 weeks elution time
        - Vancomycin 1-4 grams per 40 grams of cement -Maximum 10 g

- **Duncan & Masri** (Canada, Prospective study in BJJ, 2009)
  - 2-stage revision arthroplasty of hip for infection using Prostalac hip spacer
  - PROSTALAC functional spacer (Prosthesis of Antibiotic-Loaded Acrylic Cement)
  - At mean follow up of 12 years, success rate 89 %
  - Causative organism must be identified preoperatively for single stage
  - Single stage: Reduces cost, reduces stiffness
  - Chronic infections caused by Staph Epidermidis or Propionibacterium acnes have high recurrence rates with retention, and two-stage revision should be considered.
- **Beswick et al, (Bristol, UK) BMC Med 2012**
  - No difference in 1- or 2-stage revision in systematic review of longitudinal studies. Requires RCT to establish optimum management strategies for PJI
- Excision arthroplasty (Girdlestone)
  - For recurrent infections
  - Good pain relief & ROM
  - Shortening & unstable joint & need walking aid
- Suppression Abx: unfit patient
- General principles of treating post op infection with any implant in situ
  - Acute: Abx & aggressive debridement & retain implant
  - Chronic: Abx & aggressive debridement & remove implant
- **What would you do if you had 5 consecutive THR patients that became acutely infected whilst still an inpatient?**
  1. Stop all operating
  2. Make sure the patients who have infection are appropriately treated
  3. Assess patients that might be infected
  4. Establish a root cause analysis, using an MDT approach, looking at the entire patient pathway from pre-assessment to post-operative follow up
  5. The team in root cause analysis will include, infectious disease doctors, theatre manager, theatre engineers, ward mangers

Periprosthetic Fractures

- Intraoperative fractures: 3.5 % of uncemented; 0.5 % of cemented
- Cemented tend to fracture after 5 years and uncemented within 6 months

Risk Factors

- Press fit
- Osteoporosis
- Paget's disease
- Distorted anatomy
- Revision Surgery

Classification & Management

Vancouver Classification

a. **Trochanteric**
   - **AG**
     - Non-operative, restricted weight bearing, if undisplaced
     - Cable or claw plate if displaced
     - Non-union can result in pain and gait difficulties
   - **AL**
     - Check for prosthesis stability

b. **Around stem**
   - B1 (Well-fixed stem)
     - Locking plate with unicortical screws or cables proximally
     - Better to use bicortical screws with variable angle plate
     - Be aware of transverse and short oblique fractures as they don't heal due to damaged intra and periosteal blood supply

(Courtesy of M Kousa)

   - B2 (Loose stem; Good proximal bone stock)
     - Long porous coated cementless stem by-pass fracture by > 2 cortical diameters
     - Supplement cables or plates to maintain reduction
     - Loosening indicated by
       - Prior hip or thigh pain
       - Subsidence of stem - check immediate post op radiograph
       - Cement fracture
       - Radiolucency (osteolysis)
       - Dislocate hip and check stability of stem
   - B3 (Loose stem; Poor proximal bone stock)
     - Diaphyseal fixation stem; if adequate bone stock 4 cm proximal to isthmus
     - Impaction bone grafting

- Proximal femoral replacement - Attach abductors to prosthesis or to vastus lateralis

c. **Distal to stem**
- Avoid metalwork in the fracture
- Wall to wall fixation with screws to achieve long working distance
- Avoid stress-risers
- Overlap stem with plate with cables

The Unified classification system – by Duncan and Haddad (BJJ 2014)

➢ Core principles:
- The location of fracture
- The fixation of the component
- The adequacy of bone stock and bone strength supporting the implants

➢ Types:
- A – "**Apophyseal**" fracture
- B - Fracture through "**bed"** of implant
- C - Fracture away from the implant bed / "**clear"** of implant
- D - Fracture in the bone between two implants / "**dividing"** bone between two implants
- E - Fracture involving both bones supporting one arthroplasty / "**each"** bone fracture
- F - Fracture of the bone "**facing"** and articulating with hemiarthroplasty

Type	Subtype	Fracture description	Treatment
A		Fracture in trochanteric region	
	AG	Fracture of greater trochanter	
	AL	Fracture of lesser trochanter	
B		Fracture around stem or just below	
	B1	Well – fixed stem	ORIF
	B2	Loose stem with good proximal bone stock	Revision THA
	B3	Loose stem with poor bone quality	Revision THA
C		Fracture occurring well below tip of stem	ORIF
D		Fracture of femoral shaft between well fixed hip and knee replacements	ORIF
E		Both femur and acetabulum fractures after THA	
F		Fractured acetabulm with femur hemiarthroplasty in situ	Revision THA

➢ **Acetabular fracture**
- Stable cup: add screws
- Unstable cup: remove cup, stabilize fracture, reinsert cup with screws
- Pelvic discontinuity stabilize fracture +/- cup cage construct or allograft or custom-made implants using 3D Printing

Aseptic Loosening (Osteolysis)

Mechanism

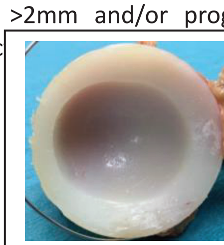
- Histological inflammatory response to wear debris resulting in resorption of bone around prosthesis
- Debris attracting macrophages (Metal on metal stimulates lymphocytes, as it generates high volume smaller particles 50-100nm)
- Debris can be poly, metal, PMMA, ceramic (wear particles of submicron 0.1-0.5 um most biologically active)
- Macrophages release osteolytic factors (cytokines)
    - PDG
    - TNF alpha
    - Prostaglandin E2
    - Hydrogen peroxide
    - IL 1 & 6
    - RANKL, which activate osteoclasts
    - Acid Phosphatase
- Can lead to prosthesis micro-motion, which can be measured with RSA
- Final stage is dissemination of more particulate debris
- Failure from aseptic loosening of hip replacement is silent in 30%
- **Schmalzried JBJS Am 1992** – gave the concept of "effective joint space"

Clinical Features

- Start-up pain: (Triphasic) occurs after many painless years with insidious onset of groin, buttock or thigh, triggered by walking, settle down with continued walking and again aggravates after prolonged walking
- Aging - decreased cortical bone thickness causes stem to move away from cement - lucency at the bone cement interface - this does not indicate a loose stem
- X-rays to check for loosening
    - Look for poly wear on X-rays
    - can be due to infection (septic) lysis without prosthesis wear

Radiological Features

- **Femoral stem loosening** - Stem fracture, cement mantle fracture, new radiolucent line, changes in stem position / subsidence, modes of loosening
- **Acetabular loosening** - Bone cement lucency >2mm and/or progressive, medial cup migration, change in inclination, eccentric poly wear, cup/cement frac

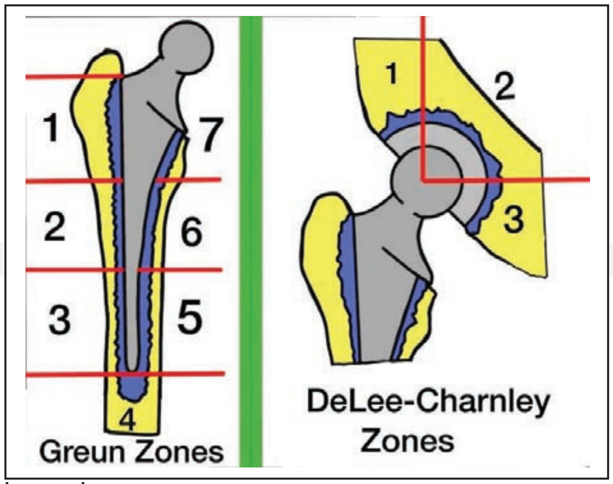


- **Technical issues contributing to loosening** - failure to remove medial cancellous bone, cement movement during implantation, less quantity, laminations and voids, inadequate pressurization, varus stem position
- Revision operations should be performed before massive bone destruction

Indications for surgery

- Fracture
- Impending fracture
- Pain

- **DeLee & Charnley zones**:
  - Radiolucency around acetabular component on an AP radiograph.
  - Vertical & horizontal lines from centre of acetabulum
- **Gruen** classified lucency around femoral stem



Hip resurfacing

- Uncemented cup and cemented femoral component
- Best outcomes in young males with good bone stock
- BHR - 13A* ODEP rating

Advantages

- Low rate of wear
- Hydrodynamic fluid film lubrication
- Bone conserving on femoral side: Reduced risk of LLD; Revision easier
- Normal femoral loading: Avoids stress shielding
- Reduced risk of dislocation: Neuromuscular disorder
- Indicated for patients with deformed femur shaft

Disadvantages

- Requires larger exposure than conventional THR
- Acetabular implants are press fit and can’t be augmented with screws
- Can’t adjust offset & LLD
- MOM complications
- Steep learning curve
- Cup made of Co/Cr - stiffer than titanium

Contraindications

- Femoral head cyst > 1cm
- Female of child bearing age (MOM)
- Renal failure (MOM)
- Coxa vara: increased risk of fracture
- RCT in **BMJ, 2012 by Costa et al** - No evidence of difference in hip function 1 year after THR versus resurfacing arthroplasty using Oxford and Harris hip scores
- **McGrory JAAOS 2010 –** Review article, Modern MoM hip resurfacing good for selective indications – young males with primary OA, and head size >50mm
- Why ASR failed?
  - Less spherical than BHR (160^0), causes edge loading and fluid lock-out - associated with higher wear rate (**Langton JBJS Br 2011**)

Complications

- Neck fracture: MC early complication
  - Due to Notching 0.5%: Avoid by central pin placement (Upsize femoral head)
  - Varus placement: vertical shear force on neck
  - Underlying AVN or osteoporosis
- MOM complications
- Femoral head collapse 1.5% usually due to pre-existing AVN
- Divot sign: Erosion at superior implant bone junction, due to implant-bone impingement or stress-shielding from

stiff Co/Cr - Uncertain prognostic value

MOM hip prosthesis

- Better wear than MOP
- Better stability for larger heads
- Debris smaller than PE and therefore reduced 3rd body wear and osteolysis
- Wear particles 20 to 90 nm

BOA & MHRA (Medicine & Healthcare products Regulatory Agency) guidelines 2017

Intervene before tissue and bone damage

- ASR THR or resurfacing (except males with >48mm head) or stemmed MoM (except head <36mm): Annual Oxford hip score and metal ions check. MARS MRI/US if score deteriorating or ion level rising
- Symptomatic MoM implants: Annual Oxford hip score and metal ions check. MARS MRI/US if score deteriorating or ion level rising
- Asymptomatic stemmed with head < 36mm: follow up annually for 5 years, every 2 years from 5-10 years, and every 3 years after
- **Blood:** Always rule out infection
    - Cobalt & Chromium high: indicators of surface wear (but increased ion levels should not be the sole indicator of revision of implants)
    - >7 parts per billion (ppb) equals 120 nmol/L cobalt or 135 nmol/L chromium
    - Number of units of contaminant per billion unit of body mass
- **MARS (Metal Artefact Reduction Sequence) MRI:** cystic or mass lesion or fluid collection
- **Metallosis:** deposition and build-up of metal debris in soft tissues of body
- **ALVAL (Pseudotumor):**
    - Adverse local tissue reaction to metal debris (ARMD)
    - Type IV hypersensitivity
    - Aseptic lymphocyte-dominated vasculitis-associated lesion
    - Metal ions slowly released from bearing surfaces as a by-product of normal wear
    - Wear particles + native proteins = Haptens
    - Granulomatous inflammatory mass causes extensive collateral damage
    - Local destructive response leads to pain, osteolysis, and loosening of prosthesis
- **Systemic effects**:
    - DNA damage and chromosomal aberrations.
    - ? Teratogenicity. Metal ions can cross placenta
- **McKee-Farrar Hip**:
    - First inserted 1951: first mass production hip replacement in the world
    - From Norfolk and Norwich hospitals
    - Cemented Vitallium socket: stem based on Thompson
    - Designed to be polar bearing - high wear due to high contact load (Smith & Nephew)

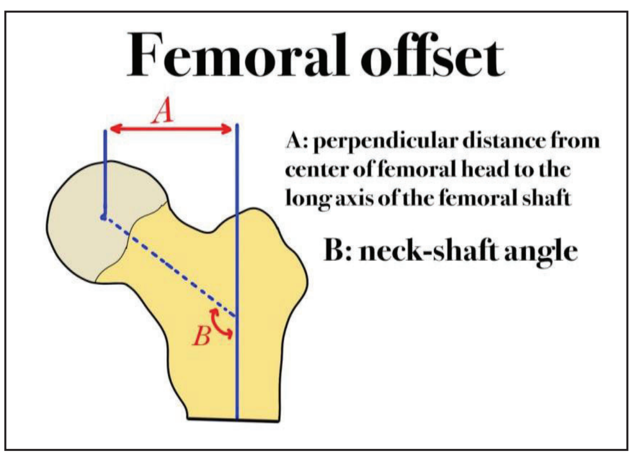
(Courtesy of H Hermina)

Dislocated THR

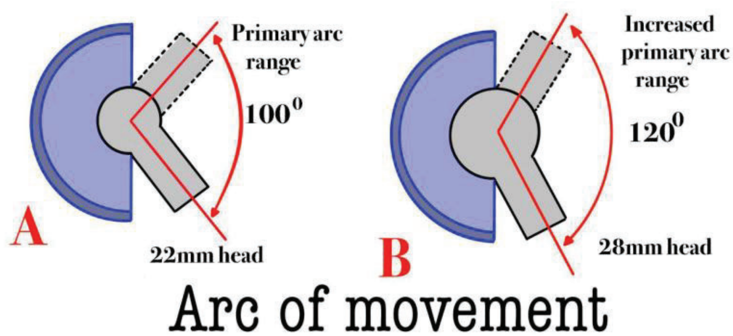
- 3-5% over life of implant
- Look for eccentric position of femoral head as an indication of polyethylene wear and risk for impending dislocation

Factors influencing stability of THR

- **Patient factors**
    - Female: male 2:1
    - Soft tissue laxity & muscle weakness due to neurological disease (spinal stenosis)
    - Patient: non-compliant, cognitive dysfunction, alcoholic
    - Poor anatomy: Revision surgery with compromised abductor function or previous infection or trauma
    - GT advancement: places abductor complex under tension
    - Spinal stiffness Reduced spino-pelvic motion. For each 1^0 – there is 0.9^0 of hip compensation
- **Surgical factors**
    - Surgeon experience; poor technique
    - Impingement from osteophytes or retained excess cement
    - Prosthesis alignment:
        - Cup 15 $\pm$ 10°Anteversion and 40 $\pm$ 10°Inclination (**Lewinnek safe zone JBJS 1978)**
        - Beware that in lateral position, the ipsilateral pelvis is adducted by 10°
        - Aim for apparent inclination of 35°
        - Stem: 15-20°Anteversion
        - Combined version = 40°
        - **Esposito et al J Arthroplasty 2015** and **Matthew Abdel CORR 2016** Mayo Clinic – dislocation of THR not related to acetabular cup alone, femoral anteversion > 15^0 also causes higher dislocation rates
        - **Battaglia et al (CORR 2006)** – Increased surgeon volume reduces THR dislocation rates (GIRFT)
        - **South Korean RCT J Arthroplasty 2016** – Dislocation rates with posterior approach is similar to anterolateral approach, with careful posterior soft tissue and capsular repair)
        - CT to assess position before discussing about revising component
    - Soft tissue tensioning - abductor complex
    - Avoid over-medialization of acetabular cup
    - Femoral offset
        - Perpendicular distance between centre of femoral head to line down centre of femur
        - Increased offset increases abductor moment arm, decrease abductor force require and decrease JRF but puts higher stress on stem



- **<u>Implant factors</u>**
  - Arc of movement- range of motion prior to impingement (Native hip has greater arc than THR)
  - Aim for a large head / neck ratio
  - Excursion/jump distance - distance femoral head must travel to dislocate
  - ½ diameter of femoral head; Increased with larger heads
  - Use of lipped liner: Elevated rim
  - Use of face changing liner: Liner angled by 10 deg in relation to shell
  - Constrained liner (capture cup): used for un-repairable soft-tissue insufficiency, severe cognitive disorders, and late dislocations with well-positioned components.
  - Limited ROM
  - Early loosening
  - Wear
  - Exchange of liner



Classification (Based on time)

- **Early:**
  - <6mths
  - Non-compliance to post-op instructions, technical error in surgery
  - Malposition of components, impingement, retained cement, faulty soft tissue repair
- **Intermediate**
  - 6mths- 5yrs
  - Older age, female gender, decreased muscle mass, predisposing factors like AVN and Rheumatoid arthritis
- **Late**
  - >5yrs
  - Trauma, soft tissue laxity, neurological decline, younger age with poly wear, female gender and weight loss

Work-up

- Check OT records: get information regarding the
  - Approach used
  - Implant used and design features of the implant esp. the head size
- **X rays**: I will assess the

- Vertical and horizontal offset restoration,
- Component position (acetabulum anteversion and inclination),
- Femoral anteversion, any features of impingement

Management

- Attempt closed reduction under GA in OT followed by checking stability
- If successful: short period of bed rest followed by hip abduction brace 6 weeks
- If closed reduction fails: Open reduction and assessment of soft-tissue interposition in the acetabulum, soft-tissue tension or an impingement problem. If a simple cause is identified, one must be prepared to address this.
- The hip dislocates again or unstable: CT scan to assess component orientation (anteversion femoral stem, acetabular component version. Rule out infection (check history ,blood tests-inflammatory markers)
- Intraoperative considerations if stable hip not achieved:
  - Resection arthroplasty last resource
  - PLAD - posterior lip augmentation device
  - Dual-mobility cup

Other complications

Iliopsoas Tendinosis

- Insufficient anteversion of large uncemented acetabular components produces prominent anterior lip
- Large marginal osteophytes or extruded cement
- Confirm with LA injection
- May respond to injection of corticosteroid or to arthroscopic tenotomy
- May require cup revision and iliopsoas debridement

Trochanteric bursitis

- Trochanteric bursa is superficial to hip abductor muscles and deep to ilio-tibial band
- **Causes:**
  - Excessive increase of offset
  - Bulky stitches
- **Treatment:**
  - Non-operative:
    - NSAIDS
    - PT stretching
    - Corticosteroid injections
    - Shockwave Therapy
  - Operative:
    - Open vs. arthroscopic trochanteric bursectomy
    - Only after conservative measures fail

Limb Length Discrepancy

- Before dislocating the hip, obtain a baseline measurement of leg length
- May be short pre-op due to OA; perceived LLD post-op when limbs made equal
- Weak abductors may give sensation of LLD - 15%
- Assess post-op with CT scanogram

Impingement

- Pain in certain positions

REVISION THR

- Assess available bone stock

Indications

- Osteolysis start-up pain
- Infection - night pain
- Instability
- Fracture of bone or implant

Goals

- Removal of implants & cement
- Reconstruction of bone
- Stable hip
- Restoration of centre of rotation

Special Instruments

- OSCAR (ultrasonic cement remover)
- Curved acetabular gouges (Renovation)
- Explant acetabular cup removal system (Zimmer)
- Acetabular component forceps
- Flexible and straight and curved revision osteotomes and burs
- Cerclage wires
- Impaction graft
- Dall-Miles cable system (crimp, crimper, tensioner, cable passer)

Imaging

- Judet views: Assess columns
- CT scan: Assess osteolysis and component position
- Delineate bony anatomy and assist with planning surgical reconstruction
- **Acetabulum**
    - Look for protrusion and superior migration
    - Get angiogram if in doubt

Classification

- **<u>AAOS classification of acetabular deficiencies</u>**

  I. Segmental (Rim or medial wall):

    - Structured allograft& Reconstruction/non-protrusio cage to form foundation - If rim incompetent **(<2/3 remain)**
        - Concerns about graft vascularization and resorption – collapse
    - Hemispherical porous coated cup augmented with screw-Trabecular metal- If **>2/3 of rim is competent**
        - Tritanium (Stryker) - porous tantalum
        - TMARS (Zimmer) - Trabecular metal augment

(Courtesy of M Elgawadi)

II. Cavitary (Volumetric loss):
- Peripheral or central
- Morselized impaction bone graft – Reverse ream to impact

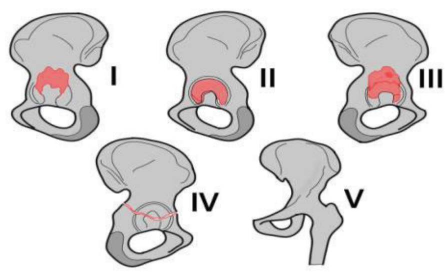
III. Combined (Cup – cage construct):
- Use trabecular metal cup as a replacement to the allograft doesn't have to be in anatomical position
- Cage fixed into the ischium and ilium
- Acetabular cup cemented independent of the position of the cage

IV. Pelvic discontinuity (Between superior and inferior columns):
- Neurovascular assessment
- Recon plates & anti-protrusion reinforcement cage
- Custom triflange acetabular components

V. Ankylosis

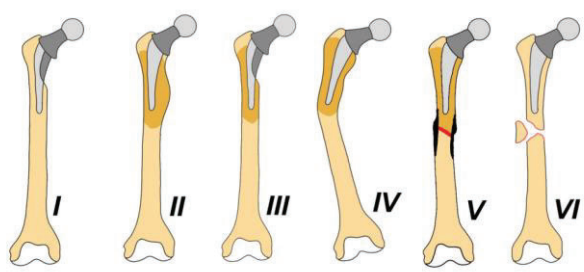
(Courtesy of H Hermina)

AAOS acetabuar bone defect classification



AAOS classification Femoral Deficiencies

• **Segmental**	Deficient supporting shell of femur
• **Cavitary**	Loss of endosteal bone with intact cortex Use morselized fresh frozen impaction (compressed) bone graft
• **Combined**	
• **Mal-alignment**	Loss of femoral geometry due to surgery, trauma or disease
• **Stenosis**	From trauma or bony hypertrophy
• **Femoral discontinuity**	from fracture



AAOS classification of femoral bone deficiencies for revision hip arthroplasty

➢ **Paproksy classification**

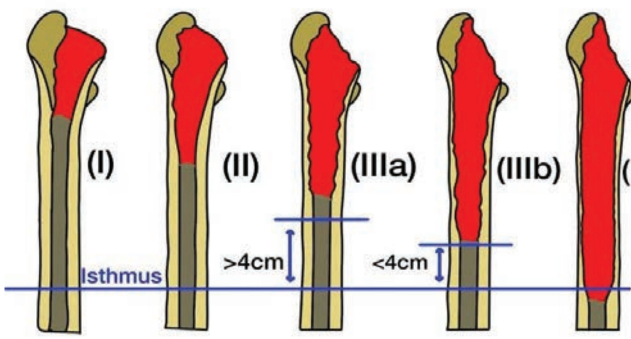
Type 1 sufficient proximal bone to support any implant
Primary stem using double wedge taper design which provides proximal fill
If compromised rotational stability - fully porous stem (diaphyseal in-growth)

Type 2 insufficient metaphyseal bone stock to support the stem
Implant must have some diaphyseal porous coating for in-growth
Or extensively Porous-coated Cylindrical

Type 3A no metaphyseal bone stock
Some deficient proximal diaphyseal bone stock
Requires diaphyseal fixation.
Extensively Porous-coated Cylindrical

Type 3B even less diaphyseal bone stock yet the femoral isthmus remains supportive
The Modular stem designs are the best option

Type 4 No supportive diaphysis to obtain initial press-fit to allow for bony in-growth
Require total femoral replacement



Paprosky classification

➢ **Cemented**

- Cement in cement with downsizing of stem if bone-cement interface is good
- Must be aseptic with well fixed cement to bone fixation
- Use same type of previous cement to improve bond
- Clear shoulder of prosthesis from cement and bone, which obstructs stem removal and causes GT fracture
- Mueller revision drills and reamers to remove cement
- Meticulous impaction bone grafting followed by long cemented stem
- Use cement drill and cement tap

➢ **Uncemented**

- Extensively porous coated
- Modular Coned / broached / calcar body
  Conical fluted / bowed stem
- Stem achieves wedge press fit for axial stability
- Flutes for rotational stability
- Also relies on the body-metaphyseal bone interface

- Extended trochanteric osteotomy ETO:
  - Between gluteus medius and vastus lateralis
  - Cable distal to prevent crack propagation
  - Use burr to avoid sharp edges
- Narrow and rounded distally to avoid stress fracture
- Prophylactic cerclage cable to prevent propagation of fracture
- Multiple osteotomes to lever out

Cannulok (Orthodynamics) - Fully HA coated, Cannulated, locked
Restoration (Stryker): Modular
S-ROM (Depuy Synthes)

Reclaim (Depuy Synthes)

ZMR (Zimmer): Modular

PAGET DISEASE (OSTEITIS DEFORMANS)

Definition

- Chronic metabolic bone disease, characterized by accelerated bone resorption by osteoclasts and compensatory exaggerated bone formation by osteoblasts, resulting in weakened bones, which leads on to fractures, deformity and arthritis

Epidemiology

- 2nd MC bone remodelling disorder after Osteoporosis
- Incidence 4% at 40yrs, 10% at 90yrs
- Common in West Europe, North America, and Australia
- Family History in 25%, Polyostotic in 83%, monostotic in 17%

Aetiology

- Unknown
- Likely viral, Pagetic osteoclasts contain mRNA from paramyxovirus and canine distemper virus – more recent studies unable to confirm,
- Environmental with high levels of arsenic and association with cats and dogs
- Genetic 5-40% first-degree relative

Pathology

- Micro - Osteoclasts increase in size and number leading to increased bone resorption followed by disorganized bone formation leading to a chaotic over activity in bone.
- Macro - Bone formed is thickened, enlarged, weak and poor in quality.
- Vascularity is increased; marrow is filled with woven bone and fibrous tissue

Clinical Features

- Osseous - pain (mild, acute, severe), deformities, arthritis, pathological / stress fracture, pseudoarthrosis, malignant change (Osteosarcoma, Chondrosarcoma, MFH, GCT), spinal canal stenosis
- Extra osseous - high output cardiac failure, metabolic acidosis, hypercalcaemia, urolithiasis
- Cranial nerve compression - Headache, deafness, blindness, vertigo tinnitus

Phases

- **Lytic** - a front of osteoclastic resorption in the metaphyseal region
- **Mixed -** combination of lysis and sclerosis with coarsened trabeculae
- **Sclerotic -** dense mosaic pattern, bone enlargement with cortical thickening

Investigations

- **Bloods**
  - Elevated serum ALP and Acid Phosphatase due to increase osteoblasts activity indicate active disease
  - Normal serum Ca & PO4
  - Raised urine Hydroxyproline & N-telopeptide: collagen I breakdown marker
- **Radiological**
  - *Long bones* - thick, bent, widened - cortex thick irregular sclerotic
  - *Cancellous bone* has thickened course irregular trabeculae
  - *Loss* of Cortico-medullary differentiation

- *Candle flame lesions* and blades of grass appearance in diaphysis
- *Stress fractures* convex side, lateral border in femur and anterior border in tibia
- *Skull* - osteoporosis circumscription (Lytic), cotton wool appearance (Mixed), diploid widening
- *Pelvis* - acetabular protrusion
- *Spine* - square vertebral body with peripheral thickened trabeculae and radiolucent inner portion, picture frame vertebra, ivory vertebra with increased sclerosis

(Courtesy of M Meda)

Treatment

- **Non-operative:**
  - Bisphosphonates; calcitonin (pre-op)in active disease
  - Teriparatide contraindicated due to risk of developing sarcoma
- **Operative** (THR):
  - **Pre-op Orthopaedic considerations**
    - Good quality full-length radiographs and templating, restoring the mechanical alignment, offset and version
    - Diagnostic dilemma with hip pain - Looking for referred pain from spine, stress fractures, radiographic bone destruction suggesting sarcomatous change, detailed focused history and examination and diagnostic intra-articular injection
  - **Pre-op anaesthesia considerations**
    - Pre-op Bisphosphonates/ calcitonin 3/12 pre-op
    - Increased bleeding requiring adequate blood for transfusion, consider cell salvage, pre-op donation, hypotensive anaesthesia
    - Pre-op surgical optimization
    - High output cardiac failure
  - **Intra-op femoral considerations**
    - Bone is very hard and sclerotic, burrs may be needed for entry, broaching can lead to increased intra-op fractures and also post-op fractures
    - Deformity of femur necessitating osteotomy, increased intramedullary cortical sclerosis might interfere with cemented fixation, large canal requiring extra cement, large bone plugs
  - **Intra-op Acetabular considerations**
    - Acetabular protrusio might cause increased risk of fractures during hip dislocation
    - May need correction with bone grafts or anti-protrusio cages
    - Increased risk of intra-op fractures, HO, increased loosening
  - **Sabre tibia:** Anterior bowing of tibia as result of Paget disease or syphilis

HETEROTROPIC OSSIFICATION

- Abnormal formation of mature lamellar bone outside skeleton
- Called **Myositis Ossificans** when occurs in muscle: might look like osteosarcoma

Risk Factors

- Male / Advanced age
- Ankylosing spondylitis/ DISH/ Paget's / RA
- Previous HO / Take down of fusion
- Post-traumatic / muscle haematoma
- Direct lateral / Anterior approach to hip
- Soft tissue dissection / muscle ischemia
- Persistence of bone debris
- Traumatic brain & spinal cord injury
- Amputation site performed through zone of injury
- Burn
- Directly related to ISS

Pathology:

- Mesenchyme precursor stem cells are converted to osteocytes, produce mature lamellar bone

Clinical:

- Incidental finding, stiffness, painless mass, signs of inflammation, can cause neurovascular compression and deficit
- U/S and bone scan for early diagnosis

Classification (Brooker)

- Based on an AP radiograph- bone which appears bridging may be located anterior or posterior to hip, and does not cause significant loss of ROM
  - **I**: Islands of bone within soft tissues around hip
  - **II**: Bone spurs in pelvis or proximal femur > 1 cm between opposing bone surfaces
  - III: Bone spurs extend from pelvis or femur < 1cm space between opposing bone surfaces
  - IV**:** Radiographic ankylosis of hip

(Courtesdy of H Hermina)

(Myositis Ossificans)

Management

- **Prevention:**
  - Indomethacin 25 mg TDS for 6 weeks after surgery
  - Low-dose radiation therapy

- **Treatment:**
  - Physio to improve ROM
  - Surgical excision after 6 months
    - Confirm decrease bone activity on bones scan activity and normalization of ALP
      - Sharp cortical margins, trabecular pattern (CT scan can be helpful)

TUMORAL CALCINOSIS

- Ca+ deposition in peri-articular soft tissues
- Well-demarcated masses
- Spontaneous
- Due to hyperphosphataemia
- Hereditary / metabolic dysfunction or in patients undergoing renal dialysis
- Term should not be used to refer soft tissue calcification in general

FIBRODYSPLASIA OSSIFICANS PROGRESSIVA

- Fibrous tissue in muscle, tendon and ligaments gets ossified
- Progressive HO
- Restricts patient's ability to move

HIP AVASCULAR NECROSIS (AVN)

AVN: death of bone due to interruption of blood supply

Classification

- **Steinberg (modified Ficat-Arlet) JBJS (Br) 1995**
    - 0: Normal X-ray & MRI & bone scan
    - I: Normal X ray (Abnormal MRI/bone scan)
    - II: Abnormal X-rays: cystic/sclerotic, osteopenia
    - III: Crescent sign (subchondral collapse/fracture)
    - IV: Flattening of head / collapse
    - V: Joint narrowing, acetabular changes
    - VI: OA

Causes / Risk Factors

- Idiopathic: 50% are bilateral – ask about other hip
- Iatrogenic: Steroids, Local injections or systemic (asthma) , Cause elevated lipid levels -micro fat emboli – venous stasis
- Radiotherapy
- Alcohol
- Haematological: Sickle cell disease, Worst prognosis
- Hypercoagulation
- Inflammatory bowel disease
- Trauma: Femoral head 75-100%
  Basicervical: 50%
  Hip dislocation 40%
- Decompression sickness (Caisson disease): Dissolved gases come out of solution into bubbles inside body on de-pressurisation
- Gaucher disease

Prognosis

- Natural history of untreated asymptomatic AVN:
    - Small medial lesions (best prognosis)
    - Sickle disease (highest progression)
    - SLE (most benign course)
- **Nam KW (South Korea) JBJS (Am) 2008**
    - Small lesion (5-10% risk of progression), <30% head involved – monitor if asymptomatic
    - Large lesion (84% progression) usually cause pain within 5 years of diagnosis – THR better if head collapsed

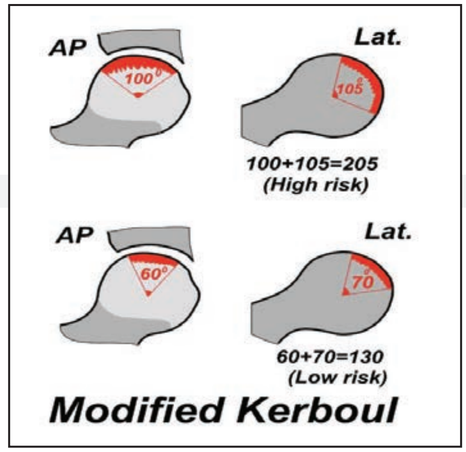
Pathogenesis

- Not fully understood
- Thrombophilic theory: Intravascular coagulation - vascular occlusion
- Hydrostatic pressure theory: due to increase venous pressure
- Lipid deposition theory: lead to increased pressure and fat emboli
- Vascular theory: occlusion of LCFA
- Primary cell death

- Abnormal mechanical stress

Investigations

- **X-rays** Crescent sign: Subchondral bone collapse
- **Prognostic factors for femoral head collapse:**
  - Risk of femoral head collapse with osteonecrosis is based on the modified **Kerboul combined necrotic angle (BJJ 1974)**- calculated by adding the arc of the femoral head necrosis on a mid-sagittal and mid-coronal MR image
  - <30% of femoral head or combined angle of necrosis < 160^o - low risk of collapse
  - >50% or > 200^o – high risk



- **MRI (highest sensitivity and specificity)**
  - T1 dark, decreased signal intensity due to loss of fatty marrow
  - T2 bright due to marrow oedema

Management

- **Pre-collapse: Stages 0 – II**
  1) Protected weight bearing (not fit for surgery, very limited disease).
  2) Bisphosphonates (Prevent collapse (**Agarwala, BJJ 2009**)
  3) Other pharmacological agents (Lipid lowering agents , anticoagulants)
  4) Core decompression (CD)
     - Relieve intra-osseous pressure
     - Promotes blood flow and stimulates healing
     - Drill 8-10 mm hole through sub-chondral necrosis Or
     - Pass 3.2 mm pin into lesion two to three times
     - Failure rate of 20%
     - (**Fairbank JBJS 1995** – Hip survival at 10 years following CD – 96% (stage I), 74% (stage II), 35% (stage III)
  5) Stem cell injection
  6) Trans-trochanteric rotational osteotomy(Shift involved portion of head away from weight bearing)
  7) Trapdoor technique (Femoral head surgical dislocation, Window in articular cartilage, bone graft)
- **Collapse/OA**
  - **THR**
    - Higher rate of loosening in cemented
    - Poor results with higher revision rates in - sickle cell, renal failure +/- transplant, Gaucher's
    - NJR 16th annual report – for selection of THR (though it doesn't specify outcome of any particular fixation in AVN). Results of cemented THR have improved because of better cementing techniques and XLPE liners.
  - **Hip resurfacing**:
    - Requires adequate bone to support resurfacing component, No steroids / renal disease
  - **Arthrodesis**
    - Consideration in young labourer

IDIOPATHIC TRANSIENT OSTEOPOROIS OF HIP

- Diffuse osteopenia of femoral head and neck
- Middle aged men; women in 3rd trimester of pregnancy
- Exclude: Femoral neck stress fracture / Infection / Malignancy / AVN, absence of focal changes on MRI and bone scan is suggestive of transient osteoporosis
- Treatment: protected weight bearing to avoid stress fracture

- Resolves spontaneously in 6-8 months

HIP ARTHRODESIS

- Provides pain relief but with some restriction of physical activity
- Requires 30% more energy expenditure for ambulation
- Increases stress of adjacent joints
- **Indications:** Young man with OA secondary to trauma and involved in heavy manual work

- **Prerequisite:** normal contralateral hip, ipsilateral knee and lumbar spine

- **Contraindications:**
  - Active infection.
  - Inflammatory arthritis.
  - Obesity
  - Contralateral THA
  - LLD >2cm.
  - Poor bone stock

- **Advantage**: painless stable hip many years

- **Disadvantage**: immobile joint, LLD, pain in adjacent joint

- **Methods of Arthrodesis:**
  - Medial displacement osteotomy and AO cobra plate
  - Trans-articular DHS: poor fixation owing to large lever arm
  - Anterior plating: abductor mechanism not violated
  - Smith Peterson nail

- **Position:**
  - 25^{o} flexion
  - 0-5^{o} adduction
  - 0-10^{o} external rotation
  - Internal rotation and abduction should be avoided

- **Goal:** to achieve apposition of arthrodesis surfaces
  Obtain rigid internal fixation
  Promote early mobilization

Conversion from Arthrodesis to THR

- **Indications:**
  - Back pain
  - Ipsilateral knee pain
  - Contralateral hip pain
  - Painful pseudoarthrosis
  - Poor position of arthrodesis consider osteotomy first

- **<u>Precautions</u>:**
  - Function & results related to integrity of abductor complex
  - Pre-op investigation of abductors - MRI+EMG studies
  - If abductors non-functional - May need constrained component
  - Sciatic closer/ add psoas tenotomy prior to THA
  - Post-op crutches for 3-6mths for recovery of gluteal and abductor muscle function it takes up to 2yrs to get full benefit of surgery

- **<u>Complications</u>**
  - Deep infection
  - sciatic / femoral nerve injury
  - dislocation

- **<u>Survival</u>**:

95% in 10 years; competence of gluteal musculature is predictive of ambulatory success

- **<u>CORR (2011) retrospective comparative:</u>**
  - Conversion of hip arthrodesis to THA provides improvement of hip function and QoL, good survival, and high level of patient satisfaction comparable primary THA

FEMORAL ACETABULAR IMPINEMENT (FAI)

- Abutment of proximal femur against acetabular rim
- **Labrum:**
  - Horse-shoe shaped structure continuous with transverse acetabular ligament
  - Contribute to hip stability increase contact area and reduce contact stress

Types

- **Cam**
  - Femoral-based disorder at the head-neck junction
  - Abnormal head - neck ratio
  - reduced or absent offset between femoral head and neck
  - Predisposing factors:
    1) Femoral retroversion
    2) Aspherical femoral head
    3) Perthes
    4) AVN
    5) SUFE (previously missed or subclinical SUFE)
    6) Femoral head or neck fracture
- **Pincer**
  - Acetabular-based disorder
  - Antero-superior acetabular rim overhang
  - Predisposing factors:
    1) Protrusio or retroverted acetabulum
    2) Os acetabulum

Complications

- Repetitive microtrauma to acetabular labrum and articular cartilage
- Labral tear
- OA

Investigations

- **Radiographs**

Pistol – grip deformity

Crossover sign indicate retroversion

- **Alpha angle**
  - Between line from centre of femoral head through middle of femoral neck ,and line through point where contour of femoral head-neck junction exceeds radius of femoral head
  - angle >55° considered indicative of cam impingement
- **False profile view:**
  - Taken with patient standing
  - True lateral view of acetabulum, to assess anterior coverage of femoral head
  - Show anterior deficiency, measured by anterior centre edge angle (similar range to LCE angle)
- **3D CT reconstructions**: Visualize extent of cam or pincer lesion; Used to produce motion analysis pictures

Principles of Surgery

- Open or arthroscopic
- Mini Smith-Peterson approach to visualize without dislocation
- Acetabular treatment involves taking down of rectus femoris head
  Non-spherical sections of femoral head & prominent sections of anterior femoral neck & acetabular rim, are resected with arthroscopic burr
- Treat labral lesions

Complications

- Femoral neck fracture: minimized by limiting osteochondroplasty to <30% of femoral neck diameter
- **Ganz (CORR, 2003):** proposed that early surgical intervention for treatment of femoroacetabular impingement, besides providing relief of symptoms, may decelerate progression of degenerative process

HIP DYSPLASIA

- Abnormal development of hip leading to lack / inappropriate coverage/containment of the femoral head with shallow Acetabulum, which is deficient and poor bone quality leading to uneven distribution of forces

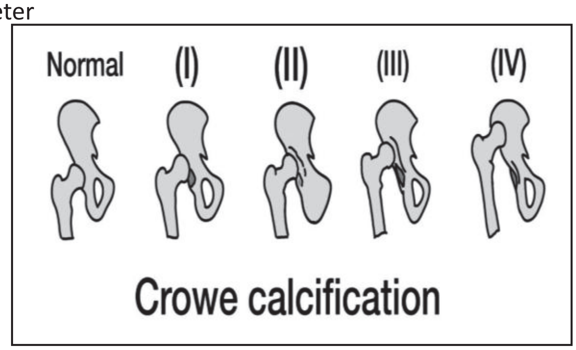
Pathoanatomy

- Femur: Coxa valga and increased anteversion
- Acetabulum Version: Retroversion and shallow

Classification

➢ **Crowe classification**

- From tear drop to junction of femoral head and neck
- Proximal migration measured in relation to femoral head diameter
    - I: Less than 50% subluxation of femoral head
    - II: 50% to 75% subluxation
    - III: 75% to 100% subluxation
    - IV: dislocated



➢ **Hartofilakidis classification**

- **Dysplasia** (Type A) Deficient superior wall, shallow acetabulum femoral head still within true acetabulum
- **Low dislocation** (Type B) False acetabulum still connected to true acetabular cavity
- **High dislocation** (Type C) Femoral head uncoverage superiorly and posteriorly with false acetabular cavity entirely separate from true cavity

Imaging

➢ **X-rays**

1) Cross over sign
2) Lateral centre-edge angle of Wiberg < 20^o
    - Assess supero-lateral coverage
    - Useful after age of 6 years
    - Vertical line through centre of femoral head
    - Line from centre of head to supero-lateral margin of acetabulum
    - Normally 25-40 Degrees
    - Increased in pincer lesions & protrusion and decrease in dysplasia
3) Acetabular angle of Tonnis (sourcil angle) > 10^o
    - Sourcil = eyebrow = weight-bearing dome: Line parallel to sourcil and line parallel to inter-teardrop line
4) Acetabular (Sharp) angle: angle between line drawn from the superior to the inferior rim of the acetabulum and inter-teardrop line

➢ **CT scan**

- To assess available bone stock and morphology
- Position of true acetabulum, AP/vertical dimension, acetabular version, bone defects in acetabulum, femoral neck size, anteversion, valgus

Management

- Acetabular or femoral osteotomy
- Arthroscopy
- Arthrodesis a consideration in young arthritis
- Total Hip Replacement

THR

➢ **Templating**

- Critical in restoring the anatomical hip center, anticipating cup uncoverage, addressing leg length discrepancy, deciding femoral stem size and designs
- GT - small and posteriorly displaced
- Risk of sciatic nerve injury and dislocation is increased 10x

➢ **Acetabulum**

- True acetabulum identification can be aided by intraoperative x -rays and drill holes in the acetabular medial wall
- Acetabular coverage by bulk femoral head autograft and auto-allografts, oblong cup, tantalum augments

➢ **Cup positioning:**

- **Anatomical:**
  - Facilitates lengthening
  - Restoration of hip centre
  - Better hip function, < JRF
  - Best bone stock available for cup placement
  - Risk traction injury to sciatic N due to lengthening
  - Subtrochanteric osteotomy & intra-operative nerve monitoring
- **Non-anatomical:**
  - High hip centre
  - Hip centre proximal to inter-teardrop line
  - Easier - No bone graft, no femoral osteotomy
  - Early loosening and higher rate of dislocation
  - GT impingement requires osteotomy and advancement
  - Small acetabular component
  - Revision difficult as bone stock is not restored

Linde et al (Acta Orthop Scand 1988)
42% loosening at 15 years if cup placed non-anatomically
13% loosening if placed anatomically

Sanchez-Sotelo et al JAAOS (2002)
Uncemented cups augmented with screws give better results in DDH reconstruction

Cotyloplasty fracture medial wall to place acetabular component within available iliac crest

➢ **Femur**

- Narrow femoral canal may make femoral reaming difficult
- Marked anteversion of the femoral neck make component positioning difficult
- Derotation with subtrochanteric osteotomy (STO) may be necessary to place the component in the proper orientation (consider if anteversion >40°).
- Another option would be to use modular femoral stem systems or the use of custom-made femoral stems.
- STO also indicated when > 4cm shortening is required, risk of sciatic nerve palsy increase with >2-5 cm

lengthening (various studies reporting different limits)

SNAPPING HIP

- Caused by motion of muscles and tendons over bony structures around hip joint

- **Types**
    - External
        - Iliotibial tract sliding over greater trochanter
        - Can be seen
    - Internal
        - Iliopsoas tendon sliding over femoral head
        - Prominent iliopectineal ridge
        - Exostoses of lesser trochanter
        - Iliopsoas bursa
        - Can be heard
    - Intra-articular:
        - Loose bodies in hip, synovial Chondromatosis
        - Labral tears – antero-superior labrum most common
- **MRI arthrogram:** imaging study of choice

- **Treatment**
    - Non-operative: activity modification, physical therapy, injection of corticosteroid
    - Operative
        - Excision of greater trochanteric bursa
        - Release iliopsoas tendon
        - Z-plasty of Iliotibial band
        - **Hip arthroscopy**
            - Removal of loose bodies
            - Debride degenerative labrum using shaver or RF device
            - Remove unstable portions of labrum; limited weight-bearing for 4 weeks
            - Repair full-thickness tears at labral-chondral junction
            - Flexion and abduction are limited for 4 to 6 weeks

PROTUSIO ACETABULUM

➢ **Definition**

- Intra-pelvic displacement of the acetabulum and femoral head, so that the femoral head projects medial to the ilioischial line or Kohlers line or the tear drop

➢ **Causes**

- Decreased bone density - Osteoporosis, Osteomalacia, Osteogenesis Imperfecta, Rickets, RA, AS,
- Normal density - OA, idiopathic
- Increased density- Hypophosphatasia, Paget’s

➢ **Aetiology**

- Primary - delayed triradiate cartilage ossification
- Infective - septic arthritis, TB
- Inflammatory - RA, AS
- Metabolic - Paget’s, Osteomalacia, Rickets
- Genetic – Otto pelvis
- Neoplastic - Neurofibromatosis, Multiple myeloma
- Trauma - Acetabular fracture

➢ **Management**

- Triradiate cartilage closure combined with valgus intertrochanteric osteotomy for skeletally immature
- **THA**
    - Template to avoid offset and leg length discrepancies
    - Because of medial migration of the femur, the sciatic nerve is often nearer the joint than normal and should be identified early and protected
    - Hip dislocation can be difficult due to the excessive depth of acetabulum and medial displacement of femoral head. Perform controlled hip dislocation after extensive capsular incision avoiding excessive force as this may result in fracture of posterior wall of the acetabulum or proximal femur. Consider in-situ neck osteotomy. In severe cases a trochanteric osteotomy may be required for adequate exposure
    - Placing the hip centre back into the correct anatomical position is essential to restore proper joint biomechanics and to lower joint reactive force.
    - The medial wall of the acetabulum is typically thin, and does not usually need reaming. The general principle is to bone graft the floor and lateralize the cup.
    - Important to achieve good rim press fit using a cementless shell as thin or deficient medial wall is not relied on
    - Add supplementary acetabular screws for further stability. Consider using lateralized liner, judicious lateralization to avoid trochanteric pain
    - Femoral head bone autograft should be placed on the medial wall, especially if there are significant cavitatory and central segmental bony defects.
    - In severe deformity, a reconstruction cage may be required

- **Intra-operative complications :**
  - Acetabular fracture, neurovascular injury, and visceral injury.
  - Penetration of the medial wall may place intra-pelvic structures such as the bladder, ureter, bowel and external iliac artery at risk.
  - Sometimes the posterior soft tissue envelope of the capsule and external rotators will not reach the posterolateral trochanter for repair.
  - Most common postoperative complications include loosening and medial migration of tacetabular component.
  - Others include dislocation, infection and LLD.

➢ **Baghdadi (CORR 2013) from Mayo Clinic**
- 15 year survival of THR cups in protrusio – 89% for uncemented and 85% for cemented
- Risk of revision increases by 24% for every 1mm distance from anatomical center of hip joint (anatomical restoration of center of rotation for hip joint gives better survival results)

➢ **Bayley et al (J. Arthroplasty 1987)**
- 50% loosening of THR if hip center not corrected to 10mm of anatomical centre
- 8% loosening if within 10mm

OSTEITIS PUBIS

- Inflammation of pubic symphysis caused by repetitive trauma
- Ligaments: superior, inferior & anterior, posterior pubic ligament
- Radiographs: osteolytic pubis with bony erosion and diastases of symphysis
- Self-limiting

ATHLETIC PUBALGIA

- Sports hernia syndrome
- Overuse – adductor strain
- Tear of transversalis fascia, rectus muscle, and/ or Adductor Magnus origin
- Must be differentiated from inguinal hernia

GIRFT – (GETTING IT RIGHT FIRST TIME)

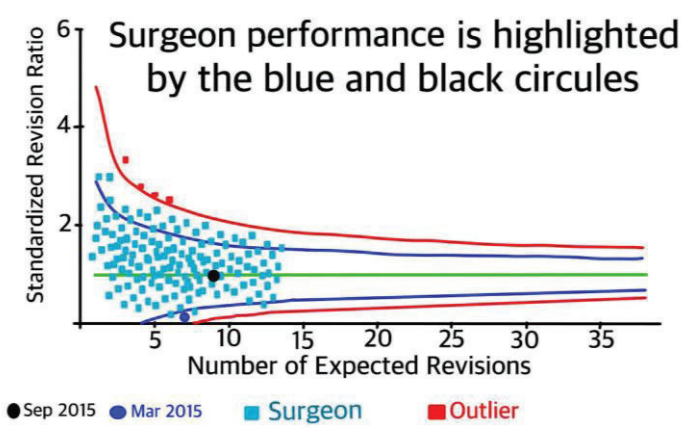
A national review of adult elective Orthopaedic services in England
Study launched in 2012 by Prof Tim Briggs to study clinical variation in practice in orthopaedics

- **GRIFT Observations showed**
  - Massive variation in Infection rates 0.2% to 5%,
  - Variation in number of cases per surgeon in primary,revision THR / TKR, uni, shoulder replacements
  - Large variation in implant with ODEP different ODEP rating being used
  - Failure to follow the evidence of registry data in decision-making
- **Recommendations and outcomes**
  - Cemented hip replacements for patients > 65 - 10% increase in the use of this method
  - ERP (Enhanced Recovery Programme) - Reduced length of stay for THR & TKR
    - Smaller wards and less nurses – reduces costs
    - Reduced risk of DVT
  - Ring-fenced orthopaedic beds, laminar flow theatres, improved theatre discipline - reducing cross infection
  - An increase in localized consolidated working between trusts - sharing resources & maximizing the number of procedures
  - Need to reduce the widespread variation in practice across the country.
  - Appropriate Orthopaedic theatre staffing
  - Minimum critical volumes

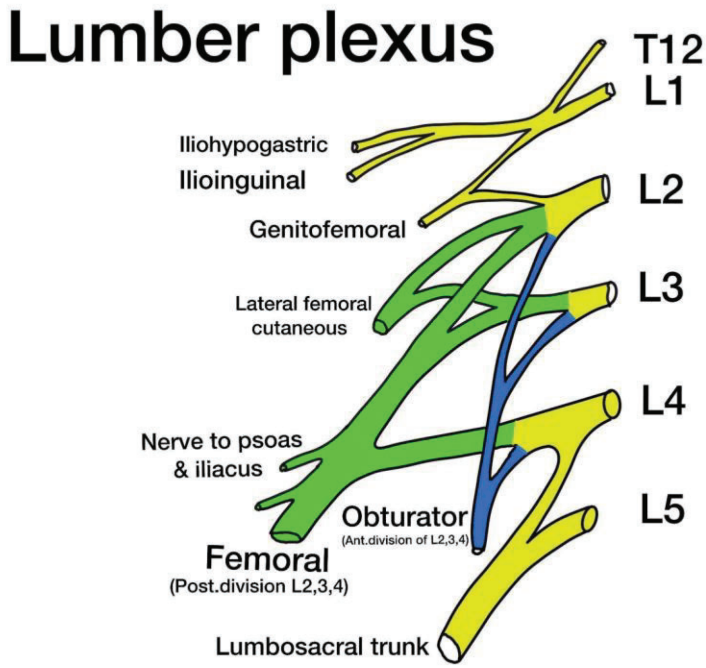
FUNNEL PLOT

- Performance measuring tool used to measure variations in performance between surgeons and/or centres and identify outliers (Above red line)
- They are scatter plots, with superimposed control limits (typically 2 SD, 3 SD or 4 SD)
- Shows 90-day mortality following hip surgery
- Surgeon/hospital highlighted as orange triangle
- The smaller the size of the sample, the wider the control limits (increased variability).
- As the sample increases the certainty increases and the 'funnel' is formed.
- Progression along horizontal axis means that surgeon/hospital done more cases
- Data within the control limits (between the dotted lines) are consistent with common cause variation or natural variation, whereas those outside these limits indicate unexpected good or bad results (outliers)

- For mortality , it means they done higher risk patients
- Can't identify someone doing very few cases (towards left side of graph) as outlier
- Progression along vertical axis means surgeon/hospital have had more of the end point (revision or death) deaths
- Vertical axis figures presented as standardized ratio.
- For mortality - data adjusted to take account of surgeons who operate on more higher-risk or lower-risk patients
- Surgeons on central (green) horizontal line have had exactly average expected mortality
- Surgeons either side of green line but below upper red line have level of mortality that is within expected range
- Surgeons that appear above top red line have mortality rate higher than expected



LUMBOSACRAL PLEXUS



- Sacrospinous lig attaches to ischial spine and separates greater & lesser sciatic notches
- Lumbar plexus: L1 – L5
- Sacral plexus: Lumbosacral trunk, S1 - S3

Femoral Nerve

- L2 – L4, posterior rami
- Exits pelvis beneath medial inguinal ligament to enter femoral triangle; lies lateral to femoral artery & vein
- **Branches**
  - Motor: Iliopsoas, Sartorius, pectineus, all quadriceps
  - Sensory: Medial & intermediate cutaneous nerves of thigh
  - Saphenous nerve:
    - Anteromedial aspect of lower leg
    - Infrapatellar branches to knee
    - Along medial border of tibia, ends with saphenous vein anterior to medial malleolus

Genito-femoral Nerve

- L1 & L2

Meralgia paraesthetica

- Lateral cutaneous nerve of thigh entrapment
- From L2 – L3
- Goes underneath inguinal ligament
- Sensory to anterolateral thigh
- Exacerbated by: tight belts, prolonged hip flexion
- Treatment: Release of compressive objects, NSAIDS
- Risk while harvesting bone graft and anterior approach to hip

Obturator nerve

- From lumbar plexus L2, L3, L4 – anterior rami
- Exits obturator foramen and divides into anterior and posterior branches
- At risk during medial (Ludloff) approach to hip
- Anterior branch innervates adductor brevis, adductor longus, and gracilis - Test adduction
- Posterior branch innervates obturator externus and part of Adductor Magnus
- Sensation to medial aspect of thigh and to hip and knee joints - hip pain radiate to knee
- Can cause chronic medial thigh pain from compression by well-developed adductors

Posterior cutaneous Nerve of thigh

- S1, S2, S3

Superior gluteal Nerve

- L4-S1
- Supplies gluteus medius, minimus, tensor fascia lata

Inferior gluteal Nerve

- L5-S2
- Supplies Gluteus Maximus

Nerves supplying short external rotators

- Nerve to piriformis (S1-2)
- Nerve to obturator internus (L5, S1-2) – supplies superior gemellus too
- Nerve to Quadratus femoris (L4-5, S1) – supplies inferior gemellus too

Sciatic N

- L4 – S3
- Course: exit pelvis through greater sciatic notch
- Pass under piriformis
- Lies on Adductor Magnus in thigh
- **Piriformis syndrome**
  - Extra-pelvic sciatic nerve compression at hip
  - Decreased internal rotation in FAI may contribute to contractures of short external rotators
- **Branches**
  - **Tibial Nerve**
    - Splits from sciatic nerve in distal thigh
    - Passes through popliteal fossa
    - Continues distally on under-surface of soleus
    - Passes into foot posterior to medial malleolus
    - Branches:
      - **Motor:**
        - ✓ Semitendinosus, semimembranosus, Gastroc-soleus, popliteus
        - ✓ Tibialis posterior, FDL/FDB, FHL/FHB, abductor hallucis
        - ✓ Foot intrinsic, quadratus plantae, flexor/abductor digiti minimi
        - ✓ Biceps femoris:
          - long head by tibial N
          - Short head by peroneal N
      - **Sensory:**
        - ✓ Sural N formed by cutaneous branches of tibial and common peroneal N
        - ✓ Continues distal on lateral aspect of TA
        - ✓ Terminates as lateral dorsal cutaneous N of foot in the 4th web space
        - ✓ Final branches in foot: medial and lateral plantar nerves and medial calcaneal nerve
  - **Common peroneal Nerve**
    - Medial border of biceps femoris
    - Can be compressed behind fibula by ganglion cyst or injured by direct blow
    - Branches
      - **Superficial**
        - ✓ Sensory:
          - Dorsum of foot
          - Terminates as medial and intermediate dorsal cutaneous N
        - ✓ Motor:
          - Lateral compartment (Peroneus longus & brevis)
          - Pierces fascia 5 cm distal to fibula head
      - **Deep**
        - ✓ Motor:
          - Anterior compartment (Tib Ant, EDL, EHL, per tertius)
          - EDB
        - ✓ Sensory
          - Ankle joint & 1st dorsal web space
          - Passes through anterior tarsal tunnel between EDL & EHL

KNEE EXAMINATION

History

- Age, occupation
- Pain
  - Site, duration, onset/ trauma, progression, continuous/ intermittent, Radiation, sharp/ dull ache/ throbbing, diurnal variation, rest/ night pain, Aggravating factors- standing, walking, stairs, sitting and getting up/ relieving factors- sitting down, lying down,
- Knee problems when young, what is done so far
- Clicking at age of 10 years: discoid meniscus
- Pain represents tear
- Pain & mechanical symptoms in OCD
- Instability: do you trust your knee?
- Walking distance
- Stiffness/ giving away
- Other joints pain
- ADL activities, limitations
- Social history - smoking/ drinking/ sports or hobbies, house conditions, stairs and social support
- Medical history, medication history, allergic history, surgical history / blood thinners
- Family History
- Expectations

Examination

- Standing, walking, sitting and lie down
- Special tests directed at suspected pathology
- **Standing**
  - Look: take shoes and socks off
  - Orthotics: shoes; ask patient if they use any orthotics / look for any walking aids
  - Bend down to knee level
  - **Front**
    - Attitude (pelvis, hip, knee, foot), weight bearing status (weight bearing equally on both LL or not),
    - Feet together: Genu valgum/varum, Patella position, Q angle
    - Muscle wasting (Quads, Abductors), general skin condition around knee and rest of lower limb,
    - Swelling around the knee - infra/ supra-patellar, scars, arthroscopy
  - **Side**
    - Flexion attitude knee, foot in plantigrade/equinus
    - Patella position
    - Hyperextended knee (recurvatum) in PCL and PLC injuries
  - **Behind**
    - Attitude: (iliac crest, spine, shoulder level), popliteal fossa fullness, surgical scars,
    - Hind foot varus/valgus

- **Gait**
  - Antalgic/ stiff knee/ varus- valgus- hyperextension thrust on stance
  - Varus/valgus thrust: knee collapses into varus/valgus as opposite foot lifted off ground
    - Most common cause is OA with erosion medial/lateral joint space
    - Other causes include tibial plateau fracture
    - Varus thrust in PLC and LCL injuries
- **Sit**
  - Patella tracking - J sign
  - Lateral deviation of patella towards end of extension and pops back into groove in early flexion
  - Test in instability and anterior knee pain


(Courtesy of M Elgendi)

- **Supine**
  - **Look:** posterior sag (loss of step-off) at 90^0 flexion suggestive of PCL injury
  - **Feel:** Look at patient face
    - Tibial plateau normally 10 mm anterior to MFC
    - Tenderness: joint line at 90^0; P/F tenderness, patella under-surface tenderness; popliteal fossa
    - Quadriceps and patella tendons
    - Retinaculum
    - Insertions of collateral ligaments
    - Pes anserinus; tibia tubercle
  - Patella effusion:
    - **Swipe test** for mild effusion: Sweep lateral side from distal to proximal look for bulge
    - **Patella tap** for moderate effusion: Push fluid (milking) supra-patellar pouch
    - **Ballottement test** for severe effusion: pressure on one side is transmitted via the fluid to the hand on the other side of the knee
      - Differentiation of effusion from synovial thickening (Diffused swelling in PVNS)
  - **Move:** ROM -10 to 130^0, heel to buttock distance
    - At full extension - no rotation, no abduction/adduction
    - At 90 deg flexion - 40^0 rotation, few degrees of abduction/adduction
    - Active/passive ROM
    - Check if valgus/varus deformity is correctable
    - SLR for extensor mechanism
    - Extensor lag is reduced active extension but normal passive
    - Test against resistance
  - Measure muscle wasting - 15 cm above patella

Tests

- **<u>Collaterals</u>:**
  - 20-30^0 flexion to relax posterior capsule and cruciate ligaments and isolate
  - MCL/LCL
  - Laxity at 0° indicates associated MCL/LCL and cruciate injury
  - Varus/valgus stress
  - Describe as
    - Normal / abnormal
    - Firm / soft endpoint
    - Correctable / uncorrectable
    - Positivity not referenced to pain but to degree of joint opening
    - Significant pain is suggestive of partial rupture
- **<u>Lachmann test</u>**
  - Knee in 20-30^0 flexion to relax hamstrings and posterior capsule
  - Most sensitive for ACL
  - Increased translation compared to other side in ACL and also in PCL injury
  - Fix femur
  - Right hand on tibia
  - Tibia rotated laterally and anterior tibial translation force applied from posteromedial aspect
  - End point may be hard (firm), soft or absent
  - PCL tear may give false Lachmann due to posterior subluxation
- **<u>Anterior drawer test</u>**
  - Can you relax your knee for me please; check for relaxed hamstrings;
  - Demonstrate checking relaxed hamstrings
- **<u>Pivot shift test</u>**
  - Most specific for ACL
  - Tibia is internally rotated whilst applying valgus force and slowly flexing knee Palpable clunk or shift at 20°-30° of flexion indicates injury of ACL
  - ITB reduces tibia at 20-30° of flexion as its pull moves posterior to axis of flexion
  - MCL bears axis of rotation; therefore, should be kept tight
  - Knee can't be pivoted if there is complete disruption of ITB or MCL
  - Also need to be able to fully extend knee
- **<u>Posterior drawer test</u>**
  - At 90^0
  - Most accurate manoeuvre for PCL injury
  - Bring knee from sagged position into neutral
  - Check PCL before commenting on ACL laxity
- **<u>Quadriceps active test</u>**
  - Attempt to extend knee flexed at 90° to elicit quadriceps contraction
  - Positive if anterior reduction of tibia occurs relative to femur suggests PCL tear
- **<u>Reverse pivot shift</u>**
  - For PLC injury
  - Knee brought from flexion to extension
  - At 20 – 30^0: produce clunk from moving anteriorly from posteriorly subluxed position.

- **<u>Hughston External rotation recurvatum test</u>**
  - Grasp big toe with each hand and lift legs off bed
  - Knees go into varus and hyperextend in PLC injuries
- **<u>Dial test</u>**
  - Prone; keep knees together
  - > 10^0 difference in external rotation is abnormal
  - Abnormal
    - at 30^0 flexion; Isolated PLC injury
    - at 30 & 90^0; PLC & PCL injury
    - at 90^0; isolated PCL
  - Remember to do it or mention it with any ligaments knee examination

- **<u>McMurray</u>**
  - History of sudden increase in knee pain (in absence of radiological changes)
  - Reproduce mechanism of injury
  - Extend knee in internal/external rotation
  - External rotation for Medial meniscus
  - Palpable click is positive sign
- **<u>Apley's grind test</u>**
  - For meniscal tear
  - Prone knee flexed to 90^0; downward and rotation force
- **<u>Clark test</u>**
  - Don't perform as very painful
- **<u>Patella glide test</u>**
  - Measures passive patella mobility
  - Measured in quadrants of translation (midline of patella is considered 0) knee flexed to 30° and patella translated medially & laterally
  - Normal movement is 1cm (<2 quadrants) compared with contralateral side
- **<u>Patella Apprehension test</u>**
  - Patient lies supine with both knees fully extended
  - Push patella laterally using thumb on medial border
  - Positive if patient reacts with apprehension or contract quads
- **<u>Wilson test</u>**
  - Pain on extension of knee between 30-90^0 with internal rotation
  - Relieved with external rotation
  - Due to impingement of tibial eminence in OCD
- Examine hip, ankle, foot and opposite knee and do neurovascular examination

OSTEONECROSIS OF KNEE

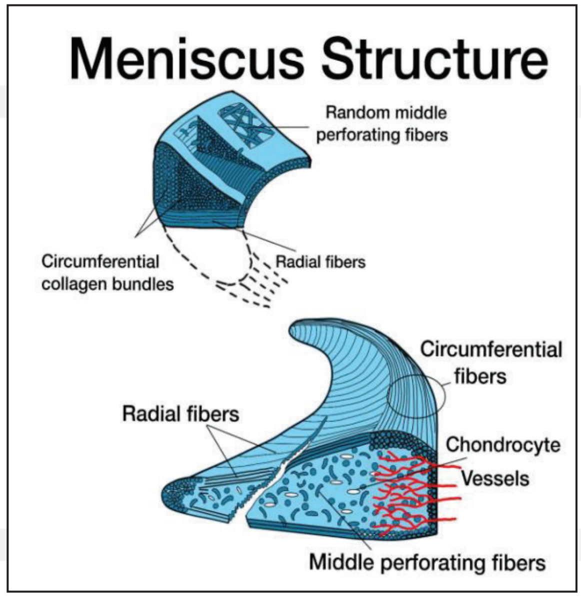
- **Primary**
  - Involves Medial femoral condyle
  - Classically, only one joint is involved
  - Common in postmenopausal females
  - Acute onset of pain in postmenopausal women
  - Believed to be caused by Root Tear or may represent Insufficiency Fracture
  - Self-limiting
  - May cause subchondral collapse
  - MRI - lesion crescent shaped & Marrow oedema seen in T2 sequence
  - Treatment:
    - Mainstay is conservative including Rest, Activity Modification and Analgesia
    - Drilling to decompress
    - Open-wedge osteotomy to offload and in presence of mal-alignment
    - UKR
    - TKR (Large lesions)

- **Secondary**
  - Risk factors same as hip AVN
  - Typically involves more than one compartment or even metaphysis
  - Seen in females <55 years with the risk factors
  - Most of them are bilateral (around 80%)
  - DD: OCD lateral aspect of medial femoral condyle in young population
    Transient osteoporosis
  - Treatment:
    - limited weight bearing
    - Core decompression
    - Osteochondral allograft
    - TKR: higher incidence of loosening - Use cemented implants and consider stemmed implant

MENISCUS & MENISCAL INJURY

Anatomy

- Crescent shaped fibro-cartilaginous discs
- Wedge shaped in cross section with tapered inner border – generate hoop stresses
- Medial meniscus covers over half of tibial surface while lateral meniscus is almost circular and covers larger area of tibial articular surface
- It exhibits biphasic property. On loading, water is driven out of the tissue while on release of pressure; Glycosaminoglycan molecules in meniscus attract the water molecules due to its negative charges
- Frontal section of medial compartment of knee
- Branching radial vessels from peri-meniscal capillary plexus (PCP can be seen penetrating peripheral border of medial meniscus)
- At 10 years - peripheral 2/3 vascular
- By adulthood - peripheral 1/3 vascular



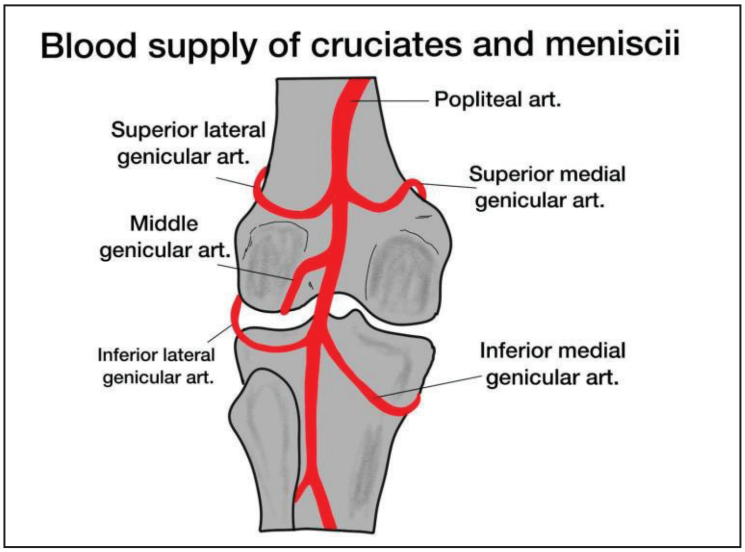
Macro-Structure

- 3 layers
  - Surface
  - Superficial
    - Radial fibers
    - Support the circumferential fibres
  - Deep
    - Fibres run circumferentially parallel to the C shape of meniscus
    - Resist hoop stresses
    - Because of this shape, the vertical mattress sutures are stronger than the horizontal mattress

Micro - Structure

- Extracellular–
  - Type I collagen - 20%
    - Layers of differently orientated fibers to resist stresses
    - Circumferential fibers for compressive load by dissipating hoop stresses
    - Force of femur on menisci act to provide hoop stress of perpendicular force along meniscus
    - Radial fibers to connect circumferential fibers to resist shear stress
  - Elastin: 10%, more elastic than articular cartilage
  - PG
  - Water - 65%
- Cellular
  - Chondrocytes
  - Fibroblasts - Responsible for healing
- **Blood supply**
  - Peri-meniscal capillary plexus supplied by medial and lateral inferior genicular artery in outer 25 % and by synovial fluid diffusion in inner 75%

- Posterior horns are supplied by middle genicular artery



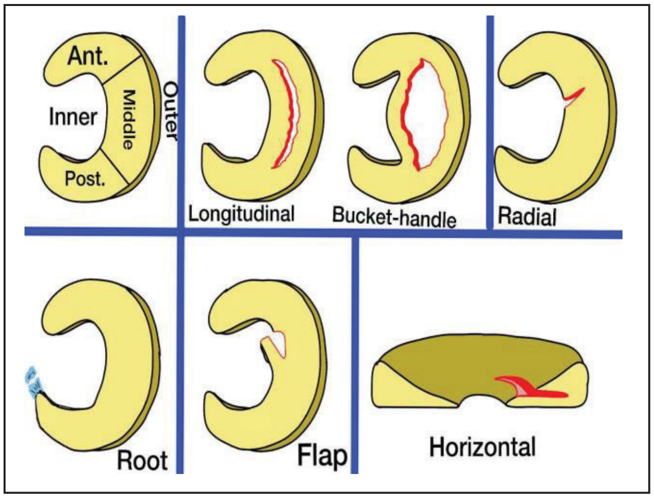
- **MM**
  - Semicircular
  - Attached to deep MCL and to coronary ligament – vulnerable to tears (3 x more commonly torn than LM)
  - Limited mobility
  - Covers 1/2 of articular tibial surface
  - Absorb 50 % of medial load
- **LM**
  - Nearly circular
  - Covers 2/3 of articular tibial surface
  - Absorb 70% of lateral load
  - More mobile + convex lateral plateau = LM move posteriorly with LFC in deep flexion
  - (LM posterior excursion is twice that of medial meniscus during flexion)

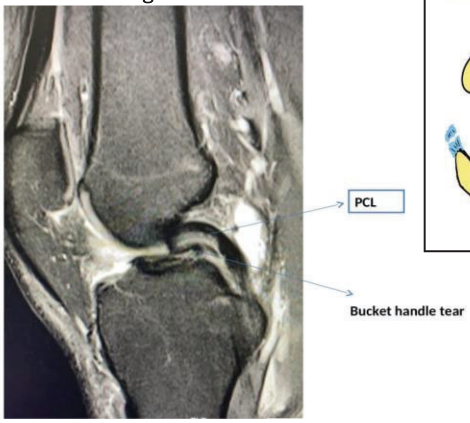
Function of Menisci

- Secondary stabilizers - posterior horn of medial meniscus is AP stabilizer
- Also, menisco-femoral ligaments
- Distribute weight – decrease contact stress
- Shock absorption, exhibit creep
- Joint lubrication
- Proprioception
- Menisco-femoral ligaments connect posterior horn of lateral meniscus to medial femoral condyle
  - Humphrey - anterior to PCL
  - Wrisberg – posterior to PCL
  - Provide secondary stabilization for posterior translation.
- Inter-meniscal ligament: connects anterior horns of medial and lateral menisci
- Coronary ligaments attach to periphery of tibia more on MM,
- Lateral meniscus has more mobility

Types of Meniscal Tears

- Longitudinal/vertical - called bucket handle when displaced into notch
- Oblique parrot peak - radial tear that extends longitudinally
- Radial
- Horizontal: common in older population
- Complex
- Root - extrudes beyond margin of tibial plateau
  - Common in ACL tear and SONK
  - Repair to bone (trans-tibial)
  - The meniscal root plays important role in optimum biomechanics of meniscus.
  - A knee with root tear, exhibits kinematics similar to knee post total meniscectomy.
  - This is because the root tear disrupts the circumferential fibers of meniscus.
- **Locked knee:**
  - Inability to fully extend
  - Caused by displaced bucket handle tear
  - Urgent treatment to prevent FFD
- **MRI** - Findings suggestive of bucket handle tears
  - Double PCL sign
  - Double anterior horn sign





"Absence of bowtie sign" seen when less than two sagittal slices demonstrate normal body of meniscus
    - It represents loss of normal appearance of menisci on Parasagittal images
    - Normally menisci are seen as bow tie shaped structures between femoral condyles and tibia plateau
  - Ghost meniscus sign in radial tears
- LM injury is more common in acute ACL rupture do to mechanism of injury (valgus force)
- MM injury is more common in chronic ACL rupture due to instability causing pressure on more fixed MM

Management

- **Meniscus debridement** to a stable rim
  - Horizontal tear - resect inferior leaf and trim superior leaf
  - **Review article BJJ 2006** - linear correlation between increase in peak stress on joint surfaces of tibia and amount of meniscal tissue removed
  - Function of knee inversely related to amount of tissue resected
  - Also indicated for tears with history of 2 previous failed attempts for repair

- **Total meniscectomy**
  - Decrease contact area by 75%
  - ↑ Contact stress MM- 100% , LM- 200-300%
  - 20% have significant arthritis 3 years after surgery
  - 100% have arthrosis at 20 years
  - **Fairbank JBJS Br 1948, Tapper JBJS Am 1969, Johnson JBJS (Am) 1974** – meniscectomy causes accelerated articular damage
- **Meniscal repair**
  - Healing capacity better in red-red zone and vertical Vs radial and with early repair
  - In young patient treat as intra-articular fracture.
  - **Criteria:**
    - red-red or red-white
    - < 50 yrs of age
    - Reducible
    - Single plane tear
    - Root tear
    - ACL intact
    - Compliant with rehab
  - **Techniques of Meniscal Repair:**
    - **All inside**: bio-absorbable anchors
    - **Inside-out**: gold standard
    - Tied down to capsule through small incision
    - Use posteromedial and posterolateral approach
    - Technically difficult
    - Risk to saphenous nerve and vein dissection should remain posterior to MCL
    - Risk to Peroneal nerve on Lateral side
  - **Outside-in**:
    - Mainly indicated for Anterior Horn Tear
    - Open, freshen up edges
    - Vertical mattress sutures have better strength as they capture circumferential fibers
  - ACL & meniscus tear: better healing of meniscus if ACL reconstructed at time of meniscus repair (Girolamo et al, **Knee Surgery Sports Traumatology Arthroscopy 2015** – 93% healing of meniscal tear repairs with ACL recon, 50% healing in isolated meniscal tear repairs)
  - Drilling bone releases stem cells and ACL reconstruction protects meniscus repair
  - Mobilize in brace limited to 60^0
- **Meniscus replacement**
  - Synthetic:
    - Collagen scaffold derived from animal sources
    - Require anterior and posterior horns and peripheral rim
  - Allograft: For young patients with near total meniscectomy, especially lateral
  - Contraindications:
    - Inflammatory arthritis
    - Outerbridge grade IV
    - Previous joint infection

    - Skeletal immaturity
    - Marked obesity
  - No long term results
  - NICE -no difference in outcome between replacement & partial meniscectomy

DISCOID MENISCUS

- Incidence: 5-20%
- Failure of resorption of central portion of meniscus
- Usually lateral meniscus
- **Watanabe classification**
  - Type I: complete
  - Type II: incomplete
  - Type III: lack posterior coronary (menisco-tibial) ligament but present posterior menisco femoral ligament of Wrisberg (Wrisberg variant)
- Usually they are asymptomatic. Type 3 can present in younger children with a peculiar history of snapping knee, which can cause apprehension and pain.
- **O/E:**
  - Clunk may be felt at 110^0 while flexing or at 10^0 while extending
  - Mcmurray test will produce pronounced clunk due to translation of posterior horn of menisci
- **Radiographs**
  - Widened lateral joint space
  - Flattening of lateral femoral condyle
- **MRI**:
  - Seen on 3 or more 5mm standard sagittal images - too many bow tie signs
  - Thicker than 15 mm on coronal view
- **Treatment**
  - Asymptomatic: observe
  - Symptomatic:
    - Partial meniscectomy (saucerisation): obtain anatomic looking meniscus
    - Capsular stitch for type III

PATELLO FEMORAL JOINT

- 7x body weight with squatting
- 2-3x body weight when descending stairs
- Importance of PFJ lies in its unique and characteristics features. It has the thickest articular cartilage in body. Lateral facet of Patella is concave which articulates with Lateral facet of trochlea which is higher and longer as compared to medial side. Medial facet of patella is convex.
- **PFJ replacement:**
  - Indicated mainly in isolated PFJ Arthritis
  - Contraindications
    - Patella mal-tracking: treat with realignment procedure prior to replacement
    - Inflammatory arthritis
  - Functional outcome equal to TKR

PCL DEFICIENCY

- **Anatomy**
  - Length: 4 cm
  - Diameter: 1.5 cm
  - Strength: 2500 – 3000 N
  - Both ACL & PCL are supplied by middle geniculate artery
  - Origin: Medial femoral condyle
  - Insertion: Tibial sulcus
  - Function:
    - Primary function: Resists posterior tibial translation on femur
    - Secondary function: Restraint to external rotation and varus/valgus and hyper extension
  - Chronic deficiency can result in PFJ OA

- **Treatment:**
  - Acute
    - Brace in extension for 4-6 weeks
    - Quadriceps rehabilitation with focus on knee extensor strengthening
    - Reconstruction for combined ligamentous injuries
    - Reconstruction options include tibial inlay vs. trans-tibial methods,
    - single-bundle vs. double-bundle
    - For Bony avulsion, repair by posteromedial approach
    - Primary repair of mid-substance ruptures not successful
  - Chronic
    - Reconstruction for isolated PCL injuries with functionally unstable knee
    - Autologous patella tendon graft Or Achilles tendon allograft

- **Complications:** Popliteal artery injury

ACL DEFICIENCY

Anatomy

- Length: 3 cm
- Diameter: 1 cm
- 2 Bundles
  - **AM**
    - Tight in flexion, more isometric
    - Anterior-posterior stability (Lachmann)
  - **PL**
    - Tight in extension, more horizontal, rotational stability
    - Damage responsible for pivot shift phenomenon
- Anterolateral ligament (ALL): bear load in setting of ACL tear
- 90% type I collagen
- Origin: Lateral femoral condyle
- Insertion: anterior and between intercondylar eminences
- Strength: 2200 N
- Innervation: tibial nerve and mechanoreceptors
- Blood supply: middle geniculate artery
- **Females: males – (4: 1) because of (Sutton et al, JBJS Am 2013):**
  - Neuromuscular imbalances is most significant factor
  - Quadriceps dominant
  - Land in more extension with higher valgus moment
  - Smaller notch and ligaments

Imaging

- **Radiographs**
  - French surgeon Paul Segond, 1879
  - Cortical avulsion of tibial insertion of lateral capsule
  - Or ALL from LFC to lateral tibial plateau (between Gerdy tubercle & LCL)
  - Structure within capsule
- **MRI Findings:**
  - **Sagittal view**
    - ACL fibers discontinuity
    - Bone bruising in middle of LFC and posterior 1/3 of lateral tibial plateau
  - **Coronal view**
    - Fluid against the lateral wall ("empty notch sign")

Management

- **Frank Noyes/McDaniel rule of thirds (JBJS Am 1983)**:
  - 1/3rd would compensate well with conservative treatment
  - 1/3rd avoid symptoms of instability through modification of activities
  - 1/3rd do poorly and require reconstructive surgery.

- Initial Management
  - Bracing and physio
  - Closed chain exercises: foot in contact with ground

- **Frobell et al. NEJM (2010)** from Denmark – RCT of treatment of ACL tears: No early difference in outcome with surgery or non-op rehabilitation, but there is increased risk of MM tears and chondral damage with non-op management, which also gives lower activity scores.
- **Associated injuries**: Instability can cause chondral damage and meniscal injury
  - **MCL injury**:
    - Allow MCL to heal and then perform ACL reconstruction
    - Varus/valgus instability can jeopardize graft
  - **Meniscal tear:**
    - Delayed repair of locked knee due to coexisting bucket handle tear would lead to FFD (repair acutely)
    - Avoid ACL recon in knees with loss of full extension because they don't regain full extension
  - **Posterolateral Corner injury**
    - Reconstruct as same time as ACL or as first stage of two-stage
    - Reconstruction

Complications

- Cyclops Lesion: Fibro-proliferative tissue which blocks extension
- Kneeling difficulty
- Ongoing instability can be due to improper femoral tunnel placement
- Graft failure is common usually in 2 years due to impingement or enlargement of tunnel
- Adverse soft tissue reaction (synovitis) appear late (5 years)
- Arthrofibrosis - when surgery done in acute phase
- OA: antero-medial (if ACL is intact) & Posteromedial (if ACL deficient)

Grafts

- BTB - High strength (Load to failure 2600 N)
  - Consistency of size
  - Bone to bone healing in 6 weeks
  - Can lead to Pain when kneeling
  - Increased chance of Patella fracture, Patella tendon rupture, Patella baja
- Hamstring - 4 strands
  - Similar functional outcome to BTB
  - Less donor site morbidity
  - Slow tendon to bone healing of 8-12 weeks
  - risk of saphenous nerve injury
  - Load to failure 4000 N
- Quadriceps - Used for revision
  - Thick but short tendon

- Allograft - non-irradiated Achilles or tibialis ant or patellar tendon
  - lack of donor site morbidity
  - easier surgical techniques
  - High re-rupture due to the sterilization process (gamma radiation)
  - inflammatory synovitis
  - cost
  - osteolysis
  - Better results with LK and LARS ligaments but no long-term results
  - LARS (Corin) – Ligament Augmentation and Reconstruction System
  - Gore-Tex (PTFE)
- **Cochrane (2012):**
  - Insufficient evidence to determine relative effectiveness of double-bundle and single-bundle reconstruction for ACL rupture
  - Limited evidence that double-bundle ACL reconstruction has superior results in objective measurements of knee stability & protection against re-rupture or new meniscal injury
- **Pes Anserinus**:
  - French for goose foot
  - Components
    - Semimembranosus
    - Semitendinosus
    - Biceps femoris
  - Common characteristics
    - Originate on ischial tuberosity
    - Innervated by sciatic (tibial) nerve
    - Blood supply from inferior gluteal and profunda femoris

Technique

ACL Reconstruction technique using hamstring

- Say Grace before Tea
  - Sartorius – Gracilis – Semitendinosus (anterior-to-posterior)
- Gracilis is rounder
  - It flexes knee, adducts thigh, and medially rotate tibia on femur
  - Originates from pubis
- Semitendinosus is flat, larger, broader insertion
  - It is difficult to palpate
  - Originates from ischial tuberosity and inserts on pes anserinus.
  - Extends thigh and flexes knee, and rotates tibia medially.
- 3-4cm vertical incision 3 fingers breadths below medial joint line
- Dissection to Sartorius fascia
- incise fascia just above Gracilis
- Use blunt instrument to isolate tendons from MCL
- Isolate gracilis &semitendinosus and harvest with tendon stripper
- Keep knee flexed when harvesting to protect saphenous nerve (muscular tissues are always inferior)
- Cut grafts and prepare with no. 2 Ethibond whip-stitch in each end

- Need a minimum of 20 cm length(10 cm when folded)
- Place graft in saline moist swab to avoid dissecation
- Tight high anteromedial portal and tight low anteromedial portal
- Debride ACL stump & Notchplasty with shaver or RF ablator
- **Femoral tunnel placement:**
  - Isometric point
  - At ACL footprint
  - Sagittal plane 1-2 mm rim between tunnel and posterior cortex of femur
  - As posterior as possible with enough bone to avoid graft blowout
  - Coronal plane - 9-10 o'clock for right and 2-3 o'clock position for left knee, to create more horizontal graft
  - knee is high flexed to 120 degrees and a guide pin is placed through the medial portal
  - Place guide wire
  - Drill button tunnel with the button drill
  - Measure femoral tunnel length
  - Drill femoral tunnel leaving 5-10 mm for the button to flip
  - Place a line on graft 6mm distal to femoral tunnel length to indicate point at which graft is seated deep enough to flip endobutton
- **Tibial tunnel placement:**
  - Coronal plane - just lateral to medial tibial spine
  - Sagittal plane - 10 mm anterior to PCL in posterior half of ACL footprint
  - Along posterior edge of anterior horn of lateral meniscus
  - Too anterior - notch impingement
  - Too posterior - PCL impingement
  - the tibial tunnel can be drilled through the initial graft harvest incision
  - Tibial drill guide is placed through anteromedial portal while the scope is viewing from the anterolateral portal
  - Tunnel angled @45 deg
  - Drill to dilate to size
  - Intrafix tibial fastener
  - Cycle the knee to achieve proper tension

Paediatric ACL

1) Physis-sparing or trans-epiphyseal
2) Transphyseal: Rarely lead to growth disturbance

- **Factors found to increase physeal injury**
  - oblique tunnel position
  - Interference screw fixation
  - High-speed tunnel reaming
  - Increasing tunnel diameter >8mm
- Extra-articular: Macintosh technique using ITB tenodesis
- **Achtnich et al. (German study), Arthroscopy 2016**– Level III case-control study
- **Systematic review Taylor (New York), Arthroscopy 2015**
  - These studies have reported that ACL refixation shows good outcomes in young patients with femoral detachment of ACL

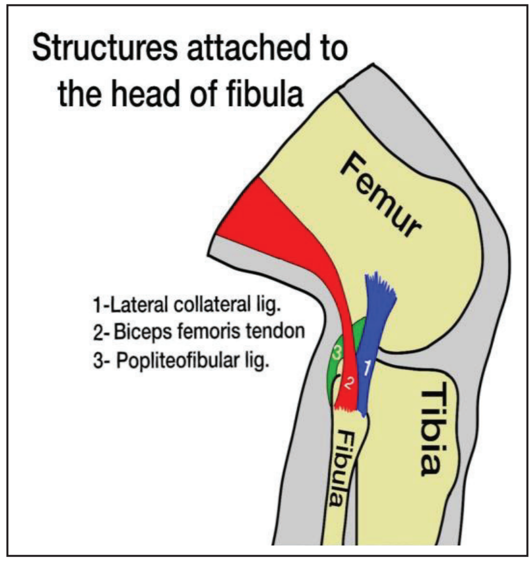
All-Epiphyseal, All-Inside ACL Reconstruction Technique for Skeletally Immature Patients

ACL rehabilitation

- No brace
- Early post-op full weight bearing
- Avoid open chain quadriceps (knee extension) exercises
- Cycling at 6 weeks
- Running at 3 months
- Twisting at 6 months
- Contact sports at 9 months

LATERAL COLLATERAL LIGAMENT LCL

- Also known as fibular collateral ligament
- Origin - lateral femoral epicondyle posterior and superior to insertion of popliteus
- Most anterior structure on proximal fibula, order of insertion from anterior to posterior
- LCL → popliteofibular ligament → biceps femoris
- Tight in extension and lax in flexion
- As compared to MCL, it is separated from Lateral Meniscus and Capsule
- **Lateral structures of knee**
  - **Layer I:**
    - Iliotibial tract and biceps femoris
    - Common peroneal nerve runs between layer 1 and 2
  - **Layer II:** Patellar retinaculum
  - **Layer III**:
    - Superficial: LCL, ALL, fabellofibular ligament
    - Deep: Arcuate & coronary & popliteofibular lig, popliteus tendon, capsule
- **Function:**
  - primary restraint to varus stress
  - Secondary restraint to posterolateral rotation
- **Treatment**:
  - Repair posterolateral approach
  - Suture anchors for avulsed ligament



MEDIAL COLLATERAL LIGAMENT MCL

- Most commonly injured ligament of knee
- **Medial Structures of knee**
  - **Layer I:**
    - Sartorius and retinaculum
    - Gracilis, semitendinosus, and saphenous nerve run between layer 1 and 2
  - **Layer II:** Semimembranosus, MPFL, superficial MCL
  - **Layer III**: Deep MCL, capsule, coronary ligament

MCL components

- **Superficial**
  - Originates from medial femoral epicondyle
  - Inserts into periosteum of tibia 5 cm distal to joint line beneath pes anserinus
  - Primary stabilizer
  - Posterior oblique ligament (POL) constitutes the posterior portion of superficial MCL
- **Deep**
  - Separated from superficial portion by bursa
  - Attaches to medial meniscus
  - Secondary stabilizer

- Blood supply - superior and inferior medial geniculate arteries
- Strength - 4000 N
- X rays: Pellegrini-Stieda lesion - chronic calcification from avulsion of MCL from femoral condyle

➢ Rupture usually occurs at femoral insertion of ligament

➢ Proximal MCL tears have greater healing rates while distal MCL tears have inferior healing and residual valgus laxity

Classification of MCL sprains

➢ **Grade I**
- No loss of ligamentous integrity
- Brace

➢ **Grade II**
- Increased joint laxity
- End point found at 30^0 of flexion with valgus stress, 5 – 9 mm of opening
- Brace

➢ **Grade III**
- Complete disruption of ligament
- Gross laxity, no end point

Management

➢ Majority are treated conservatively. May require prolonged rehab and return to play can be up to 3 months for high grade injuries.

(Courtesy of S Mansukhani)

➢ **Acute repair:**
- In grade III injuries, in setting of multi-ligament knee injury
- Displaced distal avulsions with "Stener-type" lesion (curling up of ligament or flipped into joint on MRI)
- Continued instability following non-operative treatment
- Ligament avulsion attach with suture anchors in 30^0 of flexion

➢ **Reconstruction:**
- Chronic injury with loss of adequate tissue for repair
- Graft type: semitendinosus autograft or hamstring, tibialis anterior or Achilles tendon allograft

OSTEOCHONDRAL LESION

Juvenile

- Also called Osteochondritis Dissecans (OCD)
- Subchondral delamination due to microtrauma or AVN
- Better prognosis
- Open distal femoral physis is the best predictor of successful non-operative management
- Location:
  - Posterolateral aspect of lateral femoral condyle (Poorer prognosis)
  - Posterolateral aspect of medial femoral condyle (Most common)
- **Pathophysiological sequence**
  - Initial soft Articular Cartilage
  - Separation of zone of Articular Cartilage
  - Partial detachment of lesion
  - Formation of Loose Bodies due to complete separation

Classification (Clanton & DeLee)

- I: Depressed lesion
- II: Partial Detachment
- III: Detached non-displaced
- IV: Displaced fragment

- Tunnel (notch) view: knee bent between 30 and 50^0
- **MRI:**

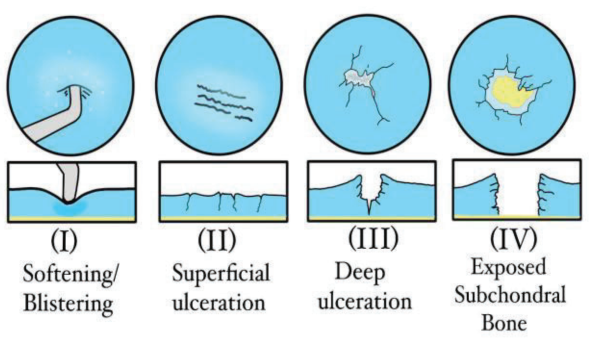
Synovial fluid behind lesion indicate fragment unstable and unlikely to heal, worse prognosis

Management

- **Stable:**
  - Undisplaced with intact overlying articular cartilage
  - Restricted weight bearing and bracing
  - Subchondral drilling with k wire or drill
  - < 12 years have good prognosis
- **Unstable/detached:**
  - Fixation needs adequate bony fragment or > 2 cm
  - Herbert or cannulated screw
  - Chondral dart
  - Expanding - subchondral drilling

Adult Form

- **Outerbridge** arthroscopic grading s of articular defects
  - 0: Normal
  - I: Softening
  - II: Partial thickness fissure or fibrillation
  - III: Full thickness fissure to subchondral bone
  - IV: Exposed subchondral bone



Outerbridge Classification of Chondral Lesions

Management

- correct mal-alignment, ligament instability & meniscal deficiency before any procedure
- **Debridement chondroplasty** of loose flaps of partial thickness damage < 1.5 cm
  - Excise unstable cartilage & stabilize edges with RF co-ablator
  - Roughening of subchondral bone encourages fibrocartilage
- **Fixation** – SmartNail
- **Microfracture**
  - Marrow stimulation technique – fibrocartilage – type I collagen
  - Lesions < 4 cm^2
  - Punctate perforations through subchondral bone with awl
  - Depth 5 mm until you see subchondral fat globules
  - Bridge 5 mm
  - Fibrocartilage biomechanically inferior to hyaline cartilage. However, it will create congruent joint surface and prevent deterioration of adjacent cartilage
  - Post-op CPM & NWB for 6 weeks
  - CPM allows for movement of synovial fluid for better diffusion of nutrients
  - Prevent fibrous scar tissue formation about joint
  - Popularized by Steadman, CORR (2001)
- **Mosaicplasty**
  - Cartilage replacement technique, hyaline cartilage - type II collagen
  - Also known as **OAT (Osteochondral autograft Transplantation)**
  - Cylindrical autograft harvested (cored-out) from non-weight bearing area
  - Lesions < 4cm^2, if >4 cm^2 osteochondral **allograft** transplantation
  - Recipient socket drilled at site of defect
  - Plugs are then press-fit into defect
- **ACI (Autologous Chondrocyte Implantation)**
  - Cellular technique
  - Superseded mosaicoplasty
  - Goal of forming autologous "hyaline-like" cartilage
  - **Cochrane review (2010)**
    - Insufficient evidence to draw conclusions on use of ACI for full thickness articular cartilage defects
    - Results similar to microfracture
  - **1st stage**
    - Arthroscopic harvest of cartilage from lesser weight bearing area
    - Cultivate cartilage cells in (vitro) lab
  - **2nd stage**
    - Open procedure in 2 -3 weeks
    - Defect prepared and chondrocytes injected under periosteal patch
  - MACI matrix associated
  - Delivered on collagen scaffold
  - Avoids problems with periosteal flap
  - Better results
  - **NICE** - uncertainties about long-term effectiveness and potential adverse effects
  - PWB for 12 weeks

- **NICE guidelines (2017)**
  - ACI recommended as an option for treating symptomatic articular cartilage defects of knee if:
    - No previous surgery to repair cartilage defects
    - Minimal OA changes
    - Defect > $2cm^2$
    - done at tertiary referral centre

MENISCAL CYST

- Can be traumatic in origin
- Associated with horizontal tears of lateral meniscus
- Also seen with myxoid degeneration of menisci
- One-way valve of synovial fluid which forms jelly-like collection
- Lump at joint line anterior to collateral ligaments
- Reduce with flexion and bigger with extension
- **Treatment**
  - Aspiration - poor outcome
  - Meniscectomy & decompression
  - Open cyst excision
- **Differential diagnosis**
  - Bursitis, Prolapsed torn menisci, tumours (Lipoma, sarcoma, fibroma), Ganglion, PVNS

POPLITEAL (BAKERS CYST)

- Benign
- Due to meniscal tears in adults and spontaneous in children
- Between semimembranosus and medial head of gastrocnemius
- From herniated posterior knee joint capsule synovium
- In children, the cyst is not in direct communication with knee joint
- Disappears in 2 years
- Re-assure
- Aspirate (high recurrence) or Excise if painful

TOTAL KNEE REPLACEMENT

- Knee flexion requirements:
  - Walking - 70^0
  - Ascending stairs - 90^0
  - Descending stairs & rising from chair without arm support - 110^0

Indications

- Pain
- Loss of function
- Deformity

Contraindications

- Infection
- Extensor mechanism disruption
- Previous arthrodesis - poor muscle power and ligaments
- Symptomatic UTI/any other infection
- Critical limb ischemia
- Several medical co-morbidities
- Hip arthrodesis should be converted first; can resolve knee pain from mal-alignment
- Neuropathic joint

X-rays

- Comment on degeneration and deformity
- Weight bearing PA (Rosenberg)
  - Knee flexed 450
  - Beam directed 10^0 caudal
- Merchant/sunrise view: to evaluate Patello-femoral space, tilt and alignment

Management of OA

Conservative

- Non-surgical alternatives should be exhausted before surgical treatment offered
- **WHO analgesia ladder**
  - 2010, Meta-analysis BMJ: Compared with placebo, Glucosamine, Chondroitin, and their combination do not reduce joint pain or have impact on narrowing of joint space
- **Lose weight**: **Prospective study (BJJ, 2008) from Scotland**:
  - In morbidly obese patients Vs pt. BMI < 30
  - Prospectively followed up for 3 years
  - Inferior Knee Society Scores
  - Higher incidence of radiolucent lines on radiographs
  - Higher rate of complications
  - Inferior survivorship
- **Physio**
  - Low impact aerobics and quad strengthening
  - To optimize knee kinematics

- **Brace**
  - For passively correctable unicompartment <10 deg
  - Varus/valgus off-loading brace
- **Intra-articular steroids**:
  - Reduce inflammation; increase viscosity of synovial fluid
  - Methylprednisolone (Depo-Medrone) Low solubility – longer duration of action
  - Followed by Triamcinolone (Kenalog)
  - Risk of peri-prosthetic infection if done within 3 months of TKR
- **Hylan (Synvisc):** 3 injections of 2 ml each over 3 weeks or 1 injection of 6 ml
  - 2007, RCT, JBJS: No differences between patients treated with intra-articular injections of Hylan and those treated with corticosteroid with respect to pain relief or function at six months
- **Knee joint distraction** in young
- **NICE Guidelines**
  - Thermotherapy, physio & weight loss recommended
  - Topical NSAID and TENS recommended
  - Acupuncture not recommended
  - Chondroitin/Glucosamine
- **Arthroscopic lavage:**
  - For knee arthritis only if having mechanical symptoms with meniscus tear
  - Provides no additional benefit to optimized physical & medical therapy

Surgical Objectives

- Technical goals of TKR
  - Restoration of mechanical alignment by making cuts perpendicular to mechanical axis
  - Preservation of joint line
  - Balanced soft tissue
  - Restore ROM
  - Balanced knee ligaments throughout ROM
  - Restore joint line:
    1) To preserve ligaments tension and kinematics
    2) Help with patella stability
    3) Determined by distal femur cut .Because every femoral implant has the same 9 mm of distal femur offset, while the tibia has many sizes of polyethylene
    4) 10mm above fibula head
    5) 5mm below lateral epicondyle / 35mm below medial epicondyle
    6) Elevation - patella baja, increased JRF, flexion instability
    7) Lowering - lack of full extension
  - Rotational alignment of femoral component for matched rectangular flexion and extension gaps
  - Restore Q angle
  - Ensure rigid durable fixation, conformity and low contact stress.
- **Which TKR would you use and what is the evidence to support this choice?**
  - BOA good clinical practice; at least 90% survival at 10 years
- **PFC (Press-Fit Condylar) Sigma Bicondylar Knee (Depuy) 16th NJR annual report**
  - 3.18% for CR at 15 yr. follow up

- 4.24% for PS at 15 yr. follow up
- ODEP 10A*

➢ **Other implants:**
- Triathlon (Stryker)
- Scorpio (Stryker) - single radius
- Insall-Burstein
- AGC Anatomical Graduated Component
- Genesis II (Smith & Nephew)
- Vanguard
- Nexgen (Zimmer)

➢ Meta-analysis **(BJJ, 2009)**

Survival and clinical function of cemented and uncemented prostheses in total knee replacement
Improved survival of the cemented compared to uncemented implants, with no statistically significant difference in the mean Knee Society score

Approaches

➢ Multiple previous scars
- Use most lateral as blood supply comes from medial
- Maximize Skin Bridge to > 5cm
- Skin supplied by perforators from muscles so make deep skin flaps

➢ **Medial parapatellar**
- Familiar approach
- Excellent exposure
- Midline incision
- End at medial side of tibial tubercle
- Between vastus medialis and quadriceps tendon (both supplied by femoral nerve)
- If difficult to flip patella then extend inter-muscular incision proximally
- Risk: Infrapatellar branch of saphenous N

➢ **Lateral parapatellar**
- Useful to access lateral side in valgus knee
- Difficult to evert patella medially

➢ **Mid-vastus**
- Does not disturb extensor mechanism
- Less extensile, more difficult exposure than medial parapatellar
- Patella can be difficult to evert and subluxed laterally instead

➢ **Sub-vastus**
- Muscle belly of vastus medialis lifted off inter-muscular septum
- Extensor mechanism remains intact
- Can't evert patella – can't do patella replacement

➢ **Leg positioned**

(Courtesy of R Bidwai)

Extensile exposures

- **Quadriceps snip**:
  - 45° oblique incision across quad tendon toward vastus lateralis
  - No change in post-operative protocol
- **V-Y turn down**: excellent exposure: Extensor lag
  Quad weakness
  Need to immobilize post op
- **Tibial tubercle osteotomy**

Minimally invasive

- RCT (JBJS, 2010): no advantage to minimally invasive TKR over conventional technique

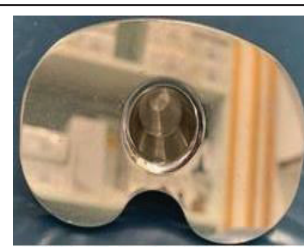
Computer-aided

- BJJ (Germany, 2004) – prospective study: Computer-assisted TKA gives better correction of alignment leg and orientation of components compared with conventional technique

Surgical considerations

Insert designs

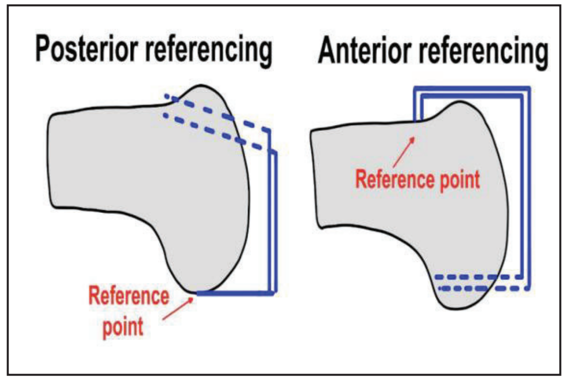
1) **Based on the conformity of the insert**
   - Deeper congruent joint, deeper cut PE - Decreases contact stress
   - Flat geometry -
     - Improves femoral rollback and optimizes flexion
     - Increases contact stress due to low contact surface
   - Highly congruent
2) **Based on mobility of the insert**
   - Fixed bearing
   - Mobile bearing
     - Dual surface articulation
     - Maximize conformity of tibial and femoral components
     - Reduce polyethylene delamination, wear and failure
     - Reduce implant-bone interface stress
     - Self-adjusting to overcome slight component positioning errors
   - LCS (Low Contact Stress) – rotating platform which might compensate for mal-rotation between tibia and femur and reduce patello-femoral maltracking


(Courtesy of N Walsh)

- **Disadvantages**
  - High contact stresses and back-side wear
  - Poly Spin-out if flexion gap too loose
- **RCT Bristol (BJJ, 2009)**
  - No significant difference in PROM between mobile and fixed bearing 2 years post-op
- **Patient Specific Instrumentation**
  - Use CT or MRI
  - J of Arthroplasty, 2014:
    - Less surgical time
    - No increase in peri-operative morbidity
    - No increased cost when compared to conventional TKA
  - Vanguard – Signature (Biomet)

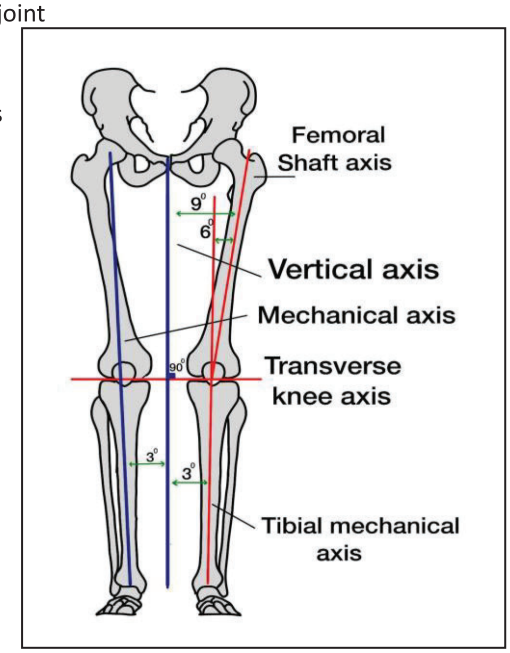
Femoral designs

- **Single radius** -
    - Maintains collateral ligaments isometric
    - Reduce joint reaction forces
    - Allows conformity
- **Double radius:** J shaped- in sagittal plane, femoral component has larger radius distally to distribute loads over larger area and more curved posterior part to improve roll back.
    - Retrospective study (Acta Orthop Traumatology, 2016)
        - No statistically significant differences between the two groups in terms of survivorship and KSS
- **Medial pivot**
    - Dynamic MRI studies showed asymmetrical roll back LFC > MFC
    - Dual radius
- **Referencing**
    - Anterior
        - Respect anterior part of femur – no notching
        - Cuts posterior condyles – risk of loose gap in flexion
        - If between 2 sizes – downsize
    - Posterior
        - Respect posterior femoral condyles
        - Risk of notching if downsized



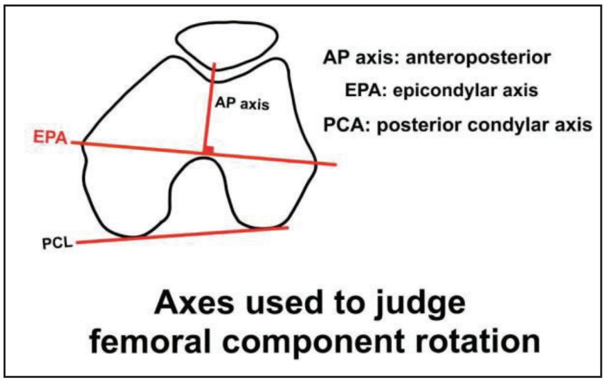
Weight bearing mechanical axis of lower limb

- Line from centre of femoral head to 5 mm medial to centre of ankle joint
- Pass through centre of knee in neutrally aligned knee
- Medial to intercondylar notch in varus knee
- Allows equal load sharing between medial and lateral compartments

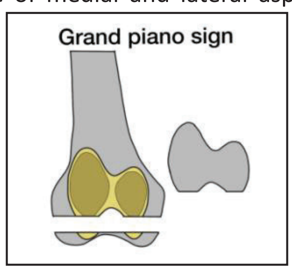


Femoral preparation

- IM alignment - Entry point 1 cm anterior to insertion of PCL and 3-5mm medial to intercondylar notch - Goes down anatomical axis
- 'Starts away from surgeon and directed towards surgeon'
- Mechanical axis from centre of femoral head to intercondylar notch
- **Valgus Cut angle = Angle between AAF and MAF (5-7^0),** to get femoral cut perpendicular to mechanical axis of femur, match other side if normal
- Size determined by anterior or posterior referencing
- Posterior femoral condylar axis in 3^0 internal rotation in relation to epicondylar axis (to accommodate 3^0 varus of tibial articular surface, so jig referencing from posterior condylar axis has in-built **3^0 of external rotation for posterior femoral cut**
- Medial femoral condyle larger and extends more distal to lateral condyle
- Posterior referencing could be unreliable in valgus knee with lateral condyle bone loss, use:
- Epicondylar axis referencing, parallel to tibial cut surface
- Whiteside line:
  - Eponymous name for AP axis at right angle to trans-epicondylar axis.
  - Runs from base of trochlear groove to apex of intercondylar notch
- Inappropriate rotation can lead to lose/tight medial/lateral gaps and PFJ instability



- **Grand-piano sign**
  - Asymmetrical bone resection produced on resected surface of medial and lateral aspects of anterior distal femur when external rotation angle applied to resection



- In valgus knee, reference from medial condyle

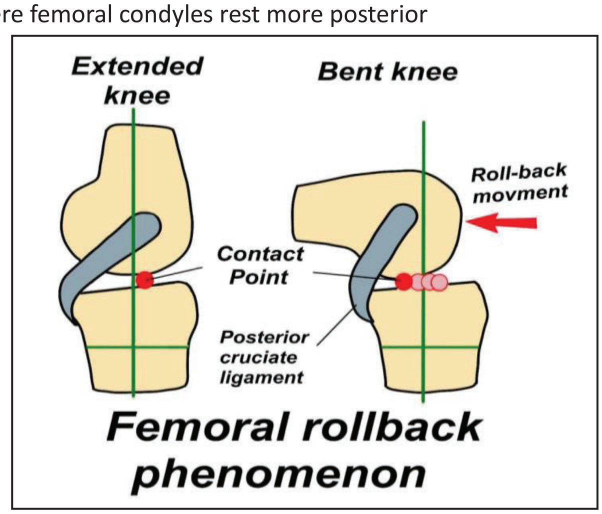
Tibial preparation

- Extramedullary / Intramedullary referencing alignment
- External rotation while flexing to dislocate tibia - Reduce risk to patella tendon rupture and improves tibial exposure
- Mechanical and anatomical axis: from centre of proximal tibia to centre of ankle
- Sagittal alignment: in line with fibula axis
- Varus – valgus alignment
- Proximal tibia cut perpendicular to mechanical axis (Loss of anatomical 3^0 varus at tibia)
- Tibial slope: 3 – 10^0 (normal is 7^0)
- Need to recreate natural tibial slope for PCL to function in CR TKR

- **Natural tibial plateau is 3^0 in varus to mechanical** axis to accommodate larger medial femoral condyle. However, it is recommended that cut is perpendicular to allow even loading and prevent fractures
- Rotational alignment: Tibial component should align with medial 1/3rd of tibial tubercle
- Cemented Metal backed
- Mono-block
- Modular
  - Allows better checking for posteriorly extruded cemented
  - More expensive
  - Forms extra surface
- All poly - increased poly thickness
- In valgus knee, reference from good side (medial)
- **Q angle**
  - Patellar mal-tracking is the most common complication of TKA
  - If increased Q angle - lateral subluxation of patella
- **Avoid:**
  - Medialization / Internal rotation of femoral component
  - Medialization / Internal rotation of tibial component
  - Placing patella button lateral on patella
- **If maltracking noted intra-operatively**
  - Tourniquet deflation to release tethered quads and re-evaluate
  - Recheck position of all components
  - Consider lateral release with diathermy
- **If maltracking noted post-operatively**
  - CT to compare epicondylar axis to posterior condylar axis of femoral

Femoral rollback phenomenon

- Posterior transition of femoral-tibial contact with progressive flexion
- Controlled by ACL & PCL
- Improve range of knee flexion by preventing posterior impingement during deep flexion (clear femur from tibia)
- Also increases lever arm of extensors by moving centre of rotation further behind centre of patella
- To compensate, newer designs move concavity where femoral condyles rest more posterior
- Steeper posterior slope to aid with flexion
- Cam is responsible for rollback in PS implants



Constraint Ladder

- Use as little constraint as possible to decrease transmission of forces at bone/cement/implant interface
- **Cruciate Retaining**
  - Roll back, improved flexion
  - Retain some proprioceptive function
  - Add to AP stability
  - Perform better with 3-50 posterior slope
  - Low conformity: Tibial insert flat to allow rollback (Round on flat design)
  - **Disadvantages:**
    - Technically difficult to balance knee
    - PCL contracture limits balancing in severe deformity
    - PCL stretches over time – may lead to delayed flexion instability
    - Less constraint - Point loading, causes increased wear
    - Important to restore posterior tibial slope and Posterior condylar offset to achieve high flexion
- **Posterior Stabilized**
  - Tibial post & femoral cam to create mechanical roll back
  - Post does not provide varus/valgus stability but some AP (sagittal) stability
  - More conforming (round on round design)


(Courtesy of N Walsh)

  - **Indications**
    - inflammatory arthritis due to risk of late PCL rupture
    - Patellectomy - weak extensor mechanism leads to increases AP instability and subsequent failure of PCL
    - FFD > 15^0, might have to do PCL release
    - Patients with PCL injury
    - Fixed varus/valgus
  - **Disadvantages**
    - Cam jump - posterior dislocation if loose in flexion
    - Bone loss
    - Extra poly
    - Patella clunk syndrome
    - More conforming - more stress transfer to implant bone interface
  - **Meta-analysis - Journal of Arthroplasty, 2013** No difference in flexion and ROM & complication rates between CR & PS
  - **Systematic review, J Knee Surg (2018) Longo UG** : Higher ROM with PS knee when compared to CR, but similar patient reported outcomes PROMs
- **Anterior stabilized**
  - No cam-post mechanism, PCL sacrificed
  - Tibia insert highly congruent with raised anterior lip
  - No rollback

- **Constrained non-hinged**
  - Large central post and deep femoral box to substitute for MCL or LCL
  - Varus/valgus instability from LCL/MCL laxity
  - Consider in obese patients with BMI> 35
  - Increased force transmission to implant-cement interface, therefore need intramedullary stem to distribute forces over larger area
  - For inadequate ligaments function and the use of extension stems and augments
  - LCCK Nexgen (Zimmer) Legacy Constrained Condylar Knee
  - TC3 (Depuy)

- **Constrained hinged/linked**
  - Femur & tibia connect via bar
  - Mobile bearing allows rotation to reduce loosening due to rotational forces Or can have fixed bearing
  - Indications:
    - Global (multiple) ligament deficiency
    - Polio
    - Massive bone loss
    - Knee resection for tumour or infection
  - Intramedullary stem to address high rotational loads
  - S-ROM Noiles (Depuy)
  - Nexgen RHK - Rotating Hinge Knee

Soft Tissue Balancing

- **Techniques**
  1) **Measured resection:**
     - Position implants according to bony anatomy then release ligaments to balance
  2) **Gap balancing:**
     - Tensioning device to place MCL & LCL under equal tension
     - Create rectangular flexion / extension gap to equalize tension on medial / lateral sides
- **Sagittal**
  - Flexion/extension gaps should be equal
  - **FFD**
    - Release posterior osteophytes
    - Release posterior capsule with Cobb
    - Cut more distal femur
    - Release PCL
    - Release gastrocnemius

- **Coronal**
  - **Valgus knee**
    - Defect in femur (Seen on X-ray)
    - RA
  - **Lateral release**
    1. Osteophytes
    2. Lateral capsule
    3. Tight in extension: ITB Z-plasty or release off Gerdy tubercle or multiple transverse stab incisions
    4. Tight in flexion: sub-periosteal release of popliteus off LFC
    5. Tight in both flexion & extension: LCL release
  - **Medial release**
    1. Osteophytes
    2. Deep MCL & capsule
    3. PCL release
    4. Semimembranosus
        - Pie-crusting of medial soft tissue sleeve
        - Superficial MCL: sub-periosteal elevation only
        - Anterior MCL if tight in flexion
        - Posterior Superficial MCL if tight in extension
        - Full release will lead to instability
        - If >16mm poly insert required, use constrained TKR
        - Can cause AVN of medial condyle – place tibial plate on cortical bone
- **Symmetrical gap in flex/ext: address tibia – McPherson's rule**
  - Tight - cut more tibia
  - Loose - thicker poly
- **Asymmetrical gap: address femur (distal/posterior femoral cuts)**
  - Tight extension: FFD management
  - Tight flexion:
    - Downsize femur
    - Increase tibia slope
  - Both tight: Cut more tibia or use thinner insert
  - Loose extension -
    - Add distal femoral augment
    - Downsize femur and thicker poly
  - Loose flexion: larger femur with posterior augment
  - Both loose: Thicker poly

Patella Resurfacing

- **Pros**
  - Restore patella height and optimize extensor mechanism
  - Reduce re-operation rate for anterior knee pain
- **Cons**
  - Over-resection, can lead to fracture or AVN
  - Need to recreate patella thickness to optimize JRF
  - Over-stuffing patella
    - Loss of extension
    - Anterior knee pain
    - Patella maltracking
- **RCT (BJJ, 2006) – Campbell et al,** No difference in American Knee Society score and Western Ontario &McMaster University Osteoarthritis index
- **RCT (BioMed, 2012,** No differences in knee-specific results between groups at 5–10 years post-operatively. Non-resurfaced group had two revisions due to anterior knee pain
- Normal thickness around 25 mm
- Place component slightly medial to improve tracking
- Minimum bony thickness (critical thickness) of 12 mm is necessary to avoid fracture
- Advances in TKA design developed "patella-friendly" implants to improve patello-femoral kinematics and thus decrease anterior knee pain
- Deepening trochlear groove and increasing conformity of patella to trochlear groove, extending anterior flange
- Patelloplasty - excise marginal osteophytes and reshape patella with circumpatellar electrocautery (Improves outcome of TKR even if patella not-resurfaced – **RCT van Jonbergen, BJJ 2011**), though the effect was short-lived with no difference noted at 3.7 year follow up – same author **BJJ 2014**)

Peri-prosthetic Patella Fractures

- Type I: Stable implant extensor mechanism intact
- Type II: Stable implant & extensor mechanism disrupted
- Type IIIa: Loose implant & preserved bone stock
- Type IIIb: Loose implant & loss of bone stock
- **Increased risk** with central single peg implant, Uncemented fixation & Metal backed

Patello-Femoral Arthroplasty

- **Indications**
  - Isolated PF arthritis
  - Young patient (<50 years)
- **Contra-indications**
  - PF instability
  - Medial or lateral compartment arthrosis
  - High demand patient with false expectations
  - Inflammatory arthritis
  - Reported results poorer than TKR (**Avon implant** 23.45% revision rate at 15 years – NJR 16th annual report)
  - BMI >30 (relative contra-indication) – higher failure rates, **Van Jonbergen et al. J Arthroplasty (2010)**

Complications of TKR

- **Peri-prosthetic fracture**
  - Causes
    - Notching
    - Forceful MUA
  - Classification (Lewis and Rorabeck)
    - I: undisplaced, fixed implants (plaster)
    - II: displaced, fixed implants – fix (Retrograde nail if CR)
    - III: displaced, loose implants -
      - long stem revision; CT to assess implant stability
      - Poor bone stock- distal femoral prosthesis
  - Sub-muscular plating has reduced non-union risk compared to extensive lateral approach
  - Patella ORIF if extensor mechanism disrupted
  - Revision if implant loose

- **Stiffness (Arthrofibrosis)**
  - **Factors**
    - Pre op: pre-op ROM - most predictive factor
    - Intra op:
      - Tight closure of anterior tissues, Prevent by closing in flexion
      - Tight gaps
      - Patella baja
    - Post op: hamstring spasm & CRPS
    - USG: synovial thickening and neovascularisation
    - MUA & CPM
      - If flexion not 900 by 6/52
      - Risk of fracture & extensor mechanism disruption
    - Persistent stiffness - Arthroscopic arthrolysis, Quadricepsplasty, Revision
  - **RCT (Physical therapy, 2006),** Results do not support CPM to conventional physical therapy after TKA because they did not further reduce knee impairments or length of hospital stay.

- **Infection - 1%**
  - Micro-organisms from skin bacterial flora gain access to surface of prosthesis during operation
  - >90% of infections during first year after operation due to contamination during procedure.
  - CRP returns to normal in 2/52 and ESR in 3-6/12
  - X-rays neither sensitive nor specific. Irregular radiological lines (Regular in aseptic loosening)
  - CT limited by artefact
  - Isotope bone scan: screening procedure, negative study excludes infection
    - Increased uptake could be normal in 12% in 1st 2 years
  - Knee aspiration - patient off antibiotics for 14 days (Sensitivity 85%)
  - Knee biopsies

- **Management**
  - **DAIR** – Debridement, Abx, Irrigation & retention of prosthesis
    - For acute post-op or acute haematological
    - Can add antibiotic beads in medial and lateral gutters
  - **2- Stage revision** Gold standard: Articulating or non-articulating drug-eluting cement spacer used prior to implantation of revision prosthesis
  - **Single-stage:** Skin breakdown treated with medial gastrocnemius flap from sural artery or free Latissimus Dorsi flap

➢ **Vascular injury** - popliteal artery is the deepest structure in popliteal fossa

➢ **Bleeding** - Tranexamic acid

- Meta-analysis (BMJ, 2012) increased incidence of transfusion when drain used

➢ **Nerve injury - 2-3 %**

- Tibial nerve, medial to artery & Common peroneal nerve
- Increased risk in
  - Preoperative valgus
  - Tourniquet time > 120 min
- Management
  - Remove compressive dressing and flex knee
  - Evacuate haematoma
  - Explore if not resolved in 3 months
  - Tib post transfer to dorsum of foot

➢ **Spinal haematoma** - Withhold anticoagulation

➢ **Loosening**- Non-progressive, radiolucent lines < 2 mm have shown no correlation with poor clinical outcome. Drill sclerotic bone to improve inter-digitation

➢ **Mortality -** 0.2 % in 30 days

➢ **Fat embolism** - transient confusion & hypoxia in 1^{st} 48 hrs

➢ **Patella clunk**

- Due to fibrous nodule behind quadriceps tendon
- Gets stuck in box of femoral component in PS TKR
- USG scan
- Physio or arthroscopic/open resection

➢ **Patella maltracking**

➢ **Symptomatic DVT**

- With prophylaxis - 1.5 % & Without prophylaxis (clinical) - 10%
- NICE: chemical prophylaxis for 2 weeks & Mechanical prophylaxis until fully mobile

- **Metal hypersensitivity:**
  - Nickel found in cobalt-chromium alloys
  - Type IV delayed hypersensitivity
  - Dermatological patch testing
  - Lymphocyte transformation test (LST)
  - Revise to non-allergenic metal prosthesis

- **MCL or LCL transection:**
  - Repair with sutures or suture anchors and hinged
  - Knee brace for 6 weeks
  - If both injured – constrained knee

- **Instability:**
  - In flexion
    - Giving way and difficulty climbing stairs
    - Due to lose flexion gap or damage to PCL at surgery or attrition rupture
  - Or Varus/valgus
  - Causes
    - Patella maltracking
    - Muscle weakness

- **CRPS:** From damage to skin branches of the saphenous nerve

- **Painful TKR**:
  - Extrinsic factors - Hip/Spine, bursitis
  - Intrinsic factors - Instability, mal-alignment, soft tissue impingement

Revision TKR

- **Goals of revision surgery**
  - Adequate exposure
  - Extraction of components with minimal bone loss and destruction
  - Restoration of bone deficiencies & joint line with augments
  - Balance knee ligaments
  - Stable revision implants
- **To optimize exposure**
  - longer skin incision
  - Extended medial parapatellar approach
  - Synovectomy
  - Sublux rather than evert patella to reduce risk to patella tendon
  - Tibial tubercle osteotomy for patella baja
  - Rectus snip or quadriceps turndown
- **Steps**
  - Aim osteotome at implant-cement (not cement-bone) interface
  - Determine tibial platform
  - Finish tibia augmentation

- Long stem to share load with diaphysis due to metaphyseal bone loss and to reduce torsional forces from additional constraint (anatomic or offset to accommodate anatomical variations)
- Prepare femur
- Determine femoral rotation
- Titanium baseplate reduces early loosening compared with cobalt chrome

Type	Description
Type I	- Metaphyseal bone is intact - Minor bone defects, not compromising component stability
Type II **IIa** **IIb**	- Metaphyseal bone is DAMAGED - Cancellous bone lost, - Defect in one condyle or plateau - Defect in both
Type III	- Metaphyseal bone is DEFICIENT - Bone loss compressing major portion of condyle or plateau - Occasionally, detachment of collateral ligament or patella tendon - requires bone grafts or custom implants

(**Anderson Orthopaedic Research Institute (AORI) classification of bone loss in revision TKR)**

Bone loss cavity filling

- Cavitary: Cement < 1cm & Bone graft > 1cm
- Segmental: Use of wedges/augments for reconstruction
- Porous metaphyseal sleeves for massive metaphyseal loss
- Massive bone loss - Endoprosthesis
- Start on tibial side first to establish joint line
- Then balance flexion – extension gaps, recreate of posterior femoral condyles to maintain stability in flexion
- Removal of well-fixed patellar component can result in severe bone loss - retain if possible.

UHMWPE

- Introduced by **Charnley in 1970s**
- Concerns in regard to wear debris and osteolysis and loosening – HXLPE developed

Properties

- Plastic polymer containing long carbon chains of millions of Ethylene units
- Polymer: A substance which has molecular structure built up from large number of similar units bonded together
- Ductile
- Tough
- Not hard - Susceptible to abrasion
- Rough - high friction
- Not wetable

Production process

- **Manufacturing**
    - Ethylene Oxide polymerized in low-temp and low-pressure environment to produce UHMWPE powder
    - From petroleum or compression of air at high Temperature
        - Ram bar extrusion: put powder in tube then heat
        - Sheet moulding: Between 2 sheets then compression
        - Direct compression moulding
            - Best
            - Directly from PE powder to desired product
            - Requires least machining post-manufacture
- **Sterilization**
    - Ethylene Oxide gas
        - Prevent free radicals
        - Prevent cross linking
    - Gamma irradiation: packaged in O2 free environment (vacuum or inert gas) to prevent catastrophic failure
- **Cross linking**
    - Repeated Gamma irradiation in O2 depleted environment
    - **Advantages**
        - Improved resistance to wear
        - Increased young modulus
        - Lab based hip simulator tests demonstrated 70% reduction in wear over earlier generation polyethylene
    - **Disadvantages**
        - Generates smaller wear particles compared to non-cross linked
        - Decreased ductility and toughness
- **Vit E addition**
    - Antioxidant
    - To limit annealing and maintain mechanical properties
    - Can decrease cross-link density and increase wear compared to HXLPE
- BioPoly - composite of UHMWPE and Hyaluronic Acid

Catastrophic wear of PE

- Macroscopic premature failure of PE due to delamination
- Delamination - mode of failure for the composite materials
- Layers separation with significant loss of mechanical toughness due to fatigue cracking
- Mostly in TKA prone to point loading
- Cause:
  - Thickness of < 8 mm (metal tray thickness is 2 mm and is added to full thickness)
  - Flat tibia PE: reduced conformity - increased contact stress
  - Irradiation of PE in O2 rich environment
  - Ram bar machining
- In Summary, **Unconstrained PCL retaining** round-on-flat tibial insert produces high contact stress but allow rotation and femoral rollback without excessive PCL tension. This non-conformity creates areas of high conformity within UHMPWE which is design specific.
- Conforming **PCL sacrificing** round-on-round designs with concavity in both sagittal and coronal planes (double dishing) reduces contact stress but with penalty of reduced rotation. This in turn increases the shear stress at the bone implant surface.
- **Sakellariou et al. HSS Journal(2013)** suggested using conventional UHMWPE for TKR as XLPE has reduced adhesive and abrasive wear but increased risk of crack propagation, deformation, pitting and delamination in TKR (increased fatigue wear)

KNEE ARTHRODESIS

- **Aim**
  - Pain relief
  - Eradication of infection
  - Sound fusion in correct alignment

- **Indications**
  - Failed knee arthroplasty with extensive bone loss
  - Recurrent infection
  - Painful ankylosis after infection or trauma
  - Neuropathic arthropathy
  - Tumour resection
  - Loss of extensor mechanism

- **Procedure**
  - External fixation
  - Intramedullary fixation - better union rate
  - Compression plate

- **Position**
  - 0 - 15^0 flexion
  - 5-10^0 external rotation
  - 5^0 of valgus

- **Complications**
  - Non-union
  - Ipsilateral hip and contralateral knee pain, low back pain
  - Increased chance of fractures around Knee (Supracondylar and Proximal Tibia)

UNICONDYLAR KNEE ARTHROPLASTY (UKA)

UKA Vs HTO

- UKR results better than HTO in over 60
- Faster rehabilitation and quicker recovery
- Improved cosmesis
- Last longer
- Easier to convert to TKA

UKA Vs TKR

- **Advantages**
  - Preserve knee kinematics by retaining cruciate ligaments
  - Faster rehab
  - Better ROM
  - Shorter hospital stay
  - Less blood loss
  - Less expensive
  - Easier to revise
  - Reduced complications
  - Better patient satisfaction

- **Disadvantages**
  - Higher revision rate
  - Results of revision are less satisfactory than primary TKR (4 times higher - from New Zealand NJR)
  - Cumulative risk of revision at 15 years,15-20% (NJR 16th annual report)

- **Indications**

Uni-compartmental OA

- **Types:**
  - Mobile bearing -reduce contact stress
  - Fixed bearing - for lateral side due to increased excursion of lateral compartment during knee movements

Technique

- Incision at medial border of patella extending distally down to tibia
- Avoid extensive releases
- Undercorrect the Mechanical axis to some extent (2-4 degrees) as complete correction or overcorrection loads the other compartment which can lead to rapid progression of arthritis and failure
- Exercise caution and avoid ACL on tibial spine while proximal tibia cut is undertaken. Ensure optimum medio-lateral placement of tibial tray and avoid impingement of ACL

Contraindications

- Inflammatory arthritis
- Fixed varus or severe varus (>15^0) / valgus deformity
- Flexion contracture > 15^0 as at this degree they are unlikely to be corrected passively
- Previous meniscectomy in contralateral compartment
- BMI >35
- Knee flexion < 90^0 - technically can't perform operation.
- Ligamentous instability, posterior wear on lateral x-ray indicate ACL deficiency
- Bi-compartmental arthritis or PFJ OA
- AVN has worse results but not a contraindication
- Coronal knee subluxation > 1cm, varus thrust, incompetent MCL

Complications

- Loosening might need stemmed implant or augment if there is bone loss
- Dislocation: Medial (0.5%) & Lateral (10%)
- Stress fracture can be picked up on bone scan
- Disease progression is most common cause for revision
- **NJR 16th annual report for UKA** – cumulative revision rates at 15 year follow-up range from 31.7% (in <55 years age group) to 8.3% (in 75+ years age group)

HIGH TIBIAL OSTEOTOMY HTO AND DISTAL FEMORAL OSTEOTOMY DFO

- **DFO:**
  - To correct valgus deformity of knee
  - Lateral opening wedge
- **HTO**
  - To correct varus deformity of knee
  - Options
    - ✓ Lateral closing wedge
      - Not used any more, peroneal nerve injury risk
      - Bone stock loss – difficult TKR later
    - ✓ Medial opening wedge -
      - No need for fibula osteotomy
      - Maintain posterior slope
- Try off-loading brace pre-op to predict post-op pain relief
- Assess mechanical alignment (axis) with scanogram (3 X-rays on 1 cassette)

Indications

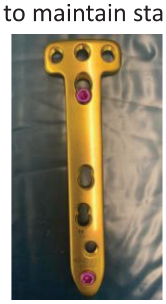
- Given by **Coventry's criteria (1973) JBJS Am** and **ISAKOS (2004)** – International Society of Arthroscopy Knee Surgery and Orthopaedics
  - Uni-compartmental pathology (Grade I-III OA medial or lateral compartment)
  - < 15^0 varus and stable knee
  - Compliant patient
  - <60 years
  - Labourer (high failure of arthroplasty)
  - Active lifestyle, non-smoker, BMI <30

Contraindications

- History of meniscectomy
- Age > 65 years
- Same as UKA

Technique

- shift mechanical axis to better compartment to off-load arthritic compartment
- Each 1 mm corresponds to 1^0
- The apex of osteotomy should be kept intact to maintain stability
- Predrill holes, osteotome to join holes
- Saline for cooling
- Low profile locking plate



(Courtesy of N Walsh)

TomoFix medial tibial osteotomy plate (Synthes)

Complications

- Patella baja (infera) with HTO -
  - Due to scaring of patella tendon
  - Raising joint line in open HTO
- Mechanical block to full flexion due to patellar impingement on tibia

  Treatment:
  - In TKR, use smaller patellar dome on superior aspect of patella
  - Trim inferior bone to decrease flexion impingement
  - Lower joint line
  - Cephalad transfer of tibial tubercle
  - Patellectomy
- Recurrence of deformity - 60 % in 3 years
- Over correct HTO 10 degrees to prevent Non-union
- Changes offset of tibial plateau from shaft – problem at TKR

High Tibial Osteotomy - Systemic review

(Osteotomies around the knee)

PATELLA INSTABILITY

- **Function:**
  - Fulcrum: Increases mechanical efficiency/lever-arm of extensor mechanism by 50%
- Without patella
  - 15-30% more force needed increased tibio-femoral reaction force by 250%
  - Protection of knee against direct trauma
- **Primary/passive restraint**
  - MPFL in 1st 30 deg
  - Patello-femoral bony structures in deeper flexion
- **Secondary/dynamic restraint:** Vastus medialis
- **Classification**
  - Acute (traumatic)
  - Chronic (malalignment)
  - Habitual

Risk Factors

- Femoral anteversion: CT to diagnose
- Ligament laxity (Ehlers–Danlos Syndrome, Marfan)
- MPFL rupture: MRI to diagnose
- Dysplastic VMO
- Patella Alta
- Trochlear / femoral condyle dysplasia, Lateral and axial radiographs (crossing sign seen in flattened trochlear grove), CT/MRI (Dejour Classification)

Increased Q angle

- Between axis of extensor mechanism (ASIS to centre of patella) & axis of patellar tendon (centre of patella to tibial tuberosity)
- < 15^0 in women & < 10^0 in men, abnormal if > 20^0
- **Causes**
  - Laterally placed tibial tuberosity (tubercle)
  - Increased femoral anteversion
  - Genu valgum
  - External tibial torsion
  - ✓ Last 3 anatomic characteristics called "**Miserable Malalignment Syndrome**" as they lead to increased Q angle
- **TTTG**
  - Superimposing 2 CT images
  - From deepest point of trochlea to highest point of tibial tuberosity
- <18mm in women &< 12 mm in men abnormal if > 20 mm
- Sunrise / Merchant views: best to assess for lateral patellar tilt
- Check for osteochondral fracture (most common on medial aspect of patella)

Patella height

- **Blumensaat's line**
  - Corresponds to roof of intercondylar notch
  - At level of inferior pole of patella at 30 deg flexion
- **Insall – Salvati ratio:** Patella tendon to patella (0.8 – 1.2)

Treatment

- Non-op - Physio
- Closed chain exercises with focus on quadriceps (VMO) and hamstring strengthening
- Increase PFJ reaction force during open chain exercises that can cause wear of PFJ
- Patello-femoral knee brace for 2 weeks

- MPFL repair: in dislocation with bony fragment (commonly at femoral insertion)
- MPFL reconstruction: using gracilis or semitendinosus
  - Femoral attachment of MPFL (Schottle point)

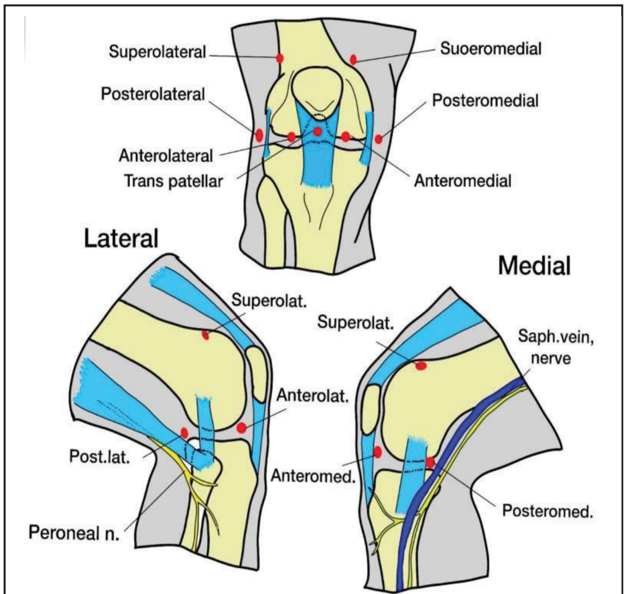
    Schottle point lies at 2 mm anterior to posterior cortex of femur, 2mm distal to posterior origin of femoral medial condyle and just proximal to Blumensaat's line
  - Patella insertion - proximal 2/3 of patella
- **Tibial tubercle transfer**
  - indicated if increased Q angle / increased TT: TG distance
  - Contraindicated in open physis and medial patella arthrosis
  - **Fulkerson osteotomy**:
    - Medialization and anteriorization.
    - Used when associated with anterior knee pain to reduce JRF
  - **Elmslie – Trillat:**
    - Medialization
    - Distalisztion: if Insall-Salvati ratio >1.3
- **Trochleoplasty** indicated in trochlear dysplasia

ARTHROSCOPY OF KNEE

- ➢ Vertical incision increases supero-inferior mobility of instruments
- ➢ Horizontal incision increases medio-lateral mobility of instruments

Portals

1. <u>Anterolateral portal</u>
   - Primary viewing
   - Knee flexion
   - Aim for the notch with scalpel
   - Obturator with cannula
2. <u>Anteromedial portal</u>
   - Primary instruments
   - Sequence: Needle, blade, obturator / probe
   - Low portal to work on lateral meniscus
3. <u>Posteromedial portal</u>
   - Posterior to MCL & 1cm above joint line
   - For PHMM & PCL
   - Risk to saphenous N
4. <u>Posterolateral portal</u>
   - Posterior to LCL & 1cm above joint line
   - For PHLM & PCL
   - Risk to peroneal N
5. <u>Superior lateral</u>
   - Water flow



Knee portals (arthroscopy)

Inspection Sequence

- ➢ Supra-patellar pouch
- ➢ PFJ tracking
- ➢ Lateral gutter
- ➢ Medial gutter
- ➢ Medial compartment
- ➢ Intercondylar notch
- ➢ Lateral compartment
- ➢ **Instruments**
  - Arthroscopy stack / tower
  - Arthroscope (30^0)
  - RF probe (co-ablator) & shaver (hand control or foot switch)
  - Camera - Controls horizon up/down
  - Probe, Punch, scissors, graspers
- ➢ **Risks**: Iatrogenic articular cartilage damage (most common complication)

POPLITEAL FOSSA

- Diamond-shaped space at back of knee

Borders

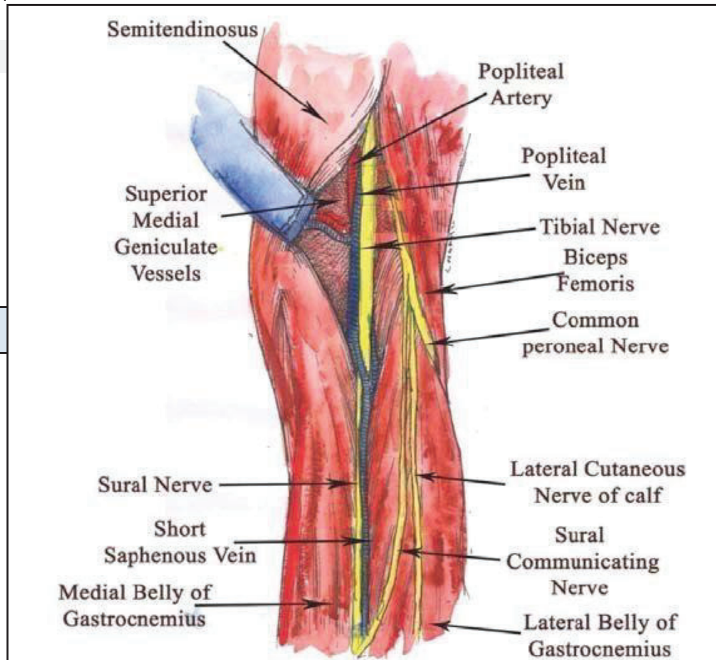
- **Supero-medial border** formed by semitendinosus and semimembranosus
- **Supero-lateral border** by biceps femoris muscle which inserts on fibula head
- **Inferior borders** formed by medial and lateral heads of gastrocnemius
- Popliteus muscle forms floor of fossa
    - Internally rotates tibia relative to femur (holds tibia in internal rotation)
    - Unlocks knee during knee flexion initiation

Contents

- Popliteal A & V
- Tibial N
- Common peroneal N
- Small saphenous V
- Posterior cutaneous nerve of thigh
- Genicular branch of obturator nerve

POSTERIOR APPROACH TO KNEE

- **Indications**
    - Excision of popliteal cyst
    - ORIF of posterior tibial plateau fracture
    - PCL avulsion fracture
- **Tourniquet**
- **Position**: Prone



(Courtesy of L Prakash)

- **Incision:** Lazy S starting postero-laterally along border of biceps femoris and end at posterior border of semitendinosus
- **Approach**
    - Short saphenous vein
    - Divide popliteal fascia
    - Identify sural nerve and follow to tibial nerve
    - Then popliteal Vein followed by Artery (lateral-to-medial) – popliteal artery -Crosses from medial to lateral as the deepest structure in the fossa (A-V-N from deep-to-superficial)
    - Popliteus and soleus are sub-periosteally elevated off posterior tibia
    - Other approach is to go on the medial head of gastrocnemius and displace it with all NV structures laterally - similar to FCR approach

ANTERIOR KNEE PAIN

Lateral Patella Compression

- Caused by tight lateral retinaculum
- Improper tracking of patella in trochlear groove
- Leads to excessive lateral tilt without excessive patellar mobility
- Lateral patello-femoral angle :
  - Formed by lateral patellar facet and line across most prominent aspects of trochlea on CT scan or Sunrise view radiograph (Normal is angle that opens laterally)
- LFC more prominent anteriorly and lateral patella facet bigger than medial
- **Treatment:**
  - VMO strengthening
  - Patient may benefit from arthroscopic lateral release for pain relief

Osgood Schlatter's Disease

- This is traction apophysitis of tibial tubercle
- More common in boys and activities involving jumping (Basketball)
- Self-limiting but does not resolve until growth has halted (maturity)
- Age 11-14y: apophysis forms
- Age 14-18y: apophysis fuses with tibial epiphysis
- **On examination:**
  - Enlarged tibial tubercle
  - Irregularity and fragmentation of tibial tubercle
  - Tenderness over tibial tubercle
- **Treatment:**
  - Conservative including modifying activities and quadriceps stretch
  - Ossicle excision reserved for skeletally mature patient with persistent symptoms

Plica Syndrome

- Embryologic remnant synovial folds that can cause painful impairment of knee function
  - Ligamentum mucosum - in intercondylar notch most common
  - Supra-patellar plica in supra-patellar space
  - Medial plica from infra-patellar fat pad to medial wall of knee
- On examination, there is painful, palpable medial parapatellar cord
- MRI can detect plica but has low sensitivity
- **Treatment:**
  - Arthroscopic resection of lesion when not responding to non-operative treatment.

Patella / Quadriceps Tendinosis

- Lower flexibility of quadriceps and hamstring muscles may contribute
- Also seen along with patella hypermobility
- **Blazina proposed classification system**
    - phase I: pain after activity only
    - phase II: pain during and after activity
    - phase III: persistent pain with or without activities
- **Investigations:**
    - Radiographs- traction spur (enthesophyte) in chronic cases
    - Ultrasound - thickening of tendon
    - MRI – intra-substance signal and thickening of tendon
- **Management:**
    - Physio - stretching and open-chain eccentric exercise. Taping reduce tension
    - USG treatment
    - Cortisone injections are contraindicated
    - Internal Orthopaedics 2010 prospective comparative study, Patients given PRP showed pain and function improvement at 6 months
    - ECSWT
    - Resect angio-fibroblastic and mucoid degenerative
    - Follow with bone abrasion at tendon insertion and suture/anchors

Chondromalacia Patellae

- May be associated with "Miserable Alignment Syndrome"
- **Outerbridge Classification of Chondromalacia**
    - Type I Softening
    - Type II Fissures
    - Type III Crab-meat changes (partial thickness cartilage injury with fibrillations)
    - Type IV Exposed subchondral bone
- T2 MRI best modality to assess articular cartilage, Abnormal cartilage of high signal compared to normal cartilage
- **Treatment:**
    - If non-operative fail – debridement +/- microfracture

Sinding – Larson – Johansson Syndrome

- Traction apophysitis of inferior pole of patella
- Radiographs may show spur at inferior pole of patella
- **Management**
    - Activity modifications, NSAIDS, physical therapy or arthroscopic excision to relive impingement

Other Causes of Anterior Knee Pain

- OCD
- Referred pain
- Bipartite patella
- Hoffa syndrome (infra-patellar pad impingement)

ITB FRICTION SYNDROME

- Friction of ITB on lateral femoral condyle as it moves from anterior in extension to posterior, at 30^0 flexion
- Weakness and pain on hip abduction
- **Treatment**
  - Stretching of Iliotibial band, lateral fascia and gluteal muscles
  - Strengthening hip abductors
  - Z-plasty lengthening

SEMIMEMBRANOSUS TENDONITIS

- History of recent increase in sporting endurance activities
- Pain in posteromedial knee
- Tenderness to palpation at tibial insertion of semimembranosus
- MRI may be helpful in making diagnosis
- Physio to stretch hamstring

POPLITEAL ARTERY ENTRAPMENT SYNDROME

- Constriction of popliteal artery by surrounding muscles, tendons and fibrous tissue
- However, constriction by gastrocnemius medial head is seen mostly
- Diminished pulses with active foot plantar flexion or passive foot dorsiflexion
- Investigations
  - Arteriogram: 100% sensitivity, Stenosis, obliteration and post-stenotic dilation
  - MRA
- Treatment: Vascular bypass with vein graft

SHIN SPLINT (TBIAL STRESS SYNDROME)

- Runners without enough shock absorption
- Caused by traction periostitis
- Anterolateral traction periostitis of tibialis anterior on tibia
- Posteromedial traction periostitis of tibialis posterior and soleus more common
- Initial X-rays are normal while periosteal exostoses are seen in longstanding cases. This can be differentiated from Stress fractures which shows a 'Dreaded Black Line' on x-ray
- 3-phase bone scan:
  Diffuse, increased uptake in posteromedial border of tibia in delayed phase (Phase 3)
  Normal findings on Phase 1 (flow phase) and blood pool (Phase 2)
- MRI shows periosteal oedema

CHRONIC EXERTIONAL COMPARTMENT SYNDROME

- Reversible ischaemia to muscles within muscular compartment
- Pain & paraesthesia which is reproduced by exercise
- Symptom-free at rest
- **Diagnostic criteria:**
  - Resting pressure > 15 mmHg
  - Immediate (1 minute) post-exercise is > 30 mmHg
  - Continuous post-exercise remains > 15 mmHg at 15 minutes after cessation of exercise
- **Second most common exercise induced leg syndrome after medial tibial stress syndrome**
- **Anterior** leg compartment most commonly affected
- Stryker intra-compartmental pressure monitor
- **Treatment:**
  - Activity modification
  - 2 incision fasciotomy in refractory cases
  - Subcutaneous fasciotomy via 1 or 2 incision

KNEE BURSAE

- Trans-illumination on examination
- **4 anterior bursae:**
  - Supra-patellar -Communicates with knee joint
  - Pre-patellar
  - Superficial infra-patellar between skin & lower half of patella tendon
  - Deep infra-patellar - lies between patella tendon & tibia
- **2 posterior bursae** -
  - Popliteal
  - Pes anserinus: Sartorius (F N), gracilis (O N), semitendinosus (T N)
  - Between tibia and 3 tendons
  - Bursitis common in breast stroke swimmers
- Pre-Patella bursitis
  - Housemaid knee
  - Aspiration to distinguish between septic versus aseptic
  - Managed conservatively by Ice, Compression +/- aspiration
  - Bursal resection done rarely

VTE PROPHYLAXIS

- **Aim**: To prevent symptomatic DVT & fatal PE (controversial)
- Coagulation cascade series of reactions lead to formation of fibrin & platelet activation leading to clot formation
- **Department of Health** recommends DVT/PE risk assessment of all surgical patients and medical patients with reduced mobility. Need to weigh thrombosis and bleeding risk

Virchow's Triad

- Blood flow stasis
    - Immobility >3 days (10 times higher risk)
    - General anaesthesia (2 times higher risk)
    - Obesity (3 times higher risk) BMI > 30
    - Age > 60 years
- Hypercoagulability
    - OC pills/HRT
    - Thrombotic states – neoplasia, dehydration, MI, CVA
    - Thrombophilia – Factor V Leiden factor, anti-phospholipid syndrome
    - Pregnancy < 6 weeks
- Endothelial injury
    - Varicose veins (1.5 times higher risk)
    - Inflammation / infection
    - Previous DVT

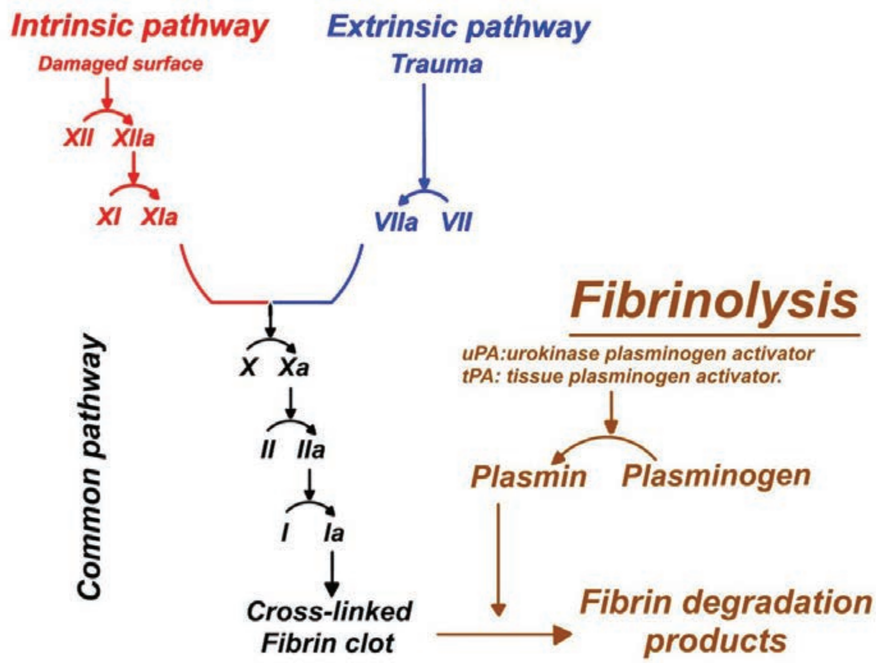
Coagulation cascade

- Coagulation **has two main pathways**
    - Intrinsic pathway (contact activation)
    - Extrinsic pathway (tissue factor activation)
- Both pathways will eventually result in the **activation of factor X** (Stuart-Power factor) which results in a cascade of reactions commonly known as the **Common pathway**.

- **Intrinsic pathway:**
    - Damaged endothelial surfaces result in activation of platelets and secretion of inorganic polymers which activate factor XII (Hageman factor)
    - Activated factor XII (XIIa) activates factor XI into XIa.
    - XIa activates factor IX into IXa
    - XIa in addition to VIIIa activate factor X into Xa

- **Extrinsic pathway:**
    - This pathway is initiated by tissue trauma, which results in the release of tissue factor (TF).
    - TF in addition to activated factor VII (VIIa) result in activation of factor X into Xa
- **Common pathway:**
    - Activated factor X in addition to activated factor V (Va) result in the conversion of Prothrombin (Factor II) into Thrombin (factor IIa)
    - Thrombin (IIa) converts Fibrinogen (factor I) into Fibrin (Ia) which is the solid base for formation of a thrombus/blood clot
    - Thrombin also activates factor XIII into XIIIa (Fibrin stabilizing factor) which stabilizes the formed clot

- **Fibrinolysis:**
  - This normally starts by the activation of plasminogen into plasmin, which acts on Fibrin in the thrombus, and breaks it down to fibrin degradation products (FDPs)
  - Coagulation is regulated in the normal circulation by Protein C and its co-factor Protein S. Both of which inhibit coagulation by inhibiting Va and VIIIa.
  - **Tranexamic acid**
    - **Anti-fibrinolytic** through inhibition of plasminogen activation (blocks lysine binding site on plasminogen molecule), no plasmin – leads to no fibrinolysis
    - Promotes and stabilizes clot formation



Chemical prophylaxis

- **Aspirin**
  - Inhibits production of prostaglandin and thromboxane
  - Inhibit platelets aggregation (Platelet lifespan 10 days)
  - Monitored by measuring bleeding time
- **Warfarin**
  - Blocks Vit K dependent factors (II, VII, IX, X)
  - Takes 2-3 days for inactive factors produced by liver to replace original ones
  - Monitor INR (PT time) - extrinsic pathway
  - Reversal by Vit K, FFP, and Prothrombin complex concentrate (Octaplex, Beriplex)
  - Increased effect with Omega 3 fish oil and decreased with green tea
- **Heparin**
  - Enhances anti-thrombin III to inhibit factor Xa
  - Inactivates Thrombin which prevents activation of fibrinogen to fibrin
  - Monitor APTT (Activated Partial Thromboplastin Time) – intrinsic pathway
  - Heparin induced Thrombocytopaenia - Platelet < 50% of pre-drug
  - Reversed with Protamine
- **Dabigatran**
  - Start 1–4 hrs after surgery
  - Direct Thrombin inhibitor
  - Thrombin time sensitive but can also do Prothrombin time (PT)
- **Fondaparinux**
  - Start 6 hrs after surgery
  - Inhibits Xa via Antithrombin III
  - Decreased incidence of DVT compared to Enoxaparin in hip fractures & TKA
  - Reduced risk of HIT (heparin induced Thrombocytopenia)
  - Highest bleeding complications – Don't use in conjunction with epidural
  - Thrombin time sensitive but can also do Prothrombin time (PT)
- **LMWH**
  - Clexane (molecular weight less than 8000 Daltons)
  - Start 6–12 hrs after surgery
  - Inhibit Xa only via Antithrombin III, less effect on thrombin than UFH (Unfractionated heparin)
  - Single daily dose
- **Rivaroxaban/Apixaban**
  - Start 6–10 hrs after surgery
  - Blocks Xa directly
  - No antidote
  - Thrombin time sensitive but can also do Prothrombin time (PT)
  - Stop 2 days before surgery, which corresponds to 4-5 half-lives
- **Dextran:** Dilute coagulation factors
- **Herbal supplements:** Gingko, Ginseng, and garlic increase bleeding - effect on platelets

Mechanical prophylaxis

- TEDS (Thromboembolic Deterrent Stockings) cause reduced venous stasis
  Produce graduated pressure
- Intermittent pneumatic compression
- IVC filter if contraindication to anticoagulation (recent stroke)

Contraindications to VTE prophylaxis (increased bleeding risk)

- Active bleeding
- Acute major trauma
- Acute liver failure
- Thrombocytopaenia < 75
- Head and spinal injury, acute stroke
- On anticoagulation (INR >2)
- Bleeding disorders (haemophilia)
- Uncontrolled hypertension > 230/120mm Hg
- Lumbar puncture/epidural/spinal anaesthesia in previous 4 hours or next 12 hours

- INR > 6.5 speak with on-call haematologist
- INR 2 – 6.5 : 1mg Vit K IV
- High risk of complications of reversal
  - Prosthetic heart valve
  - VTE event < 3 months
- Octaplex
  - Prothrombin complex concentrate
  - Combination of blood clotting factors II, VII, IX and X
  - Prepared from fresh-frozen human plasma
  - Used in cases of significant bleeding in patients with coagulopathy (INR> 8.0)
  - Also used when such patient must undergo emergency operation

SUMMARY OF THE 16TH NATIONAL JOINT REGISTRY REPORT 2019

Overall key performance indicators demonstrated

- DAIR with and without modular exchange is included in NJR
- The six categories of bearing surfaces for THR are ceramic-on ceramic (CoC),Ceramic-on-metal (CoM), ceramic-on-polyethylene (CoP), metal-on-metal (MoM), metal-on-polyethylene (MoP) and resurfacing procedures
- Resurfacing procedures are treated as a separate category.

Survival analysis methods

- Survival analysis methods are necessary in joint replacement data due to a process known as 'censoring'. There are two forms of censoring which are important to consider in joint replacement registry data: administrative censoring and censoring due to events, such as death.
  - Administrative censoring creates differential amounts of follow-up time, i.e. patients from 2003 will have been followed up for more than 15 years, whilst patients collected last year will have one year or less.
  - Survival analyses methods allow including all patients in one analysis without being concerned if patients have one day, one year or one decade of observed follow-up time; these methods automatically adjust analyses for the amount of follow-up time.

In the case of analyses, which estimate implant failure, death events are also censored, specifically they are considered non-informative censoring events. This assumes that death is unrelated to a failing implant, and can be safely ignored whilst estimating implant failure (revision).

- The survival tables in the NJR report show 'Kaplan-Meier' (KM) estimates of the cumulative chance (probability) of failure (revision) or death, at different times from the primary operation.

OUTCOMES AFTER TOTAL HIP REPLACEMENT

- The median age at primary operation was 69 years and the range was 7-105 years.
- Fixation Type: The absolute number of cemented implants used annually has remained stable between 2006 and the current year, the proportion of all hips that are cemented has nearly halved.
- The percentage of hybrid implants used has tripled over the same period and use of uncemented implants doubled.
- The overview of primary hip replacement surgery is as:

S.NO	FIXATION TYPE	MOP	MOM	COP	COC	COM
1	Cemented (32.3%)	28.5%	<0.1%	3.8%		
2	Uncemented (37.6%)	14.8%	2.7%	8.4%	11.5%	0.2%
3	Hybrid hips (20.8%)	12.4%	0.2%	5.8%	2.3%	
4	Reverse Hybrid (2.6%)	1.8%		0.8%		
5	Resurfacings (3.6%)					

- **Head Size:**

  The three most common head sizes are 32mm (1st), 36mm (2nd) and 28mm (3rd), with 22.25mm and 26mm rarely being used.
- The majority of cases were performed for osteoarthritis.

- At 15 years: The KM estimates of cumulative revision (95% CI) for:

S.NO	FIXATION TYPE	MOP	COP	COC
1	Cemented (5.46)	5.48	5.26	
2	Uncemented (9.38)	6.50	6.01	6.20
3	Hybrid hips (6.14)	5.99	5.34	3.93
4	Reverse Hybrid (9.66)	9.98	8.52	
5	Resurfacings (15.14)			

- The most common indications for revision were aseptic loosening, adverse soft tissue reaction to particulate debris, dislocation/subluxation, pain, and infection. Pain was not usually cited alone; it was cited together with one or more other indications.
- Aseptic loosening is the most common indication for single stage revisions (48.1%), stage one of two-stage (12.3%) and stage two of two stage (11.7%) procedures.
- Dislocation accounts for 15.9% as single stage, 4.1% as stage one of two-stage procedure and 3.5% as stage two of two-stage procedure.
- Infection accounts for 4.5% as single stage, 81.3 % as stage one of two-stage and 73.7% of stage two of two-stage procedure.

OUTCOMES AFTER TOTAL KNEE REPLACEMENT (TKR)

- The median age at primary operation was 69 years and the range was 7-102 years.
- Osteoarthritis was given as a documented indication for surgery in 97.4%
- Cemented TKR is the most commonly performed type (85.1% of all primary knee replacements).
- A further 4.6% were either all uncemented (3.8%) or hybrid (0.8%) TKRs.
- More than half of all operations (57.4%) were TKRs which were all cemented and cruciate retaining) with a fixed bearing, followed by 20.5% which were all cemented and posterior stabilized with a fixed bearing.
- Patellofemoral surgery is predominantly carried out on females (77.5%) who are typically younger than a TKR or unicondylar patient with a median age of 58.
- At 15 years the KM estimates of cumulative revision were as: 6.41% for all cases.
  For all cemented TKRs 4.74. The unconstrained fixed bearing had better survivorship 4.38% as compared to the unconstrained mobile bearing 5.81%
  For all uncemented TKRs were 6.16 %
  For UKRs was 17.99 %
  For Patellofemoral replacement 26.93 %
- At 15 years the KM estimate of the PFC sigma knee had the best cumulative revision of 3.58% amongst the various brands used.
- The five most common reasons for revision in descending order were for aseptic loosening / lysis, infection, pain, progressive arthritis and instability.
- For patellofemoral replacements, the top three reasons for revision were for progressive arthritis and pain
- Similarly, for unicondylar knee replacements (medial and lateral UKR), the highest three incidence rates for reasons for revising the implant were progressive arthritis, aseptic loosening / lysis and pain, respectively.

OUTCOMES OF TOTAL ANKLE REPLACEMENT), TOTAL ELBOW REPLACEMENT and TOTAL SHOULDER REPLACEMENT

PARAMETERS	TAR	TER	TSR
Time since recorded	2010	1 April 2012	1 April 2012
Median age at surgery	68 years	68 years	73 years
Gender	Men (59.6%)	Women (70.6%)	women 70.5%
Fixation Type	Uncemented 95.5% hybrid 2.1% cemented 2.4%		
Indication	inflammatory arthritis osteoarthritis	Inflammatory arthritis (50.6%), OA (34.2%), Trauma (15%)	Osteoarthritis cuff arthropathy
Brand (most common)	Fixed bearing, Infinity	Coonrad-Morrey, Discovery, Latitude and Nexel account for 97%	Stemmed – Delta Xtend and Equinoxe Stemmless – Affinis Resurfacing – Copeland Glenoid component – Affinis
Estimates of Revision	At 7 years 8.51	At 5 years 3.0 %for trauma and 7.4 %for elective cases	At 6 years were 4.2% for trauma and 5.5 for elective cases
Most Common Indication for Revision	Aseptic loosening Pain	aseptic loosening infection	Cuff Insufficiency, instability, native glenoid erosion and infection

FOOT AND ANKLE

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CONTENTS

ANATOMY

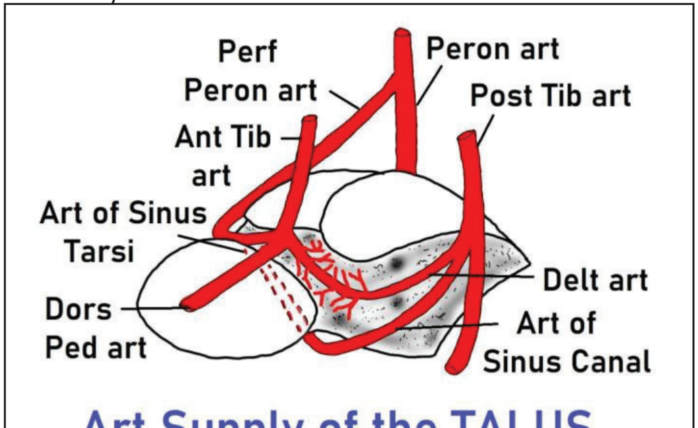
Joints

- The ankle Joint is a synovial hinge Joint, permitting primarily dorsiflexion and plantarflexion of the foot.
- The joint capsule of the ankle joint consists of a fibrous and synovial membrane. The synovial membrane attaches to the margins of these articular surfaces and the fibrous membrane covers the synovial membrane
- The subtalar Joint has 3 facets
  - Posterior is the largest facet
  - Middle is located medially and sits on the sustentaculum of the calcaneus
  - Anterior facet is continuous with the talonavicular joint
- The subtalar joint permits the inversion and eversion movements
- Transverse tarsal joint (Chopart joint) consists of two components:
- Talonavicular joint - supported by the spring ligament (plantar calcaneonavicular ligament)
- Calcaneocuboid joint - saddle-shaped supported by the bifurcate ligament (calcaneocuboid ligaments)
- Controls foot flexibility during the gait cycle

Bones

Talus

- **Blood supply: Retrograde blood supply**
  - The extra-osseous blood supply comes from:
    1. Posterior tibial artery (artery of the tarsal canal and deltoid branch). **Deltoid branch supplies medial ½ of body of talus**
    2. Dorsalis Pedis artery, continuation of anterior tibial artery (forms artery to the sinus tarsi) – supplies head and neck in anastomosis with peroneal arteries. Dorsalis pedic continues as the arcuate artery.
    3. Perforating peroneal arteries
  - The intra-osseous blood supply of the talar head comes:
    1. Medially from branches of the dorsalis pedis
    2. Laterally from the anastomosis between the artery of the tarsal canal and the tarsal sinus



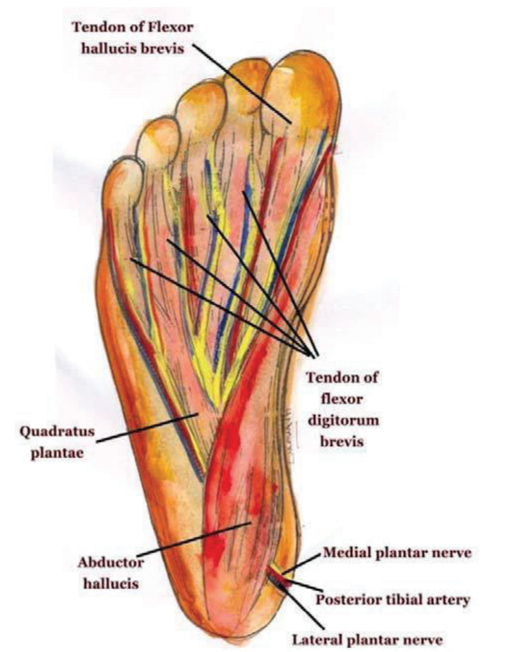
Art Supply of the TALUS

- Tarsal canal is the medial opening to sinus tarsi
- Sinus tarsi is anatomical space bounded by the talus and the calcaneus
- Talus has no muscular attachments
- Head of the talus is supported by spring ligament (plantar calcaneonavicular ligament)
- Two ligaments attach to the lateral process of the talus **(Fracture of lateral process Snowboarders fracture)**
  - Lateral talo-calcaneal

- ATFL
- **Articulation**
  - Inferior surface articulates with posterior facet of the calcaneus
  - Talar head articulates with the navicular
  - Lateral process articulates with the posterior facet of the calcaneus & lateral malleolus
- Injuries often misdiagnosed as ankle sprain, common in snowboarders

Ossification

- All the tarsal bones have one ossification centre except the calcaneus, which has two centres.
  - The centres make their appearance as follows:
  - Calcaneus – 6th month of fetal life
  - Talus – 7th month
  - Cuboid – 9th month
  - Lateral cuneiform - during the 1st year
  - Medial cuneiform - during the 3rd year
  - Intermediate cuneiform and Navicular - during the 4th year
  - The epiphysis for the posterior calcaneus begins to ossify between the 6-10 years
- The metatarsal bones ossify from two centers: a primary center for the shaft, and a secondary centre for the base or proximal end of the first, and for the head of each of the other four.



(Courtesy of L Prakash)

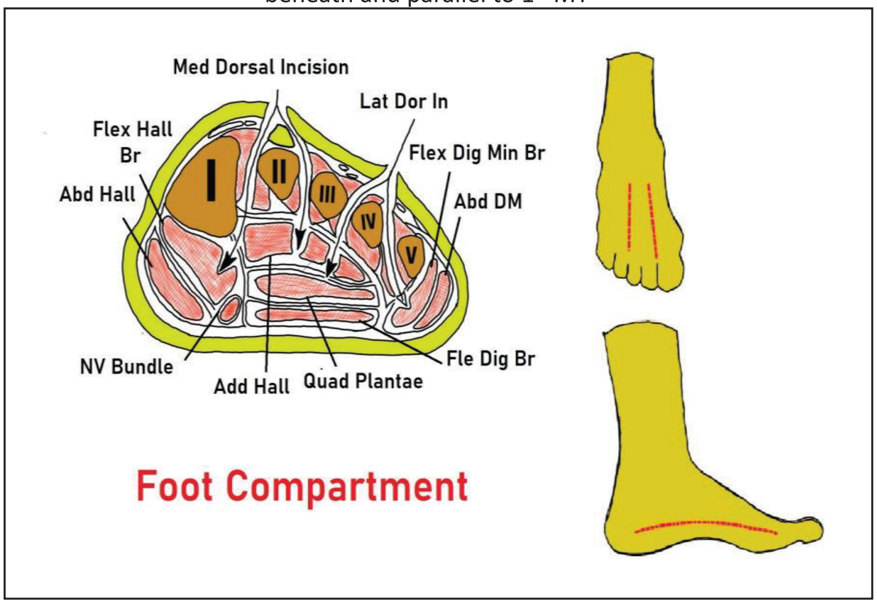
Muscles

- **Plantar Surface arrangement of the muscles: (ALADIN) (3-4-3-4):**
  - I: Abd minimi – Abd hallucis - FDB (most Superficial)
  - II: Lumbricals - FDL- FHL - Quadratus Plantae
  - III: Add halucis - FHB - FDM
  - IV: Interossei - PL - Tib Post
- N/V bundle in between the 2nd and 3rd layers

Foot compartments

- **9 compartments:**
  - Medial - abductor hallucis, flexor hallucis brevis
  - Lateral - abductor digiti minimi, flexor digiti minimi brevis
  - Interossei (x4)
    - Central:
    - Superficial — Flexor digitorum brevis
    - Middle — Quadratus plantae – attaches to FDL
    - Deep — Adductor hallucis
- Acute decompression is controversial as the long-term morbidity from multiple fasciotomy incisions is considered equivalent to the damage from ischaemia
- BOAST 10 (Management of Compartment Syndrome): There is no consensus for the management of foot compartment syndrome.
- Most common cause for foot compartment syndrome is calcaneal fracture

- Consider nerve block for severe pain
- Dual dorsal incisions:
  - Dorsal medial incision on 2nd metatarsal: Releases 1st and 2nd interosseous, medial, and deep central
  - Dorsal lateral incision on 4th metatarsal: Releases 3rd & 4th interosseous, lateral, superficial & middle central
  - Fascia of each compartment opened longitudinally
- Add medial incision - for decompression of medial compartment
  - beneath and parallel to 1^{st} MT



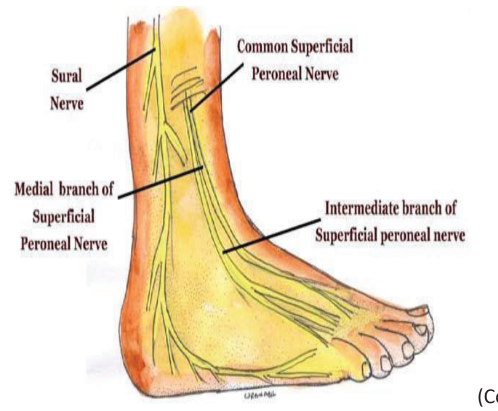
(Foot compartment syndrome)

- **Complications:**
  - Chronic pain and hypersensitivity
  - Fixed flexion deformity of digits (claw toes)
  - Near 2/3rd of patients who underwent decompressive fasciotomy complained of pain, discomfort and stiffness with ambulation at 1 year follow up

Nerve Supply to the Foot

5 main Nerves

- **Tibial N.**: passes deep to flexor retinaculum and ends by 3 branches
  - Medial planter -
  - Lateral planter (Baxter Nerve)
  - Calcaneal branch



(Courtesy of L Prakash)

- **Superficial Peroneal N**: runs superficial to external retinaculum
  supplies most of the dorsum of the foot except first web space
  Exits inermuscular septum 12 cm proximal to tip of lat malleolus
- **Deep Peroneal N.**: sensory to the first web space
- **Sural N.**: a branch of tibial and common peroneal supply lateral aspect of the foot
- **Saphenous N.**: continuation of femoral N. and supplies the medial aspect of the foot

ANKLE ARTHROSCOPY

- **Indications**
  - Diagnostic
  - Therapeutic
    1. Anterior impingement
    2. Talus OCD
    3. Ankle arthrodesis
    4. Washout for septic arthritis
- Distract joint with traction or saline injection

- **Portals**
  - Anteromedial:
    - Medial to Tib. Ant
    - Primary visualization
    - Risk to saphenous vein & nerve
  - Anterolateral:
    - Lateral to peroneus tertius (supplied by DPN)
    - Risk to superficial branch of peroneal N. - dorsal intermediate cutaneous branch
  - Antero-central
    - Medial to EDC and lateral to EHL
- Order of inspection: Talar dome - medial malleolus - deltoid ligament - lateral malleolus - AITFL - PITFL

- **Complications**:
    - Nerve injury - most common complication
    - Synovial-cutaneous fistula

BIOMECHANICS

- Foot needs to be flexible to accommodate uneven ground during stance phase and convert to rigid lever for stability in heel strike & push off phases
- Ankle & subtalar joints work simultaneously forming a functional unit that dissipates the force during weight bearing

- Movements of the F&A:

Movement	Plane	Joint
Plantar/Dorsiflexion	Sagittal Movement	Ankle
Inversion/Eversion	Coronal Movement	Subtalar
Abduction/Adduction	Transverse Movement	Forefoot

- Ankle pronation and supination refer to calcaneal motion with respect to the talus orientation at the subtalar joint
- Pronation occurs by dorsiflexion, abduction and eversion
- Supination occurs by plantarflexion, adduction and inversion
- The normal plantarflexion ranges between 40-65 deg and dorsiflexion between 10-30 deg
- Transverse diameter of talar body is wider anteriorly than posteriorly, providing increased joint stability in dorsiflexion

- Subtalar joint is torque converter, transforming tibial rotation into forefoot pronation and supination via inversion and eversion

- Subtalar Joint has a linear movement like Archimedes Spiral Screw; the calcaneus moves forward in inversion
- Subtalar ROM, 20o inversion and 5o eversion. Functional range of motion is 6o in normal feet and 12o in flatfeet
- Chopart's joint controls foot flexibility during the gait cycle through the 2 axes of TN & CC
- Mid-stance – pronated foot unlocks transverse tarsal joint; 2 axes are parallel so accommodate uneven ground
- Late Stance – supinated foot locks tarsal joint; 2 axes are diverted so the foot is rigid lever for push off
- Foot in pronation (flatfeet); the 2 axes are parallel so it is unlocked and can accommodate the surface, therefore pes planus is more tolerated than pes cavus.

- Midfoot functions as a rigid lever converting hindfoot force into forefoot propulsive force; explaining long-term pain and instability following a missed Lisfranc injury.

- Planter fascia is truss-like structure and contributes to the Windlass mechanism. When MTPJs are extended passively while standing on tiptoes, the plantar fascia is pulled to shorten the distance from calcaneus to the MT heads; this process increases the arch and locks the transverse tarsal joints helping to turn the foot rigid before push off.

- The ankle joint has a smaller load bearing surface compared to hip and knee joints, resulting in higher stress (e.g. at 500 N loading, ankle contact area is 350 mm2, compared to 1100 mm2 for the knee)

- 1 mm talar shift decreases contact area by 42% - **1976 Ramsay paper reaffirmed by Lloyd et al -2006**

GAIT CYCLE

- A series of events that produce forward propulsion of a body with minimal energy expenditure (starts when one-foot makes contact with the walking surface and ends when the same foot makes contact again – heel strike to heel strike of same foot)
- Rhythmic, cyclical, bipedal alternative shifting of center of gravity
- Normal walking speed = 2.5 – 4 mph, and includes 75 – 120 steps per minute

Gage's prerequisites of a normal gait

- Stability in stance phase
- Adequate foot clearance during swing phase
- Appropriate prepositioning during swing prior to heel strike
- Adequate step length
- Energy conservation

Determinants of gait

- Kinematic features of gait that minimize the energy expenditure by reducing vertical displacement of centre of mass
    - Pelvic rotation
    - Pelvic tilt
    - Lateral pelvic displacement
    - Knee flexion at early mid-stance
    - Plantarflexion-knee hyperextension couple
    - Foot motion

Three rockers

- **Heel rocker**
    - Heel strike, heel works as a fulcrum
    - Hip extensors contract and stabilise the hip
    - Quadriceps contract eccentrically, stabilise the knee (extended) and absorb shock
    - **Tibialis anterior contracts eccentrically,** controls plantarflexion to lower the foot to the ground
    - Gastro-soleus dormant
    - GRF posterior to the ankle
- **Ankle rocker**
    - Mid-stance
    - Ankle works as a fulcrum
    - Tibia moves forward on flatfoot
    - Increased ankle dorsiflexion
    - Tib. Ant. relaxes
    - **Gastro-soleus contracts eccentrically**
    - Hip extensors and quads undergo concentric contraction with knee in extension
    - GFR anterior to ankle

- **Forefoot rocker**
  - Push-off phase
  - Forefoot works as a fulcrum
  - Propulsion, toes dorsiflex to push off
  - **Gastro-soleus contracts concentrically**
  - Rapid ankle plantarflexion
  - Hip extension

Stance phase

- 60 % of gait cycle
- Foot is in contact with the ground
- Starts with heel-strike (initial contact), progresses through foot flat (loading response), mid-stance, heel-off (terminal stance) and toe-off (pre-swing)

Swing phase

- 40% of gait cycle
- Foot not in contact with the ground
- Starts with Toe-off and ends with heel-strike
- Foot clearance
- Terminal swing: Tib. Ant. concentrically contracts to clear the foot off the ground and prepare for heel strike

Definitions

- **Limp:** Deviation from normal age-appropriate gait pattern, resulting in uneven, jerky or laborious gait
- **Step:** Distance between initial contacts (heel strikes) of alternating feet
- **Stride:** Distance between heel strikes of same foot (distance covered in one gait cycle)
- **Cadence:** Number of steps/min
- **Foot progression Angle:** angular difference between the foot axis and walking direction

Gait analysis

- Systematic description, assessment and measurement
- Observational: 2-dimensional video analyses
- Coronal and sagittal
- Computerized motion analysis laboratory
- Includes 5 parts:
- Linear gait parameter: step length/cadence/velocity/foot-progression angle
- Kinematic: measurement of movement of body segment using infrared reflective marker
- Kinetic measure of force, moment and energy using data from force plate
- EMG: timing individual muscle during gait cycle
- Energy Expenditure: by measuring O2 consumption and calculating physiological cost index

Gait abnormalities

- **Foot drop/steppage/foot slap:**
  - Increased hip & knee flexion through swing phase to compensate
  - Weak foot dorsiflexors (anterior compartment of leg)
  - Think of Posterolateral Corner injuries - damage to peroneal nerve
  - Sciatic nerve injury
  - Tib. Ant. rupture
  - Stroke
  - True equines from calf spasticity or fixed ankle contracture

- **Crouch gait:**
  - CP
  - Hamstring tightness from spondylolisthesis
  - Toe-walking

- **Stiff ankle:**
  - Ankle fusion

How to describe gait

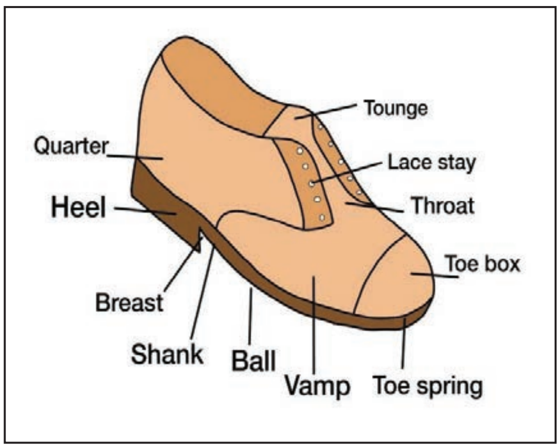
- Ask patient to walk in all lower limb examinations - they should be able to complete 5 strides
- Look at trunk, pelvis, knees, ankles and feet
- Shoulder symmetry
- Arm swing
- Excessive trunk movements, if any
- Pelvic tilt
- Rotational profile by inspecting patellae and feet
- Knee flexion/retropulsion/lateral thrust
- Foot progression angle
- Foot rockers (Normal heel to toe gait/initial contact with floor/can they clear foot?)
- Walking speed
- Walking aids
- “Gait symmetrical with normal stance and swing phases”

HISTORY INDICATIVE OF POSSIBLE DIAGNOSIS

- Pain localization Medial foot vague pain & burning & paraesthesia - Tarsal tunnel
  Heel - Plantar fasciitis
  Forefoot - Claw toes, Freiberg's, Morton's neuroma, Turf toe
- Onset after ankle sprain - OCD
- Aggravates:
- On dorsiflexion - tibiotalar impingement
- At rest
  - Synovitis
  - Instability: Chronic lateral ligament
  - Deformity: Pes cavus, Pes Planus
  - Catching: OCD, peroneal tendon subluxation
  - Burning pain & numbness in toes & feeling like there is stone under ball of foot –
  - Morton's neuroma
  - Great toe locking/triggering & posteromedial ankle pain - FHL tendinosis
  - Foot rigidity, recurrent sprains and difficulty walking on uneven surface - tarsal coalition
  - Difficulty wearing shoes - hallux varus and valgus
  - Medical History - DM, RA and smoking must be asked in any foot & ankle condition

EXAMINATION

- **Sequence** - Stand, inspect, shoes, orthotics, walking aids (look around room for clues)
- **In general** - Flatfoot - tip toes & Cavus foot - Coleman block test
- Gait assessment
- Lie on bed, sole
- Feel (focused on the suspected area e.g. forefoot/hindfoot as instructed)
- Move
- If problem is not obvious think of OA, instability, hallux Rigidus
- Look



  Expose to above knees
  Look at:
  - Shoes: {do you mind if I look at your shoes}
  - Insoles:Remove and describe (accommodative/corrective)
  - Sole:
    - Normal wear pattern
    - More wear on medial side of shoes in planovalgus
    - Built up wedges
    - Custom made shoes
  - Hands for RA & HSMN, spine
  - Forefoot, midfoot, hindfoot
  - Weight bearing scars, callosities, muscle wasting, discoloration
  - From front: Comment on:
    - Knee alignment
    - Clawing - Examine hands
    - Weight bearing over lateral border of foot in cavovarus
    - Patient bear weight on medial border of foot and talar head in planovalgus

    - Weight bearing on tip toes & Achilles tendon tightness
    - Dorsal ‘bunion’ - hallux Rigidus
    - Callosities on PIPJ - hammer toe & HV
    - Pronation of big toe - HV
    - Other lesser toe deformities
- From side:
    - Cavus
    - Plantar-flexed 1st ray
    - Calf wasting: Polio, CVA, previous CTEV
- From behind:
    - Ask patient to walk around
    - Varus/valgus hindfoot
    - ‘Too many toes’ sign in valgus (> 1.5 toes visible)
    - Calf atrophy - chronic Achilles tendon rupture

➢ **Gait assessment**

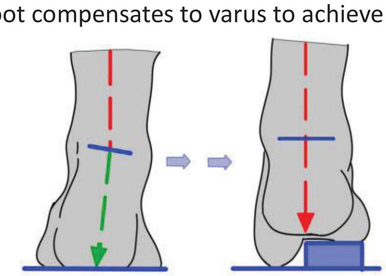
- Tip toe standing:
    - Assess physiologically correctable varus hindfoot and check for functioning tib post
    - Rigid heel valgus in coalition and subtalar arthritis
- Lying:
    - Look at the Sole and between toes for callosities and ulcers
    - Callosities under MT heads in hammer toe
    - Look at hip & knee for surgical scars if presenting with foot drop
- Feel:
    - Systematically start proximal to distal or vice versa
    - Avoid tender areas till the end
    - Don’t spend too long on palpation, be quick and focused
    - Ankle joint
    - AITFL, ATFL, CFL, deltoid
    - Palpable gap/ tenderness over Achilles tendon
    - Peroneal tendons
    - Tibialis posterior
    - Plantar fascia
    - Bunion and Bunionette
    - Tender under MT head - synovitis
    - Web spaces - Morton’s neuroma/bursitis

(Examination of the foot & ankle)

- Move:
    - Centre of rotation of ankle is within talus
    - Loss of motion in arthritis
    - Weakness to ankle plantarflexion in chronic Achilles tendon rupture
    - Ankle - ROM arc
    - Bend knee to relax Achilles (Silfverskoild’s test)
    - Subtalar - Lock the ankle in dorsiflexion and palpate talar neck
    - Inversion/eversion - 20 deg inversion, 10 deg eversion, reduced in coalition
    - Supination/pronation
    - Adduction/Abduction : TMTJ towards/away from midline in coronal plane
    - MTPJs and IPJs movements – check if deformities flexible or rigid

- Neurovascular examination:
  - Offer to examine **spine**, but examiner will skip due to paucity of time
  - Peripheral exam: Light touch/pin prick
  - Saphenous - medial malleolus
  - Superficial peroneal – dorsum of foot
  - Deep peroneal - 1st web space
  - Sural - lateral border of foot
  - Tibial - plantar surface
  - Semmes Weinstein monofilament test in DM and CMT

Special Tests

Silfverskiold	Tested by ankle dorsiflexion with knee flexed and extended More dorsiflexion with knee flexed indicates GC tightness GC originates from distal posterior femur and crosses knee soleus originates from posterior tibia Equivalent indicates Tendoachilles tightness or OA
Thompson	Increased resting ankle dorsiflexion in prone position with knee bent Lack of plantar flexion when calf is squeezed
Squeeze (Hopkin)	Compression of tibia & fibula at mid-calf causes pain at syndesmosis if injured
External rotation stress	Pain over syndesmosis elicited with external rotation/dorsiflexion of foot
Anterior drawer	For ATFL in 20 degrees of plantar flexion For CFL in neutral or inversion Grasp tibia with one hand and heel with other & draw the foot forward Always compare instability with other side
Jack test	Dorsiflex big toe and check if arch forms in flexible flatfoot Useful in children who can’t stand
Grind	For hallux rigidus OA - be gentle due to pain
Drawer	Demonstrates instability in dorsal-plantar plane in hammer toes due to MTPJ dislocated dorsally
Coleman block	To check whether subtalar joint (varus deformity) is mobile (forefoot driven) or rigid Start by standing patient fully on the wooded block then drop 1st MT Place heel & lateral border of foot fully weight bearing on the block - offload 1st MT Look for the heel varus from behind If corrected/flexible: forefoot-driven If sustained/rigid: forefoot & hind foot-driven Foot is a tripod: calcaneum, heads of 1st and 5th MTs If 1st MT flexed, hindfoot compensates to varus to achieve plantigrade  **Coleman Block Test**

PES PLANUS (PLANOVALGIS FOOT)


(Curtesy of K Syed)

- **History:**
  - Pain: lateral heel pain from calcaneal impingement against fibula
  - Age child : Coalition or flexible
    Adult Tib Post Tendon insufficiency
- **Medical History:** DM, RA, hypermobility
- **Examination:**
  - Look at shoes, more wear medially
  - Gait - reduced plantarflexion during swing in Tib. posterior dysfunction
  - Collapsed medial arch
  - Hindfoot valgus
  - Forefoot abduction - too many toes sign>1.5 toes
  - Double heel raise test for subtalar joint - Fixed ,or corrects to neutral or to varus
  - Single heel raise test for Tib. Posterior – repeat 5 times
  - Move Tib. Posterior - inversion in plantarflexion
  - Subtalar & ankle movements to assess fixed v/s flexible deformity
  - Tests Gastrocnemius tightness assessed using Silfverskiold's test
  - Jack test
- **Neurovascular exam**
- **3 Arches in foot**:
  - Medial longitudinal arch:
    - Dynamic stabiliser - Tib Post & Plantar fascia
    - Static stabiliser - Spring (calcaneonavicular) lig & Interlocking of tarsal bones
  - Lateral longitudinal arch
  - Transverse arch: Stabilised by Peroneus Longus
- **Pathophysiology:**
  - Loss of main invertor leaves its antagonist, peroneus brevis, unopposed to evert foot
  - Pull of Achilles falls lateral to axis of subtalar joint creating excessive hindfoot valgus
  - Progressive tightness of the triceps surae perpetuates the valgus deformity
  - Deltoid insufficiency
- **Causes**
  - Congenital: Vertical talus, tarsal coalition, Spina bifida, CP
  - Acquired: Tib Post insufficiency, RA, Polio, degenerative
  - Physiologic
    - Flexible due to ligamentous laxity
    - Normal variant
    - 40 % of children born with flatfeet
    - 10% of children at 10 years
- **X rays**
  - Weight-bearing views
  - Look for talar head uncoverage
  - Talocalcaneal (Kite) angle > 35 deg, divergence due to heel valgus
  - Loss of co-linearity between talus-1st MT (Meary angle <4 degrees)
  - Decreased calcaneal pitch
  - Oblique views to rule out tarsal coalition

Tib Post dysfunction

- Commonest cause of **adult-acquired flatfoot deformity**
- Tendon degeneration occurs in watershed region distal to medial malleolus
- **Origin:** From posterior tibia & fibula
- **Insertion:** navicular tuberosity, 3 cuneiforms, cuboid, MT 2-5 &sustentaculum talus
- **Function:**
  - Plantar flex &invert and adduct foot
  - Dynamic stabilizer of longitudinal arch
- **<u>Johnson & Strom stages</u>**

	Deformity	Physical exam	Radiographs
Stage I	Tenosynovitis No deformity	(+) single-heel raise	Normal
Stage IIA	Flatfoot deformity Flexible hindfoot	(-) single-leg heel raise Mild sinus tarsi pain	Arch collapse deformity
Stage IIB	Flatfoot deformity Flexible hindfoot Forefoot abduction	Too many toes Sign >40% talonavicular uncoverage	Talonavicular uncovering forefoot abduction
Stage IIC	Flatfoot deformity Flexible hindfoot Forefoot abduction & supination		
Stage III	Flatfoot deformity Rigid hindfoot Valgus	(-) single-leg heel raise Severe sinus tarsi pain	+ Subtalar Arthritis
Stage IV (Myerson)	Flatfoot deformity Rigid hindfoot Valgus Deltoid Ligament Compromise	(-) single-leg heel raise Severe sinus tarsi pain Ankle Pain	+ Talar Tilt

- **<u>Management</u>:** Conservative route always first line of treatment in all stages
  - **Tendinopathy**
    - Insoles for arch support and heel wedge/cast/physio
    - AFO
    - Tib. Posterior debridement in some cases, if severely painful
  - **Flexible deformity**
    - Orthotics, longitudinal arch support
    - Hinged AFO to control varus/valgus but allow flexion/extension
    - FDL to navicular transfer +/- TA lengthening (FDL is synergistic with Tib. Post.)
    - Medialising calcaneal osteotomy
    - Order of correction
      - TA lengthening or gastrocnemius recession (depending on Silfverskiold test)
      - Medialising calcaneal osteotomy
      - Arthrodesis screw
      - Tib posterior reconstruction +/- spring ligament repair
      - FDL Transfer
      - Opening wedge medial cuneiform (Cotton) osteotomy or lateral column lengthening (Evan's osteotomy) in stage IIB
      - If arthritis, then naviculo-cuneiform fusion

Acquired flat foot

- **Rigid deformity**
  - Triple (or double) arthrodesis: subtalar, calcaneocuboid and talonavicular
  - Joint with TA lengthening + deltoid ligament reconstruction
- **Ankle arthritis**
  - Triple arthrodesis with TAR (>60 years of age, good NV status, no DM, and without severe ankle deformity < 15o valgus) or pan-talar fusion
  - Or hindfoot arthrodesis (TTC fusion) with extension to TNJ

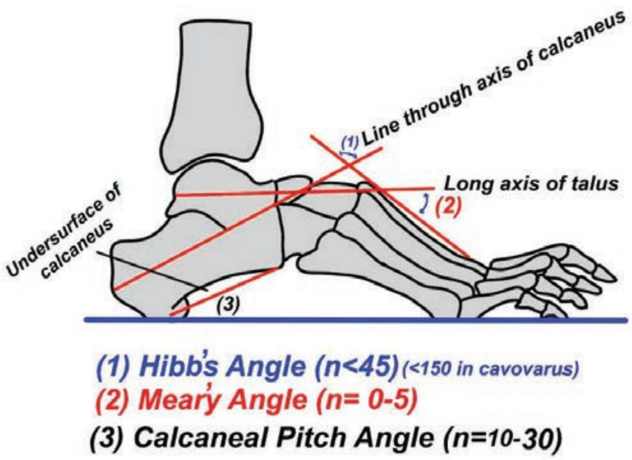
TARSAL COALITION

- **History:**
  - Symptomatic at 8-16 years when it starts to ossify and becomes stiffer
  - Medial in Talocalcaneal, lateral in Calcaneonavicular (commonest)
  - Recurrent sprains
  - Difficulty walking on uneven surfaces
- **Examination**: Heel raise – rigid flatfoot
- Failure of differentiation leads to fusion of tarsal bones
- **Forms:** fibrous, cartilaginous, osseous (bony)
- **Types:**
  - Calcaneonavicular:
    - Commonest (90%)
    - Symptomatic at 8 – 12 years
    - Flatfoot less stiff
  - Talocalcaneal:
    - Symptomatic at 12 – 16 years
    - Bilateral in 50 %
- **X-rays:**
  - Talocalcaneal
    - Talar-beaking and C sign
    - Result of limited motion of subtalar joint
    - Anterior impingement
  - Calcaneonavicular
    - Anterior nose (anteater) sign
    - 45deg oblique views
    - Elongation of anterior calcaneal process
- **CT:** choice for diagnosis for bony coalition
- **MRI:** for fibrous/cartilaginous
- **Treatment**
  - Non-operative: Stretching, heel insert, immobilise (cast)
  - Operative:
    - Resection of bar with fat graft or EDB or FHL interposition & bone wax to cover raw bone
    - Talocalcaneal coalitions involving < 50% of joint
    - Worse prognosis if > 50 %
    - Medial approach for talo-calcaneal as bar normally involves sustentaculum
    - Lateral approach for calcaneonavicular
    - Triple arthrodesis
      - Talocalcaneal coalition that involves > 50% of joint
      - Failed resection with persistent pain

PES CAVOVARUS

Think of **neurological involvement** unless proved otherwise

- **History:**
  - Metatarsalgia - lateral foot pain
  - Instability - giving way (from lateral instability in HSMN)
  - Difficulty wearing shoes
  - Onset and progression of deformities
  - Neurological symptoms
  - Medical History - neurological spine trauma
  - Family History
- **Examination**
  - Look footwear
  - Gait foot drop, high medial arch
  - Hands & spine
  - Unilateral (spinal cause) or bilateral (CMT)
  - Stand
    - Arch
    - Plantar flexion of 1st MT
    - Hindfoot varus
    - Clawing of toes
  - Sole
    - Sit down
    - Callosities on lateral foot & MT heads
    - Ulceration
  - Move ROM, active then passive
    - Correctable deformities
    - Peroneus longus resisted plantar flexion
    - Peroneus brevis eversion
    - Tib. Ant. ankle dorsiflexion
    - Tib. Post. Inversion
    - Neurovascular
  - **Special Tests:** Coleman Block Test & Silfverskiold's Test
  - Hindfoot dorsiflexed (calcaneus) and forefoot plantarflexed
  - Plantar flexed 1st ray is initial deformity
- **Causes:**
  - Idiopathic
  - Congenital: CTEV & Arthrogryposis
  - Traumatic: Crush injury – compartment syndrome
  - Neuromuscular: CMT, Spina bifida, Polio, CP, Friedrich ataxia, stroke
- **X-Rays**
  - Weight bearing AP and Lateral
  - Meary angle: between 1st MT axis and talus, normal 0 – 5 degrees
  - Hibb angle: between 1st MT and calcaneum,< 150 degrees in cavovarus
  - Calcaneal pitch between plantar cortex of calcaneum and line parallel to floor,Normal is 10 – 30 deg
    Increased in cavus and decreased in planus



Cavo-varus foot

- **MRI**
  - If deformity is unilateral
  - Dysraphism need to be treated first as deformity can recur
- **Management (MDT-approach)**: podiatrist, neurologist
  - Orthotics: Corrective rigid insole with depression for 1st ray & lateral wedge
  - Accommodative: for fixed deformity
  - Don't correct surgically if neurology progressive

<u>Cook law of foot deformity correction:</u>
1. Get heel under calf
2. Put foot square on floor (plantigrade)
3. Balance muscles
4. Varus flexible – forefoot surgery
5. Varus fixed – forefoot and hindfoot surgery

- **Rule of 2s**
  - Soft tissue releases
    - TA
    - Plantar fascia
  - Tendon transfers
    - Peroneus longus to brevis
    - Tib. Post to dorsum of foot
  - Osteotomies
    - Lateralizing (valgus) calcaneal closing wedge
    - 1st MT or cuneiform dorsiflexion osteotomy
- Hindfoot corrective fusion: for severe rigid cases
- Claw hallux (Jone's Procedure): fusion IPJ big toe & EHL to the neck of 1st MT transfer
- Clawing of lesser toes flexor tenotomy, IPJ fusion or excision

Charcot-Marie-Tooth (HSMN)

- Nerve demyelination of peripheral nervous system
- Commonest cause of **bilateral** cavus feet
- **Autosomal dominant:** most common progressive inherited neurological disease
- Present at 2nd decade of life, Progressive
- Types
  - I: Demyelination, cavus, 2nd decade, progressive
  - II: Wallerian degeneration, late onset (3rd decade), flaccid foot
- Affected muscles become weak - Peroneus Brevis, Tibialis Anterior, Intrinsic muscles of hand and foot
- Tib. Ant. and Peroneus Br. have small cross sectional area – weaken early
  - **Cavus:** caused by **Peroneus Longus** overpower weak tibialis anterior
  - **Varus:** caused by **Tibialis Posterior** (normal) overpowering weak Peroneus Brevis (compensatory tripod effect)
  - **Hammer toes:** as ankle dorsiflexion weakness results in recruitment of toe extensors for assistance
  - **Claw toes:** caused by intrinsic muscle weakness
- Hip dysplasia
- Scoliosis - characteristic left thoracic and kyphotic curves distinguish from idiopathic scoliosis
- **Investigations:**
  - X-rays: same as pes cavovarus
  - EMG
  - Genetic testing
  - MRI – spine (in cases of unilateral deformities)
- **Treatment: MDT** (Neurologist – Podiatrist – Orthopaedic surgeons)
  - **Non-Operative:**
    - Footwear modification
    - Insole: Rigid insole with depression for 1st ray & lateral wedge support
  - **Operative:**
    - Aim: achieve plantigrade stable foot
    - Depends on the deformity:
    - **Flexible**
      - Cavus: (either)
        - 1st Mt dorsal closed wedge osteotomy
        - Peroneus longus to PB decreases plantarflexion force on first ray without weakening eversion
        - Plantar fascia release
        - Tib post transfer to dorsum of foot to compensate weakness of tib ant.
        - May also require Achilles lengthening
      - Varus: Calcaneal lateral shift osteotomy
      - Clawing:
        - Big Toe: Jone's procedure – Fuse IP joint and EHL transfer to neck of 1st MT
        - Lesser toes: Girdle-stone procedure/IPJ fusion/Extensor tenotomies
    - **Rigid Deformity:** Hindfoot corrective fusion (TTC nail)

EQUINOVARUS FOOT

- **Examination:** Walks on lateral aspect of foot
- **Causes**
  - Cerebral palsy
  - Duchenne muscular dystrophy
  - Spina bifida
  - Residual clubfoot deformity
  - Tibial deficiency (hemimelia)
  - Most common ankle-foot abnormality following a stroke
- Varus caused by spasticity of Tibialis Posterior
- Equinus caused by spasticity of Gastroc-soleus complex
- **Treatment**
  - Serial casting AFO
  - Botulinum toxin injection into Tibialis Posterior and Gastrocnemius
  - Physio
  - Achilles tendon lengthening
  - Split Tibialis Anterior transfer, split tendon (SPLAAT) anchored to cuboid or
  - Peroneus Brevis
  - Calcaneal osteotomy in a rigid hindfoot varus deformity
  - Lateral closing wedge osteotomy

EQUINOVALGUS FOOT

- Valgus: caused by spasticity of Peroneus Brevis
- Equinus: caused by spasticity of Gastroc-soleus complex
- Seen with: Fibula hemimelia, cerebral palsy
- Hindfoot in equinus
- Painful callus over talar head secondary to weight-bearing
- Treatment
  - Brace
  - Botox
  - Tendoachilles and Peroneus Brevis lengthening
  - Calcaneal osteotomy
  - Subtalar arthrodesis

RHEUMATOID FOOT

Deformity

- **Forefoot:**
  1. Hallux Valgus often present but may not be often symptomatic
  2. Erosive arthropathy
  3. MTPJ dorsal subluxation and fat pad pulled forward and atrophied
  4. MT heads prominent and cause callosity/plantar tenderness
  5. Hammer toes and claw toe (intrinsic muscle contracture)
- **Hindfoot:**
  1. Valgus ankle
  2. Widespread OA
  3. TN subluxation leads to flattening the medial arch
  4. Subfibular impingement
- **Soft Tissues:**
  1. Tenosynovitis of Tib. Post & Peronei
  2. Collapse of medial arch (Tib post rupture/spring lig. rupture /TN subluxation)
  3. Tarsal tunnel syndrome
  4. Morton neuroma
  5. Retro-calcaneal bursitis

Examination

- Offer to assess hip and knee as well, as the proximal deformities must be corrected first
- Assess skin and vascular condition
- Assess neurological status
- Assess and localize which joint is the most painful
- Investigation: X-ray/MRI/CT

Management

- **MDT** Rheumatologist - PT- orthotics
- Non op: Accommodative orthosis / targeted steroid Injections
- Operative aim: **Pain-free ,plantigrade , shoeable foot**
- **Forefoot:**
  - 1st MTPJ fusion + straightening of the affected lesser toes (usually all with **Stainsby's procedure** – Proximal phalanx resection and reduction of MTPJ plantar plate + K-wire stabilisation and extensor-to-flexor suture), sufficient soft tissue/plantar plate release at the MTPJs
  - **Weil's** (distal MT shortening) osteotomy if the joints are not arthritic
- **Hindfoot:**
  - **Ankle Arthrodesis** is the gold-standard
  - **TAR** is emerging as a successful alternative however increased incidence of subsidence and implant failure
  - Jordan, Gurdip Chahal, Anna Chapman (Coventry, Birmingham) - Systemic review – JBJS, 2014 TAR Vs Arthrodesis in end-stage ankle arthrosis
  - Significance improvement in functional outcome however higher complication rate
  - Clough et al. (Wrightington) 2019 (BJJ) – 76 % implant survival for STAR implants at a mean of 15.8 years in a series of 200 ankles including 119 RA patients

DIABETIC FOOT

- **Neuropathic**
  - From uncontrolled hyperglycaemia
  - 1st neurological abnormality is loss of vibration and position sense
  - 10g Semmes Weinstein monofilament test to assess protective sensation
  - Sensory dysfunction leads to lack of protective sensation - located on pressure areas
  - Autonomic dysfunction leads to drying of skin which may crack
  - Ulcer characterised by:
    Surrounded by thick hyperkeratosis, pink punched out base
    Painless
    Bleeding
  - Motor dysfunction leads to muscle imbalance between extrinsic and intrinsic muscles resulting in claw/hammer deformities which can cause pressure points
- **Vascular**
  - Affects large and small arteries
  - Painful ulcers
  - Don't bleed
  - Necrotic edges
- **Infection**
  - High blood sugar results in decreased neutrophil function and suppression of inflammatory response
  - Organisms - Polymicrobial
  - Bacterial cultures of deep biopsies help guide management

Investigations

- Blood glucose control HbA1c (glycated Hb) level
  Abnormal if > 7 %
  (Indicator of blood sugar control over 90-day span)
- Serum albumin > 30 g/ml (required for wound healing)
- Total lymphocyte count > 1,500/mm^3
- Transcutaneous oxygen pressures (TcpO2) - Gold-standard to assess wound healing potential (> 30 mmHg is good sign of healing potential)
- ABPI > 0.45 is needed to heal ulcers - may be falsely elevated due to calcification of vessels
- X-rays to look for osteomyelitis
- WBC scan - negative (cold) for neuropathic joints and positive (hot) for osteomyelitis
- MRI - cannot distinguish between oedema secondary to infection or destructive Charcot
- Deep tissue biopsy - required as superficial swabs are colonised by commensals

Treatment (NICE Guidelines 2019)

- **MDT** approach: multi-system disease (as per guidelines)
- Diabetologist, podiatrist, diabetic specialist nurse and orthotist, vascular surgery, microbiology, radiology, casting, and wound care specialists with Orthopaedics (+ having access to plastics if required)
- Examine for risk factors:
  - Neuropathy
  - Limb ischaemia
  - Ulceration

- Callus
- Infection and/or inflammation
- Deformity
- Gangrene
- Charcot arthropathy

➢ Assess risk of developing diabetic foot problem (risk stratification)
- **Low** **(Annual foot assessments, emphasize foot care)**
  No risk factors except callus
- **Moderate** **(foot protection service within 6-8 weeks + 3-6 monthly assessments)**
  Deformity or
  Neuropathy
  Non-critical limb ischaemia
- **High** **(foot protection service within 2-4 weeks + monthly assessments)**
  Previous ulceration or
  Previous amputation or
  On renal replacement therapy or
  Neuropathy and non-critical limb ischaemia together or
  Neuropathy or non-critical limb ischaemia with callus and/or deformity

➢ **Principles:**
- Strict control of DM
- Patient education
- Aggressive treatment of ulcer
- Arthrodesis better than ORIF (rigid/heavy metalwork)
- Offloading, treat infection, control limb ischaemia, wound debridement and dressings

➢ **Goal:**
- Reduce deformity
- Provide stability to the hindfoot and ankle
- Prevent ulceration through protective braces/insoles

➢ **Debridement of infection**
- Excision of devitalised and infected tissue
- Negative Pressure Wound Therapy (NPWT) to:
  - Minimise dead space
  - Remove bacteria
  - Enhance formation of new blood vessels and cellular proliferation
- Antibiotics (follow NICE guidelines for diabetic foot problems 2019 or discuss with microbiologist)
- Wound care to offload ulcers and provide barrier to infection and absorb exudate

➢ **Offloading**
- **Total contact cast** (accommodative) to offload (duration depends on response, regular weekly/two-weekly change) – non-removable casting
- Rocker bottom offloading shoes

➢ **Surgical principles**
- Release tight gastrocnemius if causing equinus deformity and forefoot pressure
- Prophylactic removal of prominent pressure-causing bone lumps
- Amputation
- Diabetics require twice as long in plaster if they sustain fracture or Consider more rigid fixation if ORIF needed

CHARCOT JOINT (NEUROPATHIC ARTHROPATHY)

Non-infectious, destructive process causing eventual dislocation and peri-articular fracture

- **Causes:**
  - Diabetic Neuropathy (most common)
  - Spinal Cord Injury
  - Meningomyelocele
  - Syringomyelia
  - Leprosy
  - Chronic alcohol abuse
- **Pathophysiology**
  - **Neurovascular theory –** nerve damage results in increased local vascularity which precipitates osteoclastic activation
  - **Neurotraumatic theory –** microtrauma in insensate joints causes progressive bony destruction secondary to activation of pro-inflammatory cytokines
- **Differential diagnosis:** Sepsis, Gout, Cellulitis
- **X-rays (depending on stage):**
  - Bone fragmentation
  - Loss of bony architecture
  - Coalescence of bone fragment
  - Joint subluxation
  - Sclerosis
- **How to differentiate from septic joint?**
  - Clinically: Elevate the affected extremity for 5 – 10 minutes. Oedema will decrease with elevation in Charcot neuroarthropathy while an infectious process is less likely to decrease.
  - Lab: inflammatory markers slight increase in Charcot compare to be higher in infection
  - MRI: collection of pus in sepsis
  - Bone scan: WBC labelled will be positive in infection
  - Bone Biopsy
- **Brodsky Classification**
  - I: Involve midfoot
  - II: Involve triple joint
  - III:
    - IIIa: Ankle joint
    - IIIb: Calcaneal tuberosity
  - VI: Combination of areas
  - V: Forefoot


(Courtesdy of M Elgendy)

- **Eichenholtz classification**

-Stage 0	- Oedema, erythema, and mimics infection (hot, swollen)
-Stage I	- Fragmentation, destruction, subluxation, painful
-Stage II	- Deformity ceases to progress soft tissues settle - Coalescence absorption of small fragments, rounding of fragments fixed deformities
-Stage III	- Consolidation, remodelling, new bone formation, Collapse of arch (rocker bottom deformity)

- Charcot should be suspected to be active if temperature difference between both limbs is > 2° C (usually measured by infra-red thermometer)

➢ **Management:**

- Goals: Stop inflammation
  Preserve architecture of the foot
  Relieve pain
  Reverse bone demineralization
- The main treatment is immobilization until the acute phase/ulceration settles down
- **Total contact cast**
  - Maintain foot architecture until consolidation
  - Helps distribute weight bearing forces evenly
  - Changed weekly to avoid pistoning as oedema resolves
- Custom made boot for rigid deformities
- Bisphosphonate infusion over 12 months may improve pain and bone turnover **(NICE DO NOT recommend Bisphosphonates to treat acute Charcot arthropathy)**
- Excision of bony prominences (exostosis) in stage 3 if causing ulcers
- Arthrodesis in functional position
- Poor quality of bone & soft tissue may lead to loosening & infection
- Amputation for recurrent/persistent infection

(Courtesy of H Majeed)

(Charcot foot for FRCS)

ANKLE ARTHRITIS

- **History**
  - Pain and limitation of movements
  - Impingement on dorsiflexion
  - Previous h/o fracture, ligamentous injury, recurrent sprains
- **Examination**
  - Look Stiff ankle gait
  - Move Inability to dorsiflex actively and passively
- **Pathophysiology**
  - Post-traumatic (79%)
  - Idiopathic
  - Inflammatory, RA
  - Big surface area, less incidence of primary OA than knee and hip
  - Articular cartilage only 1mm thick compared to 2-3mm for knee and hip
- **Treatment**
  - Single rocker shoe
  - Intra-articular injection
  - Arthroscopic debridement
  - Supramalleolar osteotomy -
    - Joint preserving
    - For asymmetric ankle arthritis confined to medial or lateral compartment

Arthrodesis

- Indications
  - Young manual labourer with severe arthritis
  - Infection
  - Trauma
  - AVN of talus
  - Salvage of failed arthroplasty
- Position: Neutral dorsiflexion (90^o) and 5^o valgus & external rotation
- Types:
  - Open:
    - Lateral/anterior approach, Excise fibula (trans-fibular approach)
    - Remove cartilage
    - Bone graft from fibula
    - Cross screws (from superior to inferior) or anterior plating
  - Arthroscopic
    - Comparable union rates with open
    - Useful in pts with poor soft tissue envelope or poor blood supply
    - **BJJ 2005 – Winson** Mean time to union (12 weeks), Non-union (7.5%)
  - Tibiotalocalcaneal fusion - for ankle & subtalar arthritis or poor-quality bone using retrograde nail

- **Complications**
  - Wound breakdown
  - Delayed/non-union 10%
    - Increased risk in smokers/revision cases
    - Look for continuous trabeculae
  - Infection
  - Mal-alignment
  - Nearly all will have subtalar OA on x-ray, not necessarily symptomatic

Ankle replacement

- **Indications**
  - Low demand, mobile joint, good bone stock & stability
  - OA, Post-traumatic arthritis, RA
- **Contraindications**
  - Coronal mal-alignment (>15 deg)
  - History of septic arthritis
  - AVN of talus
  - Neuropathic joint (Charcot)
  - Non-reconstructable ankle ligaments
  - Subtalar arthritis (can be fused under an ankle replacement)
  - Ipsilateral arthritis
    - 1st generation:
      - Highly constrained – early loosening
      - Cemented
      - Incongruent poly
    - 2nd generation:
      - Agility - all poly tibia
      - Porous coated components with fixed poly bearing surface
      - Poor long-term results
    - 3rd generation: mobile bearing
- **Scandinavian Total Ankle Replacement (STAR)**
  - Tibial and talar components are cobalt chrome
  - Talar component has ridge to guide gliding of PE component
  - Mobile bearing manufactured from UHMWPE
  - Have two Anchor bars that improve tibial fixation
- **Infinity (Wright Medical)** currently used in 60% cases across UK
  - Promising early results for 4 years
- **BJJ (2003 & 2008) Wood – Wrightington**
  - Survival rate 5years (92.5%)
    10 years (80%)
    76 % at 15.8 years, better survival in RA than OA (81.9% Vs 68 %)
  - Significant improvement in pain and function
  - Pre-operative ROM best predictor for post-operative ROM

- Principles:
    - Long incision to decrease tension on skin
    - Thick skin flaps to maintain vascularity
    - Minimise use of retractors

- **Complications:**
    - Clough et al. TAR: what are the risks? BJJ 2019 (must read for risks)
    - Wound infection
    - Intra-op fractures (most commonly medial malleolus)
    - Aseptic loosening, osteolysis
    - Medial gutter pain
    - Fracture of PE component and edge-loading
    - VTE
- **Prospective Controlled Trial – Foot & ankle international – 2009 -** STAR Vs Ankle Fusion By 24 months, ankles treated with STAR had better function and equivalent pain relief as ankles treated with fusion

  NJR Eight-year cumulative revision risk was 8%

- **Complications:**
    - Wound problems and Infection
    - Peri-prosthetic fractures
    - Subsidence
    - Aseptic loosening

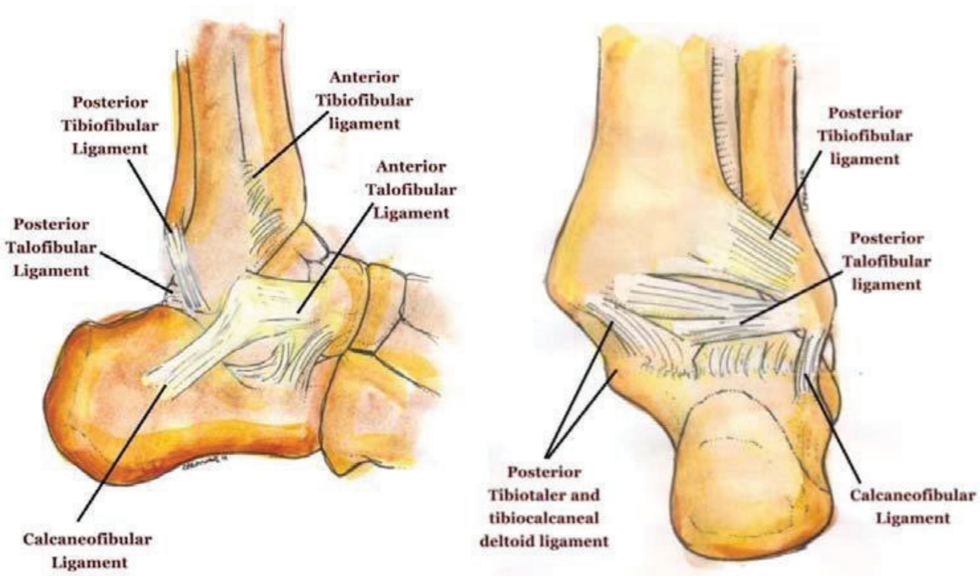
(Ankle arthritis for FRCS)

ANKLE INSTABILITY

- **History**
  - Giving way
  - Painless, if painful think of OCD/Peroneal injury/OA
  - Locking or clicking
- **Examination**
  - Anterior drawer, compare with other side
  - Exclude hindfoot varus, forefoot over-pronation or subtle cavus. All will need correction before repair
  - Beighton score, if hyperlaxity present needs robust or non-anatomical repair
- **Types**
  - Mechanical
  - Functional
- Normal hind foot in valgus to protect against inversion of the strong inverters (TA, TP)
- Increased risk with cavovarus foot

Ankle ligaments

- **Syndesmosis:**
  - Anterior inferior tibio-fibular   Most commonly injured ligament in ankle sprains
  - Posterior inferior tibio-fibular (High sprain)
  - Transverse tibio-fibular lig. (Talar shift)
  - Interosseous membrane & ligament
- **Lateral:**
  - Anterior talo-fibular ATFL
    - Weakest of lateral ligaments
    - Restraint to inversion in plantar flexion
    - Primary restraint to anterior shift
    - Most commonly involved ligament in low ankle sprains
    - Test: invert in plantar flexion
    - Talar tilt
  - Posterior talo-fibular PTFL
    - Strongest of lateral ligaments
    - Limit posterior talar displacement within mortise
  - Calcaneo-fibular CFL
    - Restraint to inversion in neutral or dorsiflexion
    - Test: invert in neural
  - Lateral talo-calcaneal: deeper to Calcaneo fibular ligament
- **Medial (Deltoid):**
  - Superficial: Tibio-navicular & Tibio-calcaneal (sustentaculum tali)
  - Deep: Anterior & posterior tibiotalar
  - Primary restraint to anterolateral talar displacement
- **Plantar:**
  - Calcaneonavicular (spring) ligament
  - Originates from Sustentaculum tali
  - Inserts onto navicular
  - Stabilizer of medial longitudinal arch and head of talus



(Courtesy of L Prakash)

- **Imaging:**
  - Stress views: 1 mm of talar shift reduces ankle joint surface contact area by 42% causing early OA
  - MRI: If pain persists for 8 weeks following sprain

Treatment

- **Acute injury:**
  - Non-operative management: Boot followed by physiotherapy, proprioception, peroneal & Strengthening
  - Operative: Anatomical vs. Non anatomical Repair
    1. Failure of conservative + MRI confirmed attenuated ligament
    2. Positive stress radiograph
    3. Anterior drawer > 10mm or >5 mm to contralateral side
    4. Varus test >10 mm or > 5mm to the contralateral side
- **Chronic Injury:**
  - Operative Management: Anatomical vs. Non anatomical Repair
  - Risk factors – hyperlaxity, associated hindfoot varus or cavus, high demand will need non-anatomical repair

Anatomical - Utilizes local tissues to restore normal anatomy and joint kinematics

- **Brostrom-Gould**:
  - Torn ends of ATFL/CFL shortened & repaired directly by mid-substance suturing or suture anchors
  - Reinforced with inferior extensor retinaculum (Gould)
  - Internal brace (Arthrex) increasingly used now as an added 'seat belt' support, particularly in hypermobility
- **Arthroscopic lateral ligament complex reconstruction**

Non-anatomical - Uses tenodesis or tendon transfer to restore stability

- **Evans**: peroneus brevis (PB) graft passed through drill hole in distal fibula
- **Chrisman-Snook procedure:** Route anterior half of PB through fibula while maintain distal attachment to the base of the 5^{th} MT

HEEL PAIN

Baxter nerve entrapment

- Compression of 1st branch of lateral plantar nerve (br. of posterior tibial nerve)
- Innervates abductor digiti minimi
- Common in running athletes
- Compressed between Abductor hallucis longus & medial side of Quadratus plantae
- **Treatment:** surgical release of abductor hallucis fascia

Jogger foot

- Compression of medial plantar nerve at point where FDL & FHL cross (Knot of Henry)
- Caused by foot orthotics

Sever's disease

- Common in skeletally immature
- Calcaneal traction apophysitis from repetitive microtrauma
- Fragmentation on X-rays
- MRI to rule out other causes (osteomyelitis, stress fracture)
- Usually resolves when growth is completed
- **Treatment:** Rest, heel-pad, cast, TA stretching

Plantar Fasciitis (dancer heel)

- **History:**
  - Occupation standing for long hours
  - Start-up heel pain, plantar pain worse on 1st step in morning then improve
  - Painful again towards evening
- **Examination:**
  - Look gait - absent heel strike if Achilles tight
  - Feel - tenderness under medial aspect of heel
  - Silverskiold's for Achilles tightness
- Aging associated with increased heel pad stiffness and plantar fascia thickening
- **Origin:** medial calcaneal tuberosity (site of pain) - Continuation of insertion of Achilles
- **Insertion:** bases of five proximal phalanges
- **Function**:
  - Increase arch height as toes dorsiflex during toe-off
  - 2nd most important medial arch support
- Repetitive trauma leads to micro tears and inflammation
- Reduced ankle dorsiflexion is the strongest risk factor for development of plantar fasciitis
- **Investigation:** MRI or US (normal thickness is < 2.5 mm)

- **Treatment**
  - Stretching of fascia and Achilles tendon - eccentric
  - Cushioned heel inserts - insoles with arch support
  - Cortisone injection - can cause fat atrophy and plantar fascia rupture (quicker action but short-lived response)
  - Extracorporeal Shock wave therapy – good add-on to physio, 50-90% benefit
  - PRP injection – slow to respond (6-weeks) but longer lasting than steroids, approx 70% benefit
  - Surgical treatment: be cautious due to high risk of recurrence/ persistent pain and complications
  - Open/endoscopic release if no improvement after 1 year (complete release leads to flat foot)
- **Differential Diagnosis:**
  - Calcaneal spur
  - Fat pad atrophy: fibrous septa secure fat pad to calcaneus and oppose migration
  - Insertional Achilles tendinosis
  - Calcaneus stress fracture - Bone scan
  - Haglund deformity
  - Posterior ankle impingement

POLIO

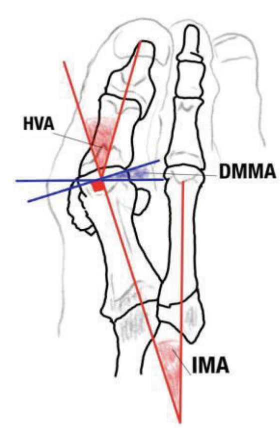
- **Look**
  - Clawing of toes
  - Pes planus – TP paralysis
  - Equinovarus deformity of the foot
  - Valgus deformity of ankle
  - Scars from previous surgery
- **Gait**
  - Trendelenburg
  - Flaccid
  - Use of calliper
- **Feel:** Sensations normal (if abnormal think of other pathology)
- **Move:** Motor weakness (Asymmetrical and patchy)
- **Caused by** viral destruction of anterior horn cells in spinal cord and brain stem motor nuclei
- Post-polio syndrome:
  - Occur in half of patients
  - Onset 20-40 years following initial infection
  - Muscle weakness, flaccid paralysis, myalgia, and fatigue
- **Treatment**
  - Limited exercise to sub-exhaustion level with periods of rest to maintain muscle tone
  - Lightweight orthosis - GRF orthosis to keep knee extended
  - Tendon transfers, contracture releases, and arthrodesis to optimise function

HALLUX VALGUS

- **History**
  - Pain over bunion or over-riding 2nd toe or transfer metatarsalgia (from dysfunctional 1st ray and loss of windlass mechanism)
- **Examination**:
  - Look
    - at shoes
    - Prominence
    - Pronation of big toe
    - Over-riding 2nd toe
    - Over-crowded toes
    - Callosities over MT heads
  - Gait: flat foot gait reduced push off
  - Feel: tenderness over bunion
  - Move:
    - MTPJ correctable to neural, if not – need lateral release
    - IPJ ROM
    - 1st TMTJ mobility particularly in adolescents
    - Translation and flexion/extension
  - Tests:
    - Grinding test
    - Silverskiold's - TA tightness might be a deforming force
  - NV status
  - Beighton score in adolescents
- **Aetiology**
  - Multi-factorial - family History (primary factor)
  - Others are all secondary: high heeled shoes, RA, Pes planus, Ligament laxity

Pathoanatomy

- Weakness and attenuation of medial capsule
- Phalanx deviates laterally
- Metatarsal head displaces medially leaving sesamoids laterally translated relative to MT head
- Adductor tendon become deforming force (inserts on lateral sesamoid and lateral aspect of proximal phalanx)
- Lateral deviation of EHL and FHL further contributes to deformity
- Bunion is partly due to swollen bursal sac
- Pronation of big toe because abductor moves plantar to axis of rotation
- **Investigations**: Weight bearing AP & lateral radiographs
- **Angles:**
  - IMA - 1st MT and 2nd MT <10^{o}
  - HVA - 1st MT and proximal phalanx <15^{o}
  - DMAA - 1st MT and distal articular line <15^{o}
  - IPA - proximal and distal phalanges < 10^{o}
- Correcting IMA without correcting DMAA will worsen HV

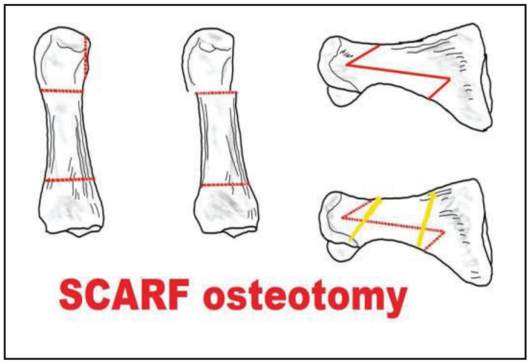


Treatment

- **Goal:**
  - Relieve pain
  - Re-function 1st ray
  - Correct deformity
  - Reduce transfer metatarsalgia
- **Non operative:**
  - Wide shoe box with low heels if symptoms mild.
  - Pressure relieving orthosis **Shoe modification/pads/spacers/medial arch support.**
  - Deformity without discomfort is **not** indication for surgical management
  - If patient insists on operative treatment – get 2^{nd} opinion.
  - Up to 20 % will have chronic pain after surgical correction
- **Operative:**

	HVA	IMA	PROCEDURE
Mild	<25	<13	Distal Osteotomy (Chevron) +/-modified McBride
Moderate	26-40	13-15	Scarf Osteotomy +/- modified McBride
Severe	41-50	16-20	Double Osteotomy/ Lapidus procedure

  - **Aim**
    - Well-aligned, pain free, congruent joint
    - To reposition 1st MT head over sesamoid
    - Surgical treatment guided by radiological parameters
  - **Modified McBride -**
    - Soft tissue procedure
    - Not done in isolation, but used to correct incongruent MTP joint
    - Release of adductor from lateral sesamoid/proximal phalanx
    - Lateral capsulotomy
    - Medial capsular plication
  - **Distal MT osteotomy e.g. Chevron:**
    - 1 cm from MT head
    - V-shaped, extra-capsular, plantar limb is horizontal to preserve the blood supply
    - Inherently stable osteotomy, but fixation with a screw is preferred to avoid mal-union
  - **Akin osteotomy:** for hallux inter-phalangeus (Medial closing wedge osteotomy)
  - **Diaphyseal MT osteotomy (Scarf):**
    - Medial approach, Divide capsule
    - Versatile and allows multi-planar correction
    - Z cut, thicker dorsally to avoid fracture by screw
    - Start about 1cm proximal to articular cartilage
    - Not too much proximal as needs good metaphyseal bone to prevent troughing
    - Cut made perpendicular to 2nd MT
    - Headless screws as prominent head uncomfortable



- **Modified Lapidus Procedure:**
  - 1^{st} TMT J arthrodesis
  - Hypermobility – instability – severe deformity – recurrence
- **Medial cuneiform open wedge osteotomy:**
  - For adolescent due to open physis, Best to wait until skeletal maturity to operate

➢ **Complications:**
- Troughing (in scarf) - Cortex of one fragment collapses into cancellous bone of another
- Fracture - 5%
- Hallux varus (from overcorrection)
- 2nd MT transfer metatarsalgia might require Weil shortening osteotomy

➢ Goal of surgery for metatarsalgia to improve pressure distribution within forefoot following failure of nonsurgical measures
- Painful neuromas - injury to dorsomedial branch of saphenous nerve
- AVN of MT head with chevron (Anastomosis b/w med & lat plantar A under 1st MT head)
- Recurrence is common if hyperlaxity
- Cock-up toe deformity in Keller or FHL injury

➢ **Degenerative**
- Fusion
- Keller resection arthroplasty
- Replacement

➢ **In RA**
- Fusion of MTPJ and Stainsby's for lesser toes
- Lapidus procedure: for hypermobile/arthritis 1st TMTJ
  - 1st TMTJ arthrodesis
  - With soft tissue procedure
  - Minimal cartilage resection to avoid shortening
  - Pseudoarthrosis (non-union) 15%

➢ METAANALYSIS – **Smith S.E et. al. 2012** (Australia) – Scarf better to correct 1^{st} -2^{nd} IMA when used for HV correction (weak recommendation based on low quality evidence)

➢ No difference or statistical significance (scarf vs. Chevron) with respect to AOFAS score, HVA and IMA – **Deenik et al 2007 (RCT from Netherlands)**

HALLUX VARUS

- **History**
  - Difficulty in wearing shoes
  - Pain indicates underlying joint arthritis or trauma
- Medial deviation (adduction) of great toe relative to 1st MT

(Courtesy of L Prakash)

- Most commonly due to:
  - Previous hallux valgus surgery due to :
    - Over tightening of medial capsule
    - Resection of adductor hallucis
    - Excessive release of lateral capsule
    - Excessive medial eminence resection
- Other causes:
  - Congenital: firm band-like abductor hallucis muscle
  - Short thick 1st MT
  - Inflammatory arthritis
- Hallux valgus angle < 0 deg

- **Treatment**
  - Wider and flexible toe box shoes
  - Pad bony prominences
  - Tape or splint deformity for early post-operative varus after hallux correction
  - Lateral closing wedge MT or phalangeal osteotomy
  - Adductor hallucis tendon re-attachment with medial release
  - Abductor hallucis muscle release - resistant congenital cases
  - First MTPJ arthrodesis fixed significant deformity and non-functioning hallux

HALLUX RIGIDUS

- **History:**
  - Pain forefoot around 1st MTPJ, bony prominence mistaken as bunion
  - ADL affected - Difficultly wearing shoes
- **Examination**
  - Look: prominent dorsal bunion
  - Feel
  - Move:
    - Normal ROM of big toe 70^{o} dorsiflexion to 25^{o} plantar flexion
    - Pain on dorsiflexion in hallux rigidus
  - Tests: Grind test (be careful in performing it due to pain)
- **Causes:** OA, RA & Post-traumatic

Classification

- **Hattrup & Johnson** radiographic grading

I	No joint space narrowing	Non-operative
II	Mild joint space narrowing & dorsal osteophyte	Cheilectomy
III	Complete loss of joint space	Arthrodesis

Treatment

- **Non-Operative:**
  - Wider/extra depth toe box
  - Morton's extension foot plate limits extension of 1st MTPJ during push-off phase of gait
- **Joint Preservation operations:**
  - Cheilectomy: minimum 20% of articular cartilage should be removed to prevent failure
  - Moberg procedure: Dorsal closing wedge osteotomy of proximal phalanx
- **Joint Scarifying operations:**
  - Keller excision arthroplasty
    - Elderly low demand patients RA
    - Significant joint degeneration & loss of motion
    - Excision of proximal end of phalanx
    - Causes instability and reduced push off
    - Can cause cock-up deformity
    - High recurrence rate
  - MTP arthroplasty: NICE recommend as an option for OA and RA
    - Silastic implants - **CARTIVA** have good short-term satisfaction. Osteolysis & synovitis may cause pain
    - Capsular interposition arthroplasty can provide good pain relief
  - Fusion: Gold-standard
    - 0-5^{o} of valgus & 20^{o} dorsiflexion compared to 1st MT
    - Indications - Night pain, plantar pain, grind test positive
    - Medial approach: Prepare surfaces using ball and socket reamers
    - Remove articular surface to subchondral bone
    - Cannulated compression screw or plate (No difference in outcome)
    - Forefoot-offloading shoes for 6 weeks
    - Women will not be able to wear high heels > 1 inch

LESSOR TOES CONDITIONS

Bunionette (Tailor bunion)

- Prominence on lateral aspect of 5th metatarsal head
- **Mechanism of disease**
  - Extrinsic causes - compression of forefoot (e.g. tight shoes)
  - Intrinsic causes - congenital deformity e.g. splayfoot
  - Inflammatory arthropathy
  - Increased 4-5 intermetatarsal angle > 10^o
- **Classification:**
  - Type 1 - Enlarged Head
  - Type 2 - Congenital bowing of 5^{th} Metatarsal
  - Type 3 - Increase in 4-5 intermetatarsal angle most common
- **Treatment**
  - Padding, wide toe-box shoes
  - Lateral condylectomy: for enlarged 5th MT head or lateral exostosis
  - Chevron medialising osteotomy
  - Diaphyseal rotational osteotomy IMA > 12o
  - MT head resection - salvage
- **Complications**
  - Recurrence
  - Transfer metatarsalgia, high risk of recurrence in younger female

Overriding/overlapping 5th toe/ Crossover toe 2^{nd} toe

- Due to contraction of extensor digitorum longus or rupture of lateral collateral or rupture of volar plate
- Can affect other toes
- 2^{nd} toe moves dorsomedial to hallux
- **Management**
  - Conservative (limited role) -
    - Strapping & stretching
    - Accommodative footwear
  - Butler procedure -
    - Dorsal racket incision
    - EDL tenotomy & dorsal capsule release
    - Toe de-rotated
    - Forced correction may place tension on digital vessels.

Congenital Curly toes

- Flexion of MTPJ and IPJs
- Contracture of FDL or FDB
- Toe deviates under adjacent medial toe
- Most commonly affects 3rd and 4th toes
- Observe until they grow
- FDL/FDB release (tenotomy) in severe deformities > 4 years old

Mallet toe

- Hyper flexion of DIPJ
- Contracture of FDL
- Callosities
- **Treatment**
  - Flexible: Percutaneous FDL tenotomy
  - Fixed: DIPJ arthrodesis or excisional arthroplasty of head of middle phalanx

Hammer toe

- Most common lesser toe deformity
- Look:
  - Callosities at PIPJ
  - Extension of MTPJ & DIPJ, Flexion of PIPJ
- Move: check if correctable
- Due to tightness of EDL

- **Treatment**
  - Non-operative
    - Shoes with deep toe boxes
    - Foam or silicone gel padding for pain/corns on dorsal PIP
    - Need to correct any associated HV
  - **Flexible**
    - Extensor tendon lengthening with Z-plasty and EDB release Or FDB tenotomy if cause is tight FDB
    - Girdlestone –Taylor procedure (FDL to EDL transfer)
    - MTPJ dorsal capsule release & release of collateral ligaments
  - **Fixed**
    - Resection arthroplasty of PIPJ, Condylectomy of PP, create fibrous joint, release
    - MTPJ, hold with K wire for 6 weeks
    - PIPJ arthrodesis
  - Metatarsal shortening with oblique osteotomy (Weil's osteotomy)
    - Also used for lesser MT overload due to long MT or subluxed MTPJ
    - Oblique shortening osteotomy parallel to sole of foot
    - Slide at least 5 mm
    - Screw and K wire
    - Decompress joint - effectively lengthen soft-tissue structures
    - Doesn't plantarflex MT heads
    - Complications floating toe deformity
  - Fowler: for dislocated MTPJs in RA (II – V MT head excision)

Claw toes

- **History:** forefoot pain
- **Look:** callosities under MT heads & Hands
- Hyperextension of MTPJ due to stretching of plantar plate (primary pathology) & Flexion of PIPJ & DIPJ
- Analogous to intrinsic minus deformity in hand(EDL -MTPJ extension& FDL – IPJs flexion)

- **Causes**
  - Neuromuscular
  - RA: synovitis of MTPJ capsule – MTPJ dislocation
  - Cavus foot
  - Previous compartment syndrome

- **Types**
  - Flexible: Muscle imbalance
  - Fixed: Joint damage & ligament shortening

- **Treatment:** Same as hammer toe

NEUROLOGICAL FOOT CONDITIONS

Tarsal Tunnel Syndrome

- **History:**
  - Medial foot vague pain
  - Burning & paraesthesia
  - Worse with exercise
- **Examination:** Tinel test behind the medial malleolus
- Compression neuropathy of tibial nerve in tarsal tunnel under flexor retinaculum
- Results in weakness of foot intrinsic - Abductor hallucis and abductor digiti minimi
- **Causes**
  - Intrinsic
    - Tendon sheath ganglion
    - Tenosynovitis
    - Lipoma
    - Exostosis/osteophyte
  - Extrinsic
    - Post-operative scaring, worst prognosis
    - Flat foot
- **Borders**
  - Anterior medial malleolus
  - Lateral talus & calcaneus
  - Covered by flexor retinaculum
- **Contents** **T**ib Post F**D**L **A**rtery **V**ein **N**erve F**H**L
  (Mnemonic: **T**rained **D**octors **A**re **N**ever **H**ealthy)
- **Investigation**
  - **EMG**
    - Delayed distal motor latencies of > 7 msec
    - Prolonged sensory latencies of > 2 msec
    - Decreased amplitude of motor action potentials of abductor hallucis or ADM
  - **MRI** Space occupying lesion within the tunnel and its relation to other structures
- **Treatment**
  - Surgical release: after 3-6 months of failed conservative management 85% success in primary surgery.

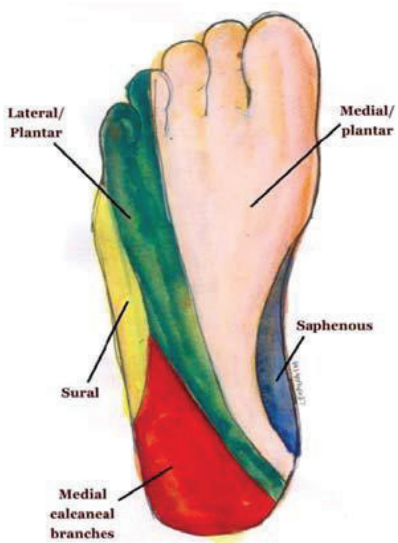
Anterior Tarsal Tunnel Syndrome

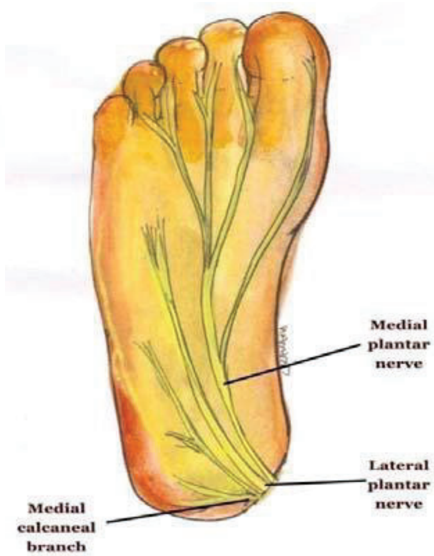
- Space defined by superior extensor retinaculum
- **Contents**: **T**ib ant E**H**L Dorsalis pedis **A**rtery Deep Peroneal Nerve E**D**L peroneus tertius
- from 1 cm proximal to ankle joint proximally to talonavicular joint distally
- **Intrinsic impingement**
  - Dorsal osteophytes over tibio-talar or talonavicular joints
  - Ganglion cyst
  - Tumour
  - Tendinitis or hypertrophic muscle belly of EHL, EDL or tibialis anterior

- **Extrinsic impingement**
  - Tight laces or ski boots
  - High heels
  - Trauma (including recurrent ankle instability)
- **Treatment**
  - Shoe modifications
  - Surgical release of DPN by releasing extensor retinaculum and osteophyte

Morton's Neuroma

- **History**
  - Pain radiating to toes
  - Tingling, numbness
  - Aggravated by shoe wear High-heeled shoe with narrow toe box
  - Feels like walking with a pebble stone inside the shoe
- **Examination**
  - Look: usually no changes
  - Feel: Tenderness in the affected web-space
  - Tests: **Mulder's clunk** - Squeeze forefoot and press in the painful web-space at the same time and see if this causes pain and clunk
- Affects 3rd and 4th inter-digital space, but never 1st
- Tibia nerve terminates as medial & lateral plantar nerves
  - Medial plantar nerve: Supplies medial three and half toes on plantar surface
  - Lateral plantar nerve: supplies everything else (Similar to ulnar nerve (supplies all intrinsic muscles of foot)





(Courtesy of L Prakash)

- **Differentials**
  - MTPJ synovitis
  - Elongated 2nd MT
    - Synovitis causes attenuation of plantar plate
    - Lead to mechanical instability and dorsal subluxation of MTPJ
    - Can lead to cross over toe or hammer toe deformity

- Plantar wart
  - Dark discoloration under MT head
  - Treated with liquid nitrogen or excision
- Metatarsalgia
  - MT head AVN
  - Stress fracture

➢ **Investigation**
- MRI: to rule out other pathology
- US: Dependant on size
- Diagnostic injection: approached dorsal after isolating neuroma with palpation or US

➢ **Treatment**
- Wide shoe box with firm sole and metatarsal pad
- Cortisone injection US-guided
- Excision

  Dorsal approach to avoid plantar scar
  - Self-retaining retractor to put tension on transverse metatarsal ligament
  - Release transverse intermetatarsal ligament nerve lies plantar to it
  - Apply plantar pressure
  - Transect 3 cm proximal to bifurcation
  - Bury proximal stump within intrinsic muscle to avoid stump neuroma
  - Send specimen to histology for confirmation of diagnosis (Shows perineural fibrosis with thickened walls, demyelination and degeneration of nerve fibre)

➢ **Complications:** stump neuroma from inadequate resection
Recurrence 10%

Foot Drop

➢ **Look**
- Splint
- Scars - hip (THR), knee (TKR, HTO)
- Wasting - peronei anterior compartment thigh
- Spine

➢ **Gait:** High-stepping gait

➢ **Move:** active then passive

➢ **Neurological exam**

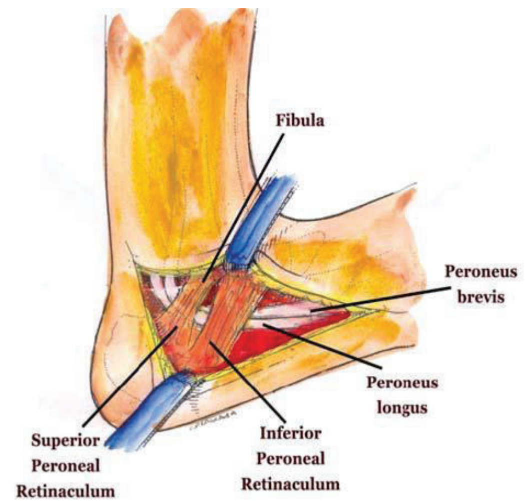
➢ **Causes**
- Peripheral nerve injury, surgery, trauma
- HSMN
- Compartment syndrome
- Lumbar radiculopathy

➢ **Management**
- Ankle foot orthosis
- Late muscle transfer if no recovery after 3 months
- In severe cases hindfoot arthrodesis may be needed to achieve a plantigrade foot

TENDON CONDITIONS OF THE FOOT AND ANKLE

Peroneal Tendons Subluxation

- **History:** Clicking, instability & pop with dorsiflexion
- **Examination:** Weak eversion
- **Peroneus longus**
  - Origin: lateral tibial condyle & head of fibula
  - Insertion: 1st MT base &medial cuneiform
  - Course: Runs behind peroneus brevis
  - Function:
    - Support transverse arch of foot
    - Plantar flex 1st ray
    - Evert foot
- **Peroneus brevis**
  - Origin: middle 1/3 of fibula
  - Insertion: base of 5th MT
  - Function: Evertor of foot
- Both supplied by superficial peroneal nerve
- **Superior peroneal retinaculum** -
  - Covers and keeps peroneal tendons contained within retro-malleolar groove of fibula
  - Attachment: posterolateral ridge of the fibula
  - Insertion: lateral calcaneus (peroneal tubercle)
  - Tears can lead to recurrent subluxation of tendons
- MRI may be used to assess the cause.
- PB is closer to the bone and fleshier distally
- **Treatment**
  - Cast, high failure rate (success rate 50%)
  - Surgical repair of retinaculum
  - Peroneal groove deepening in chronic dislocation
  - Superior peroneal retinacular reconstruction using plantaris
  - Tenodesis for chronic tears



(Courtesy of L Prakash)

Retro-calcaneal bursitis

- Inflammation of bursa between Achilles and calcaneus
- Haglund deformity - enlargement of postero-superior tuberosity of calcaneus
- External padding of Achilles tendon
- Retro-calcaneal bursa excision and resection of Haglund deformity

Achilles Tendinopathy

- Pain on resisted plantar flexion
- Formed from gastrocnemius and soleus tendons
- Inserts on middle 1/3 of posterior calcaneal surface
- Spiral tendon arrangement
  - Proximally: soleus fibers lie anterior to gastrocnemius
  - Distally : fibers rotate 90 deg (soleus fibers lie medially)
  - Facilitates elongation and release of stored energy
- **Insertional & non-insertional**
- Blood supply: Intrinsic (from muscle) & Extrinsic (Paratenon)
- Repetitive trauma leads to microscopic tearing followed by degeneration
- Watershed hypovascular area 2-6 cm above calcaneal insertion
- **Treatment**
  - Gastrocnemius-soleus stretching (eccentric training)
  - Air cast removable boot, Heel lift
  - ESWT encouraging results, better effect for non-insertional
  - Percutaneous longitudinal tenotomies
  - Debridement of diseased tendon, FHL transfer if >50% excised

Surgical options

- Insertional tendinitis
  Debridement (open/arthroscopic + excision of Haglund deformity +/- Speed bridge/Suture)
- Non insertional Tendinopathy - Arthroscopic debridement +/- FHL transfer

Achilles tendon Rupture

- Asymmetry of rest posture
- Risk factors: Fluoroquinolones, steroids, weekend worriers !
- Ruptures 2-6 cm above calcaneal insertion watershed hypovascular area
- **Treatment**
  - **Non-operative:**
    - No wound complications
    - Various regimes in practice, depends on local protocols
    - **Northampton protocol** - brace for 2 months
    - Functional brace with 3-4 wedges reduced every other week
    - AAOS - early protected weight bearing from 2 weeks
    - VTE prophylaxis due to higher risk in patients with TA rupture

Operative Vs Nonoperative treatment of acute Achilles tendon rupture

- **Operative** Meta-analysis, JBJS (2012)
  - Open operative treatment associated with lower risk of re-rupture compared with standard non-operative treatment (3 vs. 13%)
  - Higher risk of infection (4%), and disturbed skin sensibility
  - Better power and function
  - Functional bracing has equivalent results to surgery but no complications
  - Percutaneous repair associated with lower complication rate compared with open
  - Functional brace postoperatively - lower complication rate compared with cast
- **Cochrane:** Open surgical treatment reduces risk of re-rupture compared with non-surgical Higher risks of other complications, including wound infection may be reduced by performing surgery percutaneous
- **Dynamic USS -** 10 mm as a gap size at which deficits in plantarflexion strength become significantly greater (Lawrence , BJJ , 2017)
- **Repair**
  - Posteromedial incision
  - Sural nerve is posterolateral - crosses midline at 10cm above calcaneus insertion
  - 2 cm lateral at level of calcaneum
  - Accompanied by short saphenous vein
  - Paratenon repair: Krackow or Kessler repair No. 2, then vertical circumferential with 2/0
  - Paratenon repair with 2/0
  - No difference in outcome between early and late weight bearing
- Current common practice – percutaneous repair, various kits available (Echilon, PARS)
- **Chronic rupture**
  - Gastrocnemius turndown
    - Gastroc V-Y advancement plasty
    - Inverted V cut with apex at
    - musculotendinous junction
    - Limbs divergent to exit tendon
    - Incise through only superficial tendinous portion
  - FHL graft if >5 cm gap,release FHL tendon proximal to knot of Henry Transfer through calcaneus
- **Operative options:**
  - <3 cm gap: Direct repair
  - 3-5 cm gap: Gastroc V-Y advancement plasty
  - >5 cm gap: FHL graft

Tibialis Ant Tendon Rupture

- Location: anterior compartment
- Innervations: deep peroneal nerve
- Origin: tibia and IOM
- Insertion: dorsal aspect of medial cuneiform and base of 1st metatarsal
- Dorsiflex and inverts foot and adduction opposite function to Peroneus Brevis
- Occurs in middle-aged patients following eccentric loading of degenerated tib ant tendon
- The classic triad
  1. Pseudotumor at anterior part of ankle that corresponded with ruptured tendon
  2. Loss of normal contour of tendon
  3. Weak dorsiflexion of ankle accompanied by hyperextension of all toes

- **Treatment:**
  - Acute (<6 week) injuries: Direct repair
  - Chronic injuries: Reconstruction with interposition of EHL or plantaris

(Plantaris is from lateral supracondylar femur to just medial to Achilles tendon between gastrocnemius and soleus)

FHL pathology

- Impingement of flexor hallucis longus with resultant tendinosis and rupture at the posterior ankle level
- Crosses dorsal to FDL at knot of Henry fibrous connections
- Flexion can continue after harvesting FDL or FHL proximal to knot
- Can be caused by os trigonum
- Usually seen in gymnasts and dancers in pointe position and athletes
- Occasionally presents as locking / triggering of great toe with no pain
- MRI to identify tenosynovitis
- **Treatment:**
  - Arch support
  - Release FHL form fibro-osseous tunnel between posteromedial/posterolateral tubercle of talus

ACCESSORY BONES

- Accessory ossicles - secondary ossification centers that remain separated from normal bone
- **Os trigonum**
  - Trigon triangular
  - Separated posterolateral tubercle of talus
  - Present in 50% of people
  - Can cause impingement of FHL with plantar flexion of foot
  - Fracture called shepherd fracture
- **Accessory navicular**
  - Medial to navicular
  - Can be attached to navicular
  - Medial arch pain
  - Best seen on external oblique view
  - Tc bone scan increased uptake in symptomatic patients
  - MRI - demonstrate it before it ossifies
  - Management
    - Asymptomatic at skeletal maturity
    - Can result in repeated microfracture
    - Excision for recalcitrant cases that failed non-operative.
- **Os inter-metatarseum**
- **Os Sub-fibulare**, may represent avulsion fracture that secondarily ossifies or secondary ossification centre
- **Os peroneum** located in peroneus longus tendon & Seen at level of calcaneocuboid joint

OSTEOCHONDROSIS

Freiberg's Disease

- **History** : forefoot pain, 2nd MT head most common
- **Examination**:
  - Look
  - Feel: tenderness
  - Move: Reduced ROM at 2nd MTPJ
- 2nd MT head AVN
- Common in patients with longer 2nd than 1st MT due to microtrauma
- **Presenting features:** Young female, high heels
- **X-rays**: Sclerosis, flattening, fragmentation, OA
- **MRI/bone scan** in early stages

- **Treatment**
  - Stiff-soled shoe with MT bars or pads, limit physical activity
  - Short leg walking cast for 3-4 weeks
  - Dorsal closing wedge osteotomy - bring less affected plantar cartilage into contact with proximal phalanx
  - Distal MT osteotomy (excision of MT head) for severe cases

Kohler Disease

- **AVN (osteochondrosis) of navicular**
- Adult form called **Mueller Weiss syndrome:** (associated with severe pain and disability
- Last tarsal bone to ossify - might be compressed between ossified talus and cuneiforms
- Blood supply of central third of navicular is watershed zone
- Occur in children 2 – 5 years old
- Male: female 4:1
- Can be bilateral
- **Stages on X-rays**: Sclerosis, fragmentation, flattening, remodelling

- **Treatment** Self-limiting, can take 18 months & if symptomatic, cast
  Initially treated conservatively with analgesics and orthotics
  surgical treatment is fusion

Iselin

- Traction apophysitis of base of fifth metatarsal
- Due to repetitive traction of peroneus brevis tendon at site of attachment
- Rest, activity modification, icing

CONGENTIAL FOOT CONDITIONS

Syndactyly of toes

- Fusion of bone or skin in foot digits
- Most frequently occurs between second and third toes
- Incomplete or absent apoptosis during gestation
- **Two types**
  - Simple: soft tissue only
  - Complex: bony fusion present
- Rarely requires surgical release as this is an aesthetic deformity

Polydactyly of toes

- Failure of differentiation in apical ectodermal ridge during first trimester of pregnancy
- **Post-axial**
  - Lateral side of foot
  - Most common
  - Observe
- **Central:** duplication of second, third or fourth toe (Observe)
- **Pre-axial**
  - Medial side of foot
  - Ablation of extra digit

(Courtesy of S Chenow)

Brachymetatarsia

- Congenital hypoplasia of one or more metatarsals
- Shortening of 4th metatarsal is the most common
- Often bilateral
- **Treatment:**
  - Extra-depth or extra-wide shoes
  - Metatarsal lengthening if symptoms persist in older child
  - Amputation

FOOT TRAUMA

Calcaneum Fractures

Anatomy

- Posterior facet the largest
- Middle facet - Anteromedial sits on sustentaculum tali
- Anterior facet
- Sinus tarsi:
  - Between middle and posterior facets lay the interosseou sulcus (calcaneal groove)
  - Together with talar sulcus makes up sinus tarsi
- Sustentaculum tali - projects one fingerbreadth below medial malleolus and supports neck of talus
  FHL passes beneath it
- Attachments:
  - Superficial deltoid
  - Talocalcaneal ligament
  - Plantar calcaneonavicular (spring) lig
- Exclude potential associated injuries spine-proximal femur - knee- ankle

(Anatomy of the calcaneus)

Investigations

- **X-rays** Lateral, Axial (Harris)
  1. **Bohler's angle:**
     - Between anterior process to posterior facet and superior tuberosity to posterior facet
     - Normal is 25-40^{o}
     - Measured from lateral foot x-ray
     - Flattening (decreased angle) represents collapse of posterior facet
  2. **Angle of Gissane:**
     - Downward and upward slopes of the calcaneal superior surface. (Critical angle) Normal is 120-140^{o}
     - Increase represents collapse of posterior facet
- **CT:** Shortening & comminution & status of sustentacular fragment & Lateral wall

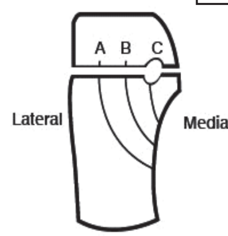
Classification

- **Extra-articular:**
  - Tuberosity
  - Anterior process and sustentaculum
  - Body
- **Intra-articular** **Essex – Lopresti**: Primary fracture line from posteromedial to anterolateral
  1. **Tongue type**:
     - Horizontal fracture through calcaneal tubercle (secondary fracture line crosses posteriorly towards the tuberosity)
     - Reduce urgently to prevent skin necrosis
     - Immobilize in plantar flexion to reduce Pressure on the skin
  2. **Joint depression**: more common

(Courtesy of M Yousef)


(Courtesy of M Meda)

- **Sanders:** Based on number of fragments at widest portion of posterior facet
  - Type I: non-displaced - regardless of fragments
  - Type II: 2 displaced fragments
  - Type III: 3 displaced fragments
  - Type IV: comminuted 4 or more fragments



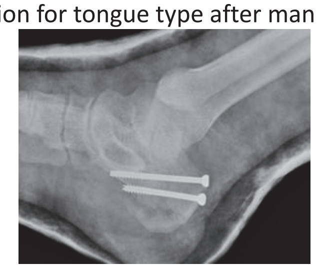
(Courtesy of Samir Hakeem)

A: Fracture lateral of posterior facet
B: fracture in middle of posterior facet
C: fracture medial to posterior facet (worst). Close to the (sustentaculum) so no enough bone to reconstruct

Treatment

- Elevation on Braun frame or pillows
- Respect soft tissue to decide optimum time for surgery, when skin wrinkle (7-14 days)
- Cryotherapy
- **ORIF**
  - For displaced tongue type (usually urgent to decompress posterior skin)
  - Widened hind foot, to avoid peroneal impingement
  - Hindfoot varus
  - Avoid in smokers, Diabetics (High risk of complications)
- **<u>Surgical Approaches</u>**
  - Extensile lateral approach (Atkins):
    - Inferior limb at junction of dorsal and plantar skin
    - Superior limb at anterior border of Achilles tendon
    - Sural N protected in superior flap halfway b/w Achilles &fibula
    - Damage causes neuroma
    - Full-thickness flap to bone to maintain soft tissue vascularity
    - Dissect sub-periosteally
    - K-wires into talus, fibula, and cuboid allow hands-free retraction
    - May divide peroneal tendons by Z-plasty and repair after fixation
  - **Sinus tarsi approach (Mini open)**
    - Between peronei and EDL
    - Detach EDB
    - Use specific plates

- **Option of fixation**
  - Low profile lateral calcaneal plate
  - Primary subtalar arthrodesis: in Sanders type III & IV +/- with ORIF to restore calcaneal height in flat Bohler's angle
    - Loss of heel height may lead to anterior tibiotalar impingement - indication for subtalar distraction arthrodesis
  - Percutaneous 2 lag screws fixation for tongue type after manipulation with K wires



(Courtesy of M Yousef)

- **<u>Complications</u>**
  - Surgical outcome correlates with number of intra-articular fragments & quality of articular reduction
    - Subtalar arthritis: treated with subtalar fusion in 5o valgus
    - Wound dehiscence & infection most common complication of surgery - 15%
    - Night pain is sign of infection
    - Varus Mal-union: treat with corrective osteotomy and Achilles tendon release
    - FHL damage with lateral to medial screws at level of sustentaculum tali
    - Sural nerve
    - Achilles tendon shortening

Evidence

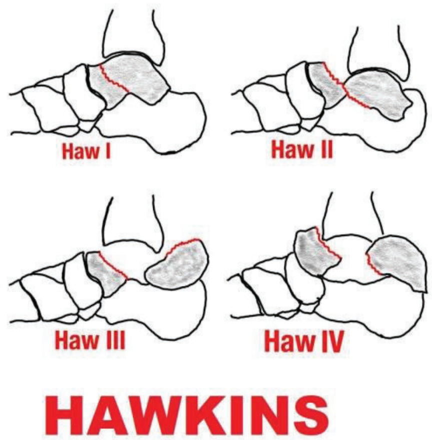
- **BMJ 2014, Griffin (Warwick) – UK heel trial**
  - No symptomatic or functional advantage of operative treatment after 2 years; however heavily criticized due to poor patient selection

- **JBJS 2002, Buckley (Canada) – RCT** Operative compared with Non-operative Treatment of displaced intra-articular calcaneal fractures - Functional results were equivalent. But patients receiving worker compensation had poor outcomes.

Talus neck fractures

- **Mechanism:** forced ankle dorsiflexion with talar neck impacting against anterior margin of tibia
- **Hawkin's classification of talus neck fractures -** help to quantify risk of AVN
  - I Non-displaced (AVN 15-20%)
    - Cast, non-weight bearing for 8 weeks
  - II Subtalar dislocation (AVN 40%)
    - Closed reduction and cast
  - III Subtalar & tibio-talar dislocation (AVN 60-100%)
    - ORIF
  - IV Subtalar, tibio-talar & talonavicular dislocation (AVN 80-100%)
    - ORIF


(Courtesy of M Elgawadi)

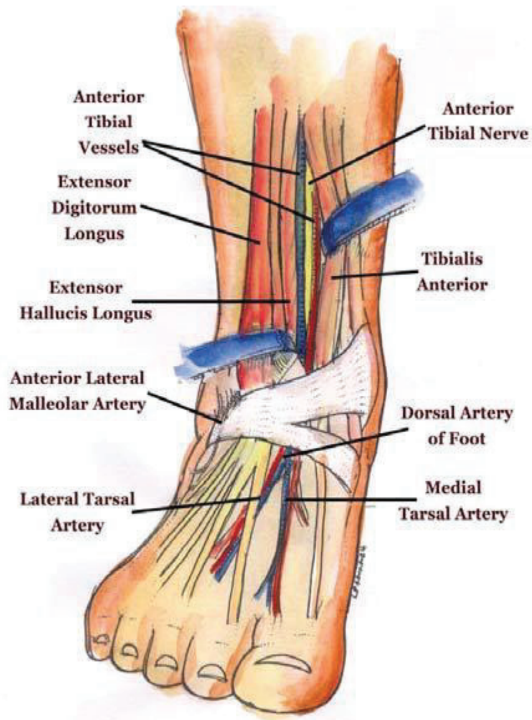


Radiographs

- Canale View
- Hawkin's sign
  - Subchondral radiolucent band in dome of talus
  - 6-8 weeks following injury
  - Good indicator of talus vascularity following a fracture.
  - Indicates that vascularity is sufficient to allow normal resorption associated with disuse osteopenia
  - Lack of Hawkin's sign with sclerosis is indicative of AVN

Management

- Surgical emergency, reduced urgently if skin compromise
- **Approach:** 2 incision approaches to visualize medial and lateral neck to assess reduction
  - **Anteromedial**
    - From medial malleolus to navicular tuberosity
    - Between Tibialis Anterior and Posterior
    - Preserve soft tissue attachments, especially deep deltoid ligament (Blood supply)
    - Medial malleolus osteotomy to preserve blood supply



- **Anterolateral -** Ollier approach
  - Between tibia and fibula proximally, in line with 4th ray
  - Between Peroneus Tertius/EDL (DPN) &Peroneus Brevis (SPN)
  - Exposure to subtalar joint, talonavicular joint and calcaneocuboid joint
  - Detach fat pad
  - Elevate extensor digitorum brevis and remove debris from subtalar joint
  - Risk of damage to superficial peroneal nerve
  - Fix with 4 mm cannulated screws or bilateral plating to maintain height and avoid varus mal-reduction
- Use titanium cannulated compression screws to allow for post op MRI
- When dislocated, risk of skin necrosis – contact plastics

Complications

- AVN (follow up for 2 years)
- Subtalar arthritis: (most common complication)
- Varus mal-union
  - leads to decreased subtalar eversion
  - Weight bearing on lateral border of foot
  - Reduced with accurate reduction and medial neck bone graft

Subtalar Dislocation

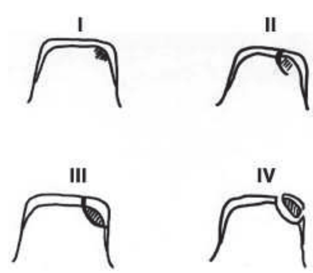
	Lateral dislocations	Medial dislocations
More Common	Open	incidence 80%
Associated fractures	▪ cuboid ▪ anterior calcaneus ▪ lateral process of talus ▪ fibula	Dorsomedial talar head posterior talus navicular
Foot will be locked	Pronated	supinated
X-ray talar head will	inferior to navicular on lateral image	superior to navicular on lateral image
Reduction blocked by	▪posterior tibialis tendon ▪flexor hallucis longus ▪flexor digitorum longus	*peroneus tendons *extensor digitorum brevis

- Closed reduction: bend knee to relax Achilles tendon.
- Open dislocation:
  - wound care
  - Reduction of dislocation
  - Trans-fixation with smooth K wire

Osteochondral Lesions of the Talus

Medial talar dome	Lateral talar dome
▪ usually no history of trauma ▪ more common ▪ more posterior ▪ larger and deeper than lateral lesions	▪ usually have a traumatic history ▪ more superficial and smaller ▪ more central or anterior ▪ lower incidence of spontaneous healing ▪ more often displaced and symptomatic

- **Berndt and Harty classification**
  - I: bone compression/subchondral fracture /bone oedema
  - II: partially detached
  - III: completely detached undisplaced
  - IV: detached and displaced
  - V: cyst formation (poor prognosis)



(Courtesy of Samir Hakeem)

- Arthroscopic fragment excision and microfracture bone marrow stimulation >1cm -ORIF
- Or osteochondral graft (mosaicoplasty) from intercondylar notch
- or non-weight-bearing surface of talus

Navicular fractures

- **Types**
  - Traumatic:
    - Dorsal ligamentous avulsion fracture of talonavicular lig
    - Tuberosity avulsion fracture of tibialis post
    - Body - Sangeorzan classification
      - Type1: undisplaced

- Type 2: displaced
- Type 3: comminuted
- Stress fracture: Non-union is common as it occurs in watershed area

➢ **Treatment**
- Displaced fractures:
  - ORIF with bridge plate, remove at 6 months to prevent stiffness
  - Cannulated screws from medial to lateral
  - Medial approach between Tib. Ant and post
- Comminuted: primary fusion of TNJ

➢ **Complications**
- AVN: Large articular surface
- Blood supply from radial arcade from dorsalis pedis and medial plantar arteries

Lisfranc Injury

➢ **Lisfranc**: Field surgeon in Napoleon army

➢ **Lisfranc joint**
- Medial column: first tarso-metatarsal joint (keystone of the roman arc)
- Middle column:
  - Second and third tarso-metatarsal joints
  - Least mobile - for rigidity during push-off
- Lateral column:
  - Fourth and fifth tarso-metatarsal joints
  - Most mobile - for walking on uneven ground

➢ Stability of midfoot during stance depends on 2^{nd} MT as centre (corner keystone) of arch

➢ **Ligaments**
- Lisfranc interosseous lig. from medial cuneiform to base of 2nd MT on plantar surface
- Plantar tarso-metatarsal ligament - stronger
- Dorsal tarso-metatarsal ligament weaker - displacement with is often dorsal
- Intermetatarsal lig

➢ Mobile joints, essential to stay mobile (4^{th} and 5th TMTJs, CCJ, TNJ)

➢ Rigid joint (1^{st}, 2^{nd} and 3^{rd} TMTJs and intercunieform joint)

➢ **Mechanism**
- Direct crush injury landing on plantar flexed forefoot
- Indirect torsional force

➢ **Classification**
- Isolated: 1st ray displaced, lateral 4 rays in place
- Homo-lateral: all rays displace in one direction
- Divergent: 1^{st} ray medial, lateral 4 rays go lateral

➢ **Examination**
- Medial plantar bruising
- Check for compartment syndrome

- **X-rays**
  - Bilateral weight bearing
  - Fleck sign: Lisfranc ligament avulsion.
  - AP view:
    - Disruption of continuity from medial border of 2nd MT to medial side of middle cuneiform
    - Widening of interval between first and second ray
  - Oblique view: Medial side of base of fourth metatarsal does not line up with medial side of cuboid
  - Lateral view: Metatarsal base dorsal subluxation
- **CT**: Bony injury
- **MRI**: Liagamentus injury

(Courtesy of H Salame)

- **Treatment**
  - Non-operative no displacement on weight-bearing and stress radiographs
  - Operative Principles: Respect soft tissues & Maintain length
  - When dislocated– treat as any fracture dislocation – reduce, temporary K-wires
  - Reduce 2^{nd} MT base, await soft tissues to settle before definitive fixation
  - ORIF approach for bony Lisfranc injuries
    - Longitudinal incision in the web space between first and second rays
    - Between EHL and EDL
    - Screws for medial and middle columns - Controversial to remove or not
    - K wires for lateral column as it has greater mobility
    - Bridging/spanning plate for comminuted fractures
    - Remove if crossing talonavicular joint as it is mobile, otherwise leave
    - In poly trauma - Reduce and stabilise to protect soft tissues and vascularity
    - Can use K wires or spanning Ex-Fix
  - Primary arthrodesis of first, second and third tarso-metatarsal joints
    - For purely ligamentous arch injuries
    - Add bone graft
  - Similar outcomes of primary fusion and ORIF

(Courtesy of M Elgawadi)

- **Complications:**
  - Arthritis
  - Non-union
  - Loss of longitudinal and transverse arches
  - Factors related to poor outcomes - accuracy of initial reduction, medico-legal claim against work

METATARSAL AND TOE CONDITIONS

- Goals of treatment: maintenance of transverse and longitudinal arch of forefoot

(Coutesy of M Elgendy)

March fracture

Stress fracture of distal metatarsals
Most commonly 2nd as it experiences more stress during gait

Jones fracture

- Transverse fracture at or just distal to articulation between 4th & 5th MT
- At metaphyseal-diaphyseal junction
- Watershed area – risk of non-union

Treatment of MT fractures

- Non-operative Below knee plaster NWB for 6/52
- Operative: Intramedullary screw fixation (Long screws can perforate cortex
  Use 4.5 mm screw to fill canal)
- ORIF:
  - First metatarsal any displacement
  - Central metatarsals sagittal plane deformity > 10O
  - >4mm translation
  - Multiple fractures

Turf Toe

- Injury to plantar plate and sesamoid complex of MTP joint of great toe
- Hyper-extension and axial loading injury of hallux MTPJ
- Can be associated with sesamoid fracture

Sesamoids

- Bones incorporated into tendons and move with tendon motion
- Absorb weight
- Reduce friction at MT head
- Fulcrum for FHB to increase flexion power
- Protect FHL
- Fibular & tibial, tibial is more commonly injured as it is larger than fibular sesamoid
- Bone scan distinguishs bipartite from fracture and exclude proximal phalanx stress fracture
- Can develop sesamoiditis in RA and Reiter and psoriasis
- Axial sesamoid view
- **MRI:** will show disruption of plantar plate/fracture / AVN
- **Treatment**
  - Stiff-sole shoe or walking boot
  - Repair sesamoid fracture with headless screw or suture
  - Sesamoidectomy in recalcitrant cases - Excision of both sesamoids can lead to
  - cock-up or claw deformity
  - Excision of tibial sesamoid can lead to hallux valgus
  - Excision of fibular sesamoid can lead to hallux varus

In growing Toe Nail (Onychocryptosis)

- Ablation: Chemical with phenol & Surgical Zadek's procedure

Puncture Wounds

- Pseudomonas: sensitive to Fluoroquinolones (Cipro)
- Surgical treatment
    - Delayed presentation with deep infection and no improvement with ABx
    - Foreign body removal
    - Tract debridement
    - Deep culture
    - Bony curettage (if osteomyelitis)
    - Packing with wick to allow for healing by secondary intention

ORTHOPAEDIC TRAUMA

AUTHORS

Mohamed Imam, Firas Arnaout, Amgad Medani and Fouad Chaudhry

CONTENTS:

SELECTED 'NICE' GUIDANCE ON FRACTURES

Initial pharmacological management of pain in adults (16 or over)

- Mild Pain: Oral Paracetamol
- Moderate pain: Oral Paracetamol and Codeine
- Severe Pain: IV Paracetamol supplemented with IV Morphine titrated to effect
    - Do not offer non-steroidal anti-inflammatory drugs to frail or older adults

Pharmacological management of pain in children with long bone fractures

- Oral Ibuprofen, or oral Paracetamol, or both for mild to moderate pain
- intranasal or intravenous opioids for moderate to severe pain

Splinting long bone fractures of the leg in the pre-hospital setting

- In the pre-hospital setting, consider the following for people with suspected long bone fractures of the legs
    - A traction splint or adjacent leg as a splint if the suspected fractures is above knee
    - A vacuum splint for all other suspected long bone fractures

Arterial injuries with fractures & dislocations

- BOAST-Management of Arterial Injuries Associated With Fractures and Dislocations
    - Life-threatening injuries first
    - Control haemorrhage by applying direct pressure/tourniquet
    - Emergent reduction and repeat examination
    - Duplex/angiography (CT or on-table)? Do not delay
    - Assume pink, pulseless limb to have an arterial injury until proven otherwise and involve vascular team
    - Devascularised limb – Urgent exploration
    - Amputation decision to be made by two consultants
    - First restore perfusion with vascular shunts, next stabilise skeleton, then vein graft
    - Low threshold for fasciotomy
- 10th edition of ATLS (Changes in C-Circulation)
    - Early use of blood transfusion
    - Infusion of more than 1.5 litres of crystalloids is associated with mortality
    - Massive transfusion defined as transfusion of ≥10 units of blood in 24 hours or ≥4 units in one hour
    - Decreased mortality when tranaexamic acid is given within three hours of injury
    - Base deficit and GCS included in the classification of shock

Fracture Clinic Services

- BOAST-Fracture Clinic Services
    - Patients should be reviewed in <72h, consultant-led (supervised)
    - A management plan should be set in <72h
    - Plaster room and x-ray facilities provided
    - Further imaging should be prompt and NOT delay surgery
    - Direct access to physio/Occupational therapy
    - CRPS should be identified early and pain clinic access available
    - Fracture Liaison services available (falls prevention / fragility # services)
    - Patient information leaflets available for common injuries
    - Facilities should allow planned admission within safe time frame set by the surgeon for those who require surgical intervention

Fracture Liaison Services

- BOAST -Fracture Liaison Services
  - Should be a part of in-patient trauma care or fracture clinics (BOAST 7).
  - Led by consultant physician or GP with osteoporosis expertise.
  - Systems in place to identify patients who are 50+ with fragility fracture.
  - Patients should have a leaflet on lifestyle, nutrition & osteoporosis.
  - Identify falls risks, and arrange a DEXA scan within 3 months.
  - Links with a metabolic bone specialist, and should update GP with all findings/advice.

Rehabilitation & Communication with Trauma Patients

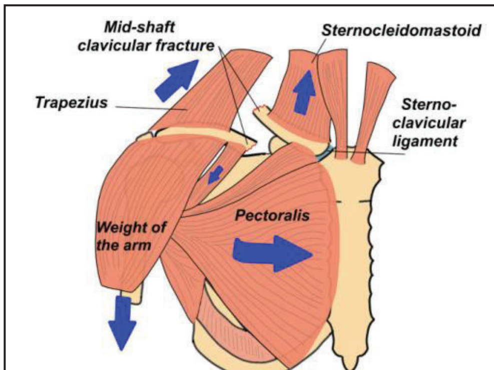
- BOAST-Rehabilitation & Communication with Trauma Patients
  - Start rehab plan within 24hrs: diagnosis, treatment, management, transfer, medication, VTE, expected goals, OPD follow-up, wound care and referrals for further care (e.g. psychological support).
  - Management plan communicated with patients and/or relatives promptly
  - Each unit should have a designated coordinator for communication & liaison.
  - Patients/carers should have at least one face-to-face meeting with their coordinator.
  - Give location information to family (e.g. phone numbers, visiting times, parking, rest areas and hotels).
  - Discuss return to work, driving, sports, etc.
  - A system in place to make contact with patients within 2 weeks of discharge to assess progress.

Fracture Related Infections (FRI)

- BOAST-Fracture Related Infections
  - Applied to patients with surgically managed fractures.
  - Every hospital must have a policy relating to the pathway management of a patient with a 'leaky' fracture fixation wound with a prompt consultant review.
  - Any patient who has signs of systemic sepsis should have a consultant-led assessment immediately.
  - Diagnostic workup: (Blood cultures/ Plain radiology to assess loosening, periosteal reaction and lysis/ Clinical photography of wound, with images available for a comparison at a subsequent review).
  - IV antibiotic treatment must not be delayed in an acutely septic patient.
  - A patient who is systemically well should be reviewed by a consultant in a clinic within 48 hours. Antibiotic treatment should not be commenced before that review.
  - If recurrent infection, discuss with the bone infection MDT team.
  - Consider ultrasound-guided aspiration of collections for culture particularly if surgery might be delayed.
  - If debridement, take 5 samples for culture. In chronic/doubtful acute infection take 2 samples for histology.
  - For stable patients, the antibiotic-free duration before sampling should be discussed with microbiology. In non-acute infections, this should be a minimum of 2 weeks.
  - Empiric antibiotics without a diagnostic workup should not be given and if already started- should be stopped.
  - Consider if metalwork can be removed if the fracture union is achieved.
  - Broad-spectrum antibiotics started after sampling. Antibiotics must be reviewed after 48 hours with culture results. Antimicrobial therapy should be narrowed and be culture-specific ASAP.
  - Hospitals should provide 24-hour Microbiology advice for drug choice, monitoring and duration.
  - The presence of infection should be considered in any patient having further surgery following initial fracture fixation for instance for a non/delayed union.

CLAVICLE FRACTURES

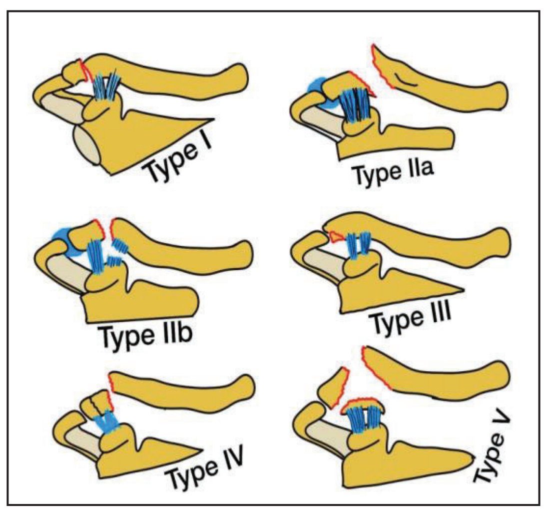
- **Midshaft Clavicle Fractures**
  - 2-4% of adult fractures
  - Open clavicle fractures have high rates of associated pulmonary and closed head injuries
  - Treatment is controversial. Majority of clavicle fractures can be managed non-operatively
  - Epiphysis ossifies at 18 years
  - Medial clavicle is last physis to close (age 20-25) - great propensity to remodel
  - Acts as fulcrum for lateral arm movements
  - Check for tenting of skin
  - Medial fragment: Sternocleidomastoid muscle pulls the medial fragment postero-superiorly
  - Lateral fragment: Pectoralis and weight of arm pull the lateral fragment infero-medially
  - Mid-shaft 75-80% of all clavicle fractures will occur in the middle third segment)
  - Neer Classification
    - Non-displaced
    - Displaced - If >100%, has non-union 5%



Deforming forces on displaced midshaft clavicle fracture

Neer Classification of Lateral 3rd Fractures

Type I	Lateral to CC ligaments (Stable)
Type IIA	Medial to CC ligaments
Type IIB	Between CC ligaments, Unstable (50% non-union)
Type III	Intra-articular Stable, but may develop ACJ arthritis
Type IV	Physeal ▪ Osteogenic capacity of intact inferior periosteal remodel ▪ CC ligaments remain attached to periosteum
Type V	Comminuted ▪ Unstable ▪ High risk of non-union (Up to 30 %)



Treatment

- **TIP**
  - Increased risk of non-union in females, elderly, and fractures >100 % displacement or >2 cm shortening (**Hill et al, JBJS Br 1997**)
  - Only predictor for non-union and increased failure in operative group is smoking (Jarvis et al 2017, JSES)
- **Sling**
  - Same functional and cosmetic results as figure of eight which causes more discomfort
  - Aim at gentle ROM exercises at 2-4 weeks and strengthening at 6-10 weeks
- **Indication for surgery**
  - Skin tenting
  - Neurovascular compromise
  - Open fracture
  - Floating shoulder (clavicle and neck of scapula)
- **Operative**
  - Superior plate Vs anterior plate
  - Higher risk of skin irritation & NV injury
  - Biomechanically higher load to failure
  - Better for inferior bony comminution
- **Canadian Trauma Society – multicentre RCT, JBJS 2007**
  - Operative fixation of displaced (> 2cm) mid-shaft clavicle fracture results in better functional outcome (faster time to union – 16 weeks in ORIF vs. 28 weeks in conservative group) and reduced non-union compared to the non-operative management (2% in ORIF vs. 7% in conservative group)
- **McKee et al JBJS (2012)**
  - Systematic review of RCTs, non-union rate (non-op 14.5% vs. 1.5% in surgical group), but only 8.5% of non-union patients are symptomatic.
- **Cochrane review (2013)**:
  - Individualization of decision (risk, benefit and patient profession) as there is insufficient evidence for op vs. non-p (complication of wound infection and hardware irritation in surgical group)
- **UK Clavicle trial, JBJS 2017**
  - Multi-centre RCT – non-union rate at 9 months, follow up of 301 patients, 11% in non-op and <1% in ORIF group (DASH, Constant score higher in operative group at 6 weeks and 3 months)
- **Leiden et al (Netherlands) JBJS Am, 2017** and **Denmark study Qvist et al, BJJ 2018**
  - Same functional results ,DASH and Constant ,at 6 months and 1 year in both non-op and surgical group
  - Surgical group required secondary removal of metalwork in 20% , and non-op group required secondary surgery in 15% for symptomatic non-union
- **Hook plate**
  - Considerations
    - Neer II
    - Removed after healing to prevent irritation of acromion or Impingement of rotator cuff.
    - Placed posterior to ACJ
  - Advantages of the Hook plate are that it is technically simple and does not disrupt the deltoid
  - Disadvantages: the plate has to be removed; osteolysis of the acromion, regeneration/ healing of ruptured CC ligaments is required to regain stability, the range of movement must be restricted until the plate is removed at 3–4 months post-operation.

- **Rehabilitation**
    - Early active motion, return to activities at 3 months
    - Hook plate range of motion restriction: No forward flexion >90° or abduction >90° until plate is removed.

➢ **Surgical techniques**
- Beach chair position
- Head tilted away on a ring to stabilize the head
- Can use DHS drape to allow easy access
- Curvilinear incision parallel to skin lines inferior to clavicle so scar does not lie directly over plate, supraclavicular sensory nerve branches identified and protected
- Carefully divide platysma to expose clavicle periosteum
- Trapezius (accessory nerve) superiorly and Pectoralis major (medial & lateral pectoral N) inferiorly
- Clavicle plate (Synthes)
- Vessels lie posterior to clavicle medially ,and inferior in middle and lateral third
- Pre-contoured Plate

➢ **Bauer et al, 2017 (OTSR)**
- In a cadaveric study reported that reconstruction plates offered superior fitting accuracy and lower implant prominence compared to pre-contoured plates.

➢ **Complications**
- Non-union
    - Significantly increased by
    - Advancing age
    - Female gender
    - Displacement > 100%
    - Comminution
    - Shortening > 2cm

Robinson & McQueen – JBJS, 2004 (Cohort study)

Prevalence of non-union at 24 weeks was 6 %
8 % of medial end fractures
4.5% of diaphyseal fractures
11.5% of lateral end fractures

Assessment

2 radiographs- 6 weeks apart showing no progress towards healing
No treatment if asymptomatic
Take non-union down
Carefully mobilize callus to prevent neurological injury

- Neurological injury
- Decreased shoulder strength & endurance in displaced mid-shaft fracture with > 2 cm shortening
- Scar pain
- Prominent metal-work
- Infra-clavicular numbness: Supraclavicular nerve 3 branches (medial, intermediate, lateral) – try to preserve
- Subclavian vein injury

STERNOCLAVICULAR JOINT

- Stability depends on ligamentous structures
- Posterior capsular ligament: Most important structure for anterior-posterior stability
- Anterior Sternoclavicular ligament: Primary restraint to superior displacement of medial clavicle
- Costoclavicular (rhomboid) ligament
- Intra-articular disc ligament prevents medial displacement of clavicle

- **Classification**
    - Atraumatic
        - Generalized ligamentous laxity
        - Reassure
    - Traumatic
        - Acute posterior
            - Dyspnoea or dysphagia
            - Reduction with cardiothoracic back up
        - Acute anterior
            - Supine with arm at edge of table
            - Abduct and extend arm while applying axial traction and direct pressure
            - Little functional impact if left untreated
    - Chronic/recurrent
        - > 3 weeks old
        - Medial clavicle excision
        - < 15 mm to preserve Costoclavicular ligament

- **Investigations**
    - Radiograph
        - Serendipity (Zanca) view
        - Anterior dislocation: Affected clavicle above contralateral clavicle
        - Posterior dislocation: Affected clavicle below contralateral clavicle
        - CT scan

- **Treatment of Chronic subluxation**:
    - Reconstruction of the SCJ ligaments using allo, Auto or Synthetic grafts

- **Tip**
    - The stability is dependent on the ligamentous structures, with anterior dislocation most common. Exclude associated pneumothorax and the injury to other vascular structures. If symptoms persist, open reduction is indicated in conjunction with a thoracic surgeon.

SCAPULA FRCATURES

Anatomical classification

- Acromion: Distinguish os acromiale from fractures of acromion
- Coracoid
- Glenoid
- Neck
- Body
- Scapulothoracic dissociation

Management

- Non-operative
  - Indicated for the majority of scapula fractures
- Operative
  - Indications
    - Gleno-humeral instability
    - Displaced scapula neck fracture > 400
    - >25% glenoid involvement
    - Displaced coracoid fracture > 1cm
    - Absolute indication for ORIF: Floating shoulder injuries

Complications

- Scapulothoracic crepitation
  - Sequelae of scapular body fracture and cause pain
- Neurovascular injury
  - Open treatment typically utilizes the posterior Judet approach, with risk of injury to the suprascapular nerve, artery and circumflex scapular artery

Surgical Approach: Judet posterior approach to shoulder

- Position
  - Lateral with arm over gutter
- Landmarks
  - Spine of scapula and acromion
- Internervous and intermuscular planes
  - Infraspinatus (suprascapular nerve) and teres minor (axillary nerve)
- Structures at risk:
  - Axillary nerve (wrong plane), suprascapular nerve (retraction)
- Extension is Limited

Scapulothoracic dissociation (STD)

- Traumatic disruption of the scapulothoracic articulation is often associated with severe neurologic injuries (90%), vascular injuries and musculoskeletal injuries; usually caused by a lateral traction injury to the shoulder girdle
- Have a great index of suspicion for Scapulothoracic dissociation with neurovascular injury with >1 cm lateral displacement of the scapula on AP Chest radiographs
- Mortality is 10% mainly because of increased risk of associated injury to the heart, chest wall, lungs, and the shoulder girdle

FLAIL CHEST

- **Definition**
  - 3 or more ribs with segmental fractures
- **Paradoxical respiration**
  - Area of injury sinks in with inspiration, and expands with expiration
- **Management**
  - Requires ORIF

- **Complications**
  - Pneumonia
  - Intercostal neuralgia
  - Alters mechanics of ventilation / causes respiratory compromise
  - Significant morbidity 33%
  - Significant mortality 12%
  - **Swart et al J Orthop Trauma 2017**
    - Meta-analysis of surgical fixation - decreased mortality; decrease mechanical ventilation times, decreased ICU and hospital stay and decreased rates of pneumonia and tracheostomy
- Marasco et al J Am Coll Surg 2013.
  Prospective RCT of operative rib fixation in traumatic flail chest.
  Flail chest: Operative rib fixation improves cost-effectiveness and clinical outcomes
- Yiu et al, J Surg Res. 2019

RCT of Surgical Rib Fixation in Polytrauma Patients with Flail Chest.

Surgical treatment of flail chest to result in less time on mechanical ventilation, less time in the ICU, lower incidence of pneumonia, acute respiratory distress syndrome, and thoracic deformity, and lower post-treatment pain scores during coughing and deep breathing compared to conservative treatment.

Management of Blunt Chest Wall Trauma

- BOAST
  - **NICE suggests that a proportion of patients will benefit from early operative chest wall stabilisation.**
  - Management should be directed by a consultant-led trauma team
  - Exclude associated chest injuries (e.g. haemothorax /pneumothorax and other life-threatening injuries)
  - Agreed protocols for resuscitative thoracotomy with suitable expertise and resources
  - CT scan with contrast should be immediately available to define chest wall injuries. 3D reconstruction images available within 24 hours if rib fractures are identified
  - Agreed guidelines for the drains, antibiotics and analgesia protocol must be available
  - Consultant-led MDT approach (surgical, anaesthetic, pain management and physiotherapy) for severe injuries
  - Persistent (> 48 h) air leak should be discussed with a thoracic surgeon
  - Surgical stabilisation indications (flail chest, respiratory compromise or inadequate pain control)

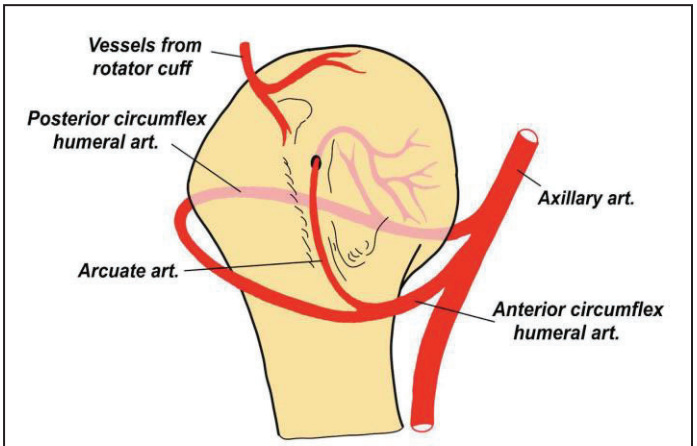
- **The joint**
  - **Primary motion**
    - Elevation & depression - Movement up and down along rib cage
    - Trapezius
  - **Secondary motions**
    - Protraction & retraction - Movement away from or toward vertebral column
    - Protraction (anterior & lateral motion) - Serratus anterior and pectoralis major & minor
    - Scapular retraction (medial motion): Rhomboid major and minor muscles

- **Plain Radiographs**
  - Laterally displaced scapula
  - Edge displaced > 1 cm from spinous process compared to contralateral side
  - Angiogram - Indicated to detect injury to subclavian and axillary artery

- **Management**
  - Thoracotomy (For vascular injury to subclavian artery)
  - Amputation: For brachial plexus injury (Forequarter amputation)

PROXIMAL HUMERUS FRACTURES

- 4-6% of all fractures
- Anatomical neck
  - Old physeal plate: Insertion site of capsule
- 80% of humerus growth comes from proximal physis – excellent remodelling potential
- Blood supply
  - Main supply is Posterior Circumflex Humeral Artery
  - Anterior circumflex humeral artery: runs parallel to lateral aspect of long head of biceps in bicipital groove



Blood supply of humeral head

- **Hertel et al JSES 2004**
  - The vascularity of articular head is preserved if ≥ 8mm of calcar is attached to articular segment
- Three most precise predictors of humeral head ischemia are
  - <8 mm of calcar length attached to articular segment (short calcar)
  - Disrupted medial hinge > 2mm
  - Basic fracture pattern – anatomical neck fracture

Neer classification

- This scheme defines the fracture according to the number of osseous parts (Codman's parts) that are displaced.
- Neer classified displacement if >10mm translation (5mm for GT) or >45^0 angulation
  - Surgical neck - most common fracture pattern (85%)
  - Greater tuberosity
  - Lesser tuberosity
  - Head
  - Shaft
- **Plain radiographs**
  - Inferior subluxation of humeral head due to deltoid atony
  - Axillary view as supraspinatus pulls fragment posteriorly
- **CT** To assess fracture configuration and look for head split (cannot reconstruct)

Management

- **Non-operative**
  - Minimally displaced
  - Paediatric
    - Due to remodelling ability and shoulder range of motion
    - Any amount of displacement in children < 6 years
    - Aim for angulation < 300 and translation <50 % in adolescents > 11 years old
    - Periosteum or biceps tendon can block reduction
    - Percutaneous pins or retrograde flexible nails
    - Collar and cuff - gravity to help reduce

(Neer - Displaced Proximal Humeral Fractures: Classification and evaluation)

- **ORIF**
  - Displacement > 1 cm or angulation > 45^0
  - 4 parts and Head splitting fracture in young
  - Anatomical neck fracture
  - Valgus impacted
  - Fracture dislocation
- Approaches
  - Delto-pectoral approach
  - Deltoid splitting for GT fractures
- Principles of fixation
  - Restore head-neck-shaft angle
  - Restore GT & LT
  - Rotator cuff repair
- **Locking plate**
  - Place lateral to bicipital groove to avoid injury to ascending Br of ACHA
  - Place inferomedial calcar screw to prevent post op varus collapse
  - Proximal Humeral Internal Locking System or cloverleaf plate
  - Avoid plate for GT due to risk of impingement
  - Use TBW or screw in young
  - Non-absorbable suture for osteoporotic bone
- **Nail**
  - Violates cuff
  - For combined proximal humerus and shaft fractures or 2 part surgical neck
  - Shoulder pain is the most common complication after surgery
  - Biomechanically inferior with torsional stress compared to plates
  - Favourable rates of fracture healing and ROM compared to ORIF

- **Hemiarthroplasty**
  - Comminuted 4-part or head splitting fracture in elderly with poor bone quality
  - Un-reconstructable in young (high demand)
  - Avoid retroversion
  - Cerclage wire passed through hole in prosthesis and tuberosities
  - Results are poor due to poor rotator cuff function
- **Orthopaedics 2014**
  - Meta-analysis, both operative & non-operative treatment can achieve similar treatment

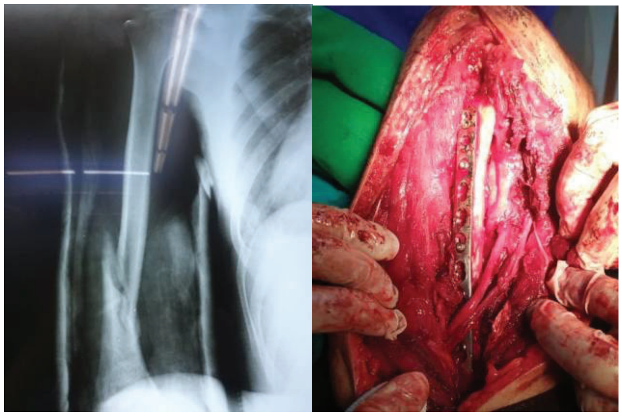
- **A. Rangan et al, PROFHER (Proximal Fracture of the Humerus Evaluation by Randomisation trial – JAMA 2015, BJJ 2017**
  - 250 patients with displaced surgical neck humerus fracture recruited and followed up to 2 years.
  - Surgical group underwent either fixation or arthroplasty.
  - Surgical group showed no significant difference when compared with nonsurgical treatment in patient-reported clinical outcomes (OSS score) over 2 year following fracture occurrence.
  - Majority of patients (85%) were 2 & 3 parts fractures with mean age of 66 years (24-92 year range).
  - Excluded patients with fracture dislocation, open fracture, comorbidities precluding surgery/anaesthesia, clear indication for surgery, severe soft tissue compromise multiple upper limb fractures), pathological fractures (other than osteoporosis)
  - Critique – Low recruitment rate (250 patients randomized from 1250 people screened), cannot generalise result to younger age group
  - The results in 5 years have not changed
- **Reverse shoulder arthroplasty:**
  - Indicated in elderly individuals with non-reconstructable tuberosities
- **Complications**
  - AVN up to 75% in 4 parts fractures
    - Higher risk when GT is detached and for anatomical neck fractures
  - Arthritis
  - Rotator cuff injury
  - Adhesive capsulitis
  - Intra-articular screw cut-out/penetration
  - Varus mal-union
- **Shukla et al JSES 2016**
  - Meta-analysis: Hemiarthroplasty vs. reverse shoulder (rTSA)
  - rTSA gives better patient outcome

Deltopectoral approach to shoulder and proximal humerus

- Position
    - Beach chair, always check fluoroscopy prior to final positioning
- Landmarks
    - Coracoid, delto-pectoral interval, lateral border biceps brachii
- Internervous/Intermuscular plans
    - Pectoralis major (medial and lateral pectoral nerves) and anterior deltoid (axillary nerve)
- Extension
    - Distally along lateral border of biceps
- Structures at risk
    - Cephalic vein, musculocutaneous nerve, axillary nerve
- **Tip**
    - Identify the long head of biceps tendon in groove to help identify greater tuberosity and lesser tuberosity. In trauma, the lesser tuberosity goes with the subscapularis

HUMERUS SHAFT FRACTURES

- **Holstein-Lewis fracture**
    - Spiral fracture of distal 3rd humeral shaft commonly associated with neurapraxia of radial nerve due to entrapment/laceration



(Courtesy of W Abd)

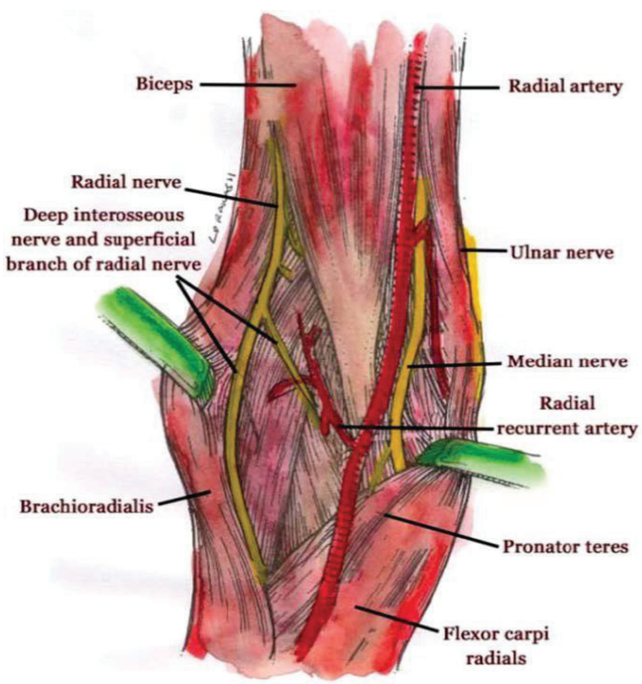
- AO classification –
    - 12 A: Simple, B: Wedge, C: Complex
- Radiographs -
    - joint above and below
- **Treatment**
    - Non-operative
        - Modalities include hanging cast, functional bracing, and plaster U splint
    - **Sarmiento JBJS Am 2000**
        - Original paper about functional bracing in 1977 ,922 patients followed up for 12 years (620 patient data, 67% follow up rate) – non-union rate of 6% in open and 2% in closed fracture
    - U slab: from shoulder to axilla - For 2 weeks followed by
    - Functional brace
        - Anterior & posterior plastic components with Velcro straps to maintain compression
        - Reduce and stabilize fracture by soft tissue compression
        - Success depends on
            - Upright patient
            - Tightening daily
            - Can't lean on elbow
            - Exercise elbow
            - Can be used for distal shaft fractures
    - Acceptable alignment
        - <30° varus/valgus angulation, <20° flexion/extension, <3 cm shortening, <15° malrotation (**Klenerman, JBJS Br 1966**)

- Operative Indications
  - Open fractures
  - Associated vascular injury requiring repair
  - Ipsilateral fractures
  - Floating shoulder or elbow
  - Bilateral humerus fractures
  - Polytrauma
  - Failure to obtain and maintain an acceptable closed reduction
  - Pathologic fractures
  - Neurologic or brachial plexus injuries
  - Intra-articular fracture or extension and unfavourable body habitus, particularly in ladies with large breasts which might act as a fulcrum at the fracture site
- Plate
  - Better union compared to nailing
  - Used with bone graft for non-union
  - Radial nerve 15 cm above lateral epicondyle
  - Significant torsional forces – fix with a compression 4.5 LC-DCP
  - Parallel plating is more stable than perpendicular .**Stoffel et al**
- IM nail
  - Better for segmental and pathological fractures
  - Antegrade: ends 2.5 cm above olecranon fossa, place a rolled pillow under shoulder to elevate
  - Retrograde: entry 2.5 cm above olecranon fossa
  - Radial nerve at risk with lateral to medial distal locking screw
  - Musculocutaneous nerve at risk with anterior-posterior locking screw
  - Flexible nail in children - Antegrade
  - **Bhandari et al Acta Orthop (2010) – meta-analysis, Cochrane review (2011)**
    - IM nailing associated with increased risk of shoulder impingement, with restriction of shoulder movement and need for removal of metalwork
- **Cochrane review (2012) – Gosler et al. from Netherlands**
  - No evidence to ascertain whether surgical intervention gives better or worse results than conservative management of humeral shaft fractures in adults.
- **McCormack, RCT published in BJJ, 2000**
  - ORIF with DCP is the best treatment for unstable fractures of shaft of humerus
  - Fixation by IMN may be indicated for specific situations
  - No difference in function but reduced complications and reoperations with DCP

- **Associated radial N palsy**
  - Most commonly stretch injury
  - Neurotmesis suspected in high energy or open fractures
  - 9 out of 10 recovers spontaneously, could take 6 months for full recovery
  - EMG at 2 months
  - Fasciculations: Observe
  - Fibrillations: Indicate Wallerian degeneration - Explore
  - Splintage and stretching to keep muscles and joint supple and tendons length
  - Monitor carefully - 1st to recover is brachioradialis and last is EIP
  - **Systematic review** – BJJ, Shao and Giannoudis from Leeds (2005)
    - Spontaneous recovery occur by 4 months in 70 %
    - No significant difference comparing managed expectantly with explored early
    - Early exploration may risk additional injury to nerve
  - EMG/NCS at 4-6 weeks and referral to nerve injury unit if no recovery by 3 months,
  - explore by 4-6 months
- **Indications for surgery in radial nerve palsy**
  - Open fracture, possibility of neurotemesis by fracture ends
  - No improvement in 6 months
  - Palsy following manipulation
  - Holstein-Lewis fracture, relative indication with higher chance of nerve entrapment (still controversial)
  - High energy fracture pattern, due to risk of sharp injury from bony fragments
- **Management**:
  - Nerve repair or graft
  - Tendon transfer if graft not possible

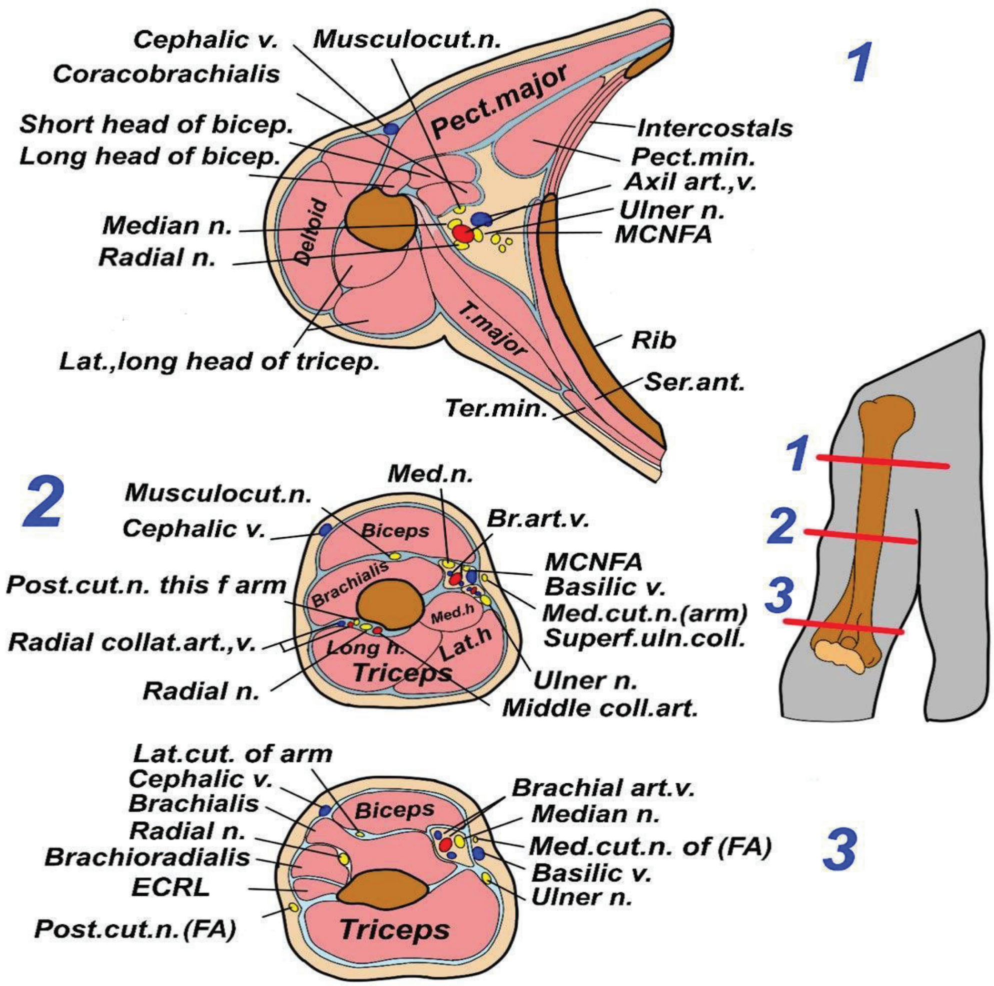
ANTEROLATERAL APPROACH TO HUMERUS

- **Indications**
  - Humerus shaft fractures proximal and middle 3rd
- **Internervous plane**
  - Proximal
    - Deltoid (axillary N) and pectoralis major (medial & Lateral pectoral N)
  - Middle
    - Interval between biceps & brachialis
    - Through brachialis: Medial (musculocutaneous Nerve) and Lateral (radial Nerve)
  - Distal
    - Brachialis & biceps retracted medially and mobile wad `(BR & ECRL & ECRB) laterally
- **Positioning**
  - Supine on arm board
- **Incision**:
  - From tip of coracoid process distally in line with deltopectoral groove along lateral aspect of humerus or more lateral along anterior border of deltoid
  - Plate placed on lateral aspect
- **Risk**:
  - Anterior circumflex humeral artery
  - Lateral cutaneous nerve of forearm (terminal branch of Musculocutaneous Nerve)
  - Radial nerve (brachialis and brachioradialis interval) place plate medial to nerve.



POSTERIOR APPROACH TO HUMERUS

- **Good** exposure to middle and distal thirds humerus
- **Positioning**:
  - Lateral with arm over padded bolster so forearm hangs downwards
  - **Always** test imaging before prepping and draping
- **Landmarks**:
  - Posterior end of acromion to olecranon
  - Olecranon, mid-posterior arm. Raphe between long and lateral heads of triceps
- **Muscle splitting**
  - No Internervous plane
  - Between long and lateral head of triceps
  - Split medial head
  - Mark ulnar / radial sides preoperatively
  - Ulnar nerve always on side of elbow facing feet
  - Pass tape around ulnar nerve to identify all the time
  - Draw/mention nerve position in related to the metalwork in operating notes
  - Retract long & lateral heads of triceps to reveal radial nerve accompanied by profunda brachii artery
  - Mobilize radial nerve and put sling
- **Extension**
  - Over olecranon along proximal ulna. Not easily extensile proximally
- **Structures at risk**:
  - Radial nerve and branches (14 cm from olecranon in spiral groove; pierces lateral Intermuscular septum 7.5 cm proximal to the radiocapitellar Joint).
  - Profunda brachii artery
- **Olecranon osteotomy**
  - For intra-articular fractures
  - Chevron - Apex distally, and through the bare area
  - Finish with osteotome, Prior drill
  - Fresh blade to avoid necrosis and thin blade to avoid bone loss
  - Fix with partially threaded cancellous screw or TBW
- **Gerwin approach**
  - Between lateral head of triceps and intermuscular septum
- **Triceps**
  - **Long head:** Infraglenoid tubercle of scapula
  - **Lateral head:** Posterior surface of humerus, superior to radial groove
  - **Medial head:** Posterior surface of humerus, inferior to radial groove
  - **Avulsion**
    - Flake sign on lateral radiograph
    - Risk factors (Steroids, Quinolones, Renal disease
- **Ljungquist et al, JSES 2012**
  - Systematic review showed better results with triceps sparing / splitting approach. Olecranon osteotomy showed complication rate of 36% and re-operation rate of 14%
- **Triceps aponeurosis flap**


1
Cephalic v.
Musculocut.n.
Coracobrachialis
Short head of bicep.
Long head of bicep.
Pect.major
Intercostals
Pect.min.
Axil art.,v.
Ulner n.
MCNFA
Median n.
Radial n.
Deltoid
T.major
Rib
Ser.ant.
Lat.,long head of tricep.
Ter.min.
2
Musculocut.n.
Cephalic v.
Med.n.
Br.art.v.
Biceps
Brachialis
MCNFA
Basilic v.
Post.cut.n. this f arm
Med.cut.n.(arm)
Superf.uln.coll.
Radial collat.art.,v.
Med.h
Long h.
Lat.h
Triceps
Radial n.
Ulner n.
Middle coll.art.
3
Lat.cut. of arm
Cephalic v.
Brachialis
Radial n.
Brachioradialis
ECRL
Post.cut.n.(FA)
Biceps
Triceps
Brachial art.v.
Median n.
Med.cut.n. of (FA)
Basilic v.
Ulner n.
1
2
3

DISTAL HUMERUS FRACTURES

- **Anatomy**
  - Hinged Joint
  - Trochlea axis is centre of rotation
    - 40^{o} anterior angulation in sagittal plane
    - Trochlea 3-8^{o} externally rotated, 4 - 8^{o} valgus
- **Classification**
  - Supracondylar
  - Intercondylar (single column)
  - Bi-columnar
- **Investigation:**
  - CT for surgical planning

- **Treatment**:
  - Undisplaced columnar
    - Immobilize in supination for lateral condyle fractures
    - Immobilize in pronation for medial condyle fractures
  - Distal intercondylar fractures are the most common variant.
  - Maintain a high index of suspicion for neurovascular injury
  - Goal to restore functional elbow range of motion: 30–130°
  - For ORIF, both parallel plating and 90–90 plating configurations are supported
  - Triceps splitting, triceps sparring/para-tricipital, and trans-olecranon osteotomies may be employed with different potential advantages and disadvantages depending on fracture configuration
  - Ulnar nerve transposition not shown to decrease incidence of ulnar nerve symptoms
  - Surgical fixation of multi fragmented, osteoporotic fractures is very challenging – consider total elbow arthroplasty

Principles of surgical fixation

- Reduce fragments and fix temporarily with K wires
- Reconstruct articular fragments
- Fix articular block to diaphysis
- Dual plate fixation, orthogonal at 90^{0} to each other (AO)
  - Dorsolateral plate
  - Medial plate on medial ridge
- Or parallel, trochlea keystone of elbow (roman arch) - The Mayo concept
- Both provide adequate biomechanical strength but most recent evidence support parallel plates
- LCP
- Rest wound and soft tissues in cast for 1 week
- Fixation secure to allow early ROM to reduce risk of stiffness

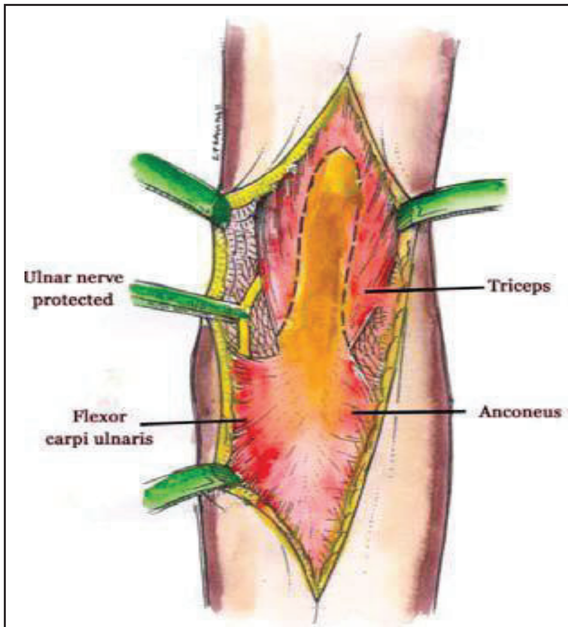
- **Total elbow arthroplasty**
  - Elderly with poor bone quality
  - Extremely difficult to reconstruct and rehabilitate multi fragmented fractures

- **COTS** (Canadian Orthopaedic Trauma Society) - McKee et al JSES 2009 RCT
    - ORIF vs. TER for displaced intra-articular distal humeral fractures in elderly, Improved function and reduced reoperation rate with TER
- **If Patient is elderly** and not a surgical candidate
    - Initial rest in plaster then mobilisation.
    - Outcomes surprisingly good in terms of ROM and function
- **Complications**
    - Hypertrophic Ossification
    - Cubitus valgus/varus
    - Stiffness (Most common complication)
        - Treatment
            - Static progressive splinting
            - Excision
            - Capsular release
            - Release of posterior band of Ulnar Collateral Ligament
- Lee et al, EJOS 2013

RCT on best biomechanical construct of Orthogonal and parallel plating methods:
Equivalent for distal humerus fracture treatment based on clinical and radiographic outcomes measured for over 2 years.

- Schemitsch et al, JSES 2017.

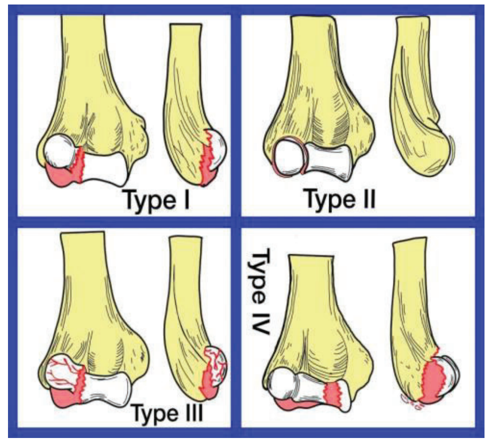
Multicenter RCT comparing ulnar decompression versus transposition in plate fixation of distal humeral fractures.
No difference in ulnar nerve symptoms, functional outcomes, sensory assessment, or nerve conduction studies over 1 -year follow-up.



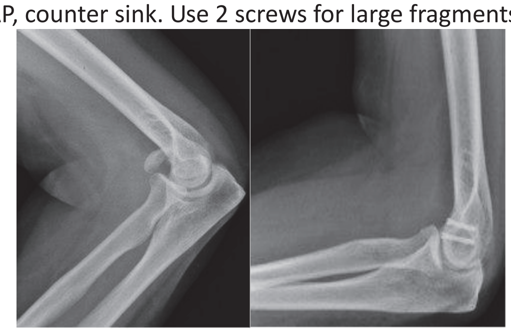
(Courtesy of L Prakash)

CAPITELLUM FRACTURES

- More common in females due to greater carrying angle and ability to hyperextend
- Simple coronal shear fractures of the capitellum are rare – Usually more complex
- High rates of elbow stiffness, but most patients are able to regain functional elbow range of motion
- Morrey classification
  - I: Large piece
  - II: Shear fracture of articular cartilage
  - III: Comminuted
  - IV: Coronal shear fracture that includes trochlea



- Treatment
  - Non-displaced and minimally displaced fracture
    - Amenable to non-operative management with initial splint and early range of motion.
  - Consider ORIF if fracture fragments are sufficiently large versus fragment excision if fracture fragments are too small or too multi fragmented to support fixation
  - Consider total elbow arthroplasty for un-reconstructable capitellum fractures in elderly patients
- Displaced
  - Lateral approach
  - Mini fragment screw, AP, counter sink. Use 2 screws for large fragments



(Courtesy of M Imam)

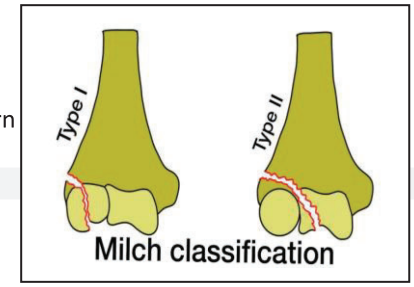
- **Complications**
  - AVN: blood supply come from posterior – avoid posterior dissection
  - Elbow stiffness, most common
  - Non-union

ORIF capitellum

LATERAL CONDYLE FRACTURES

Milch classification

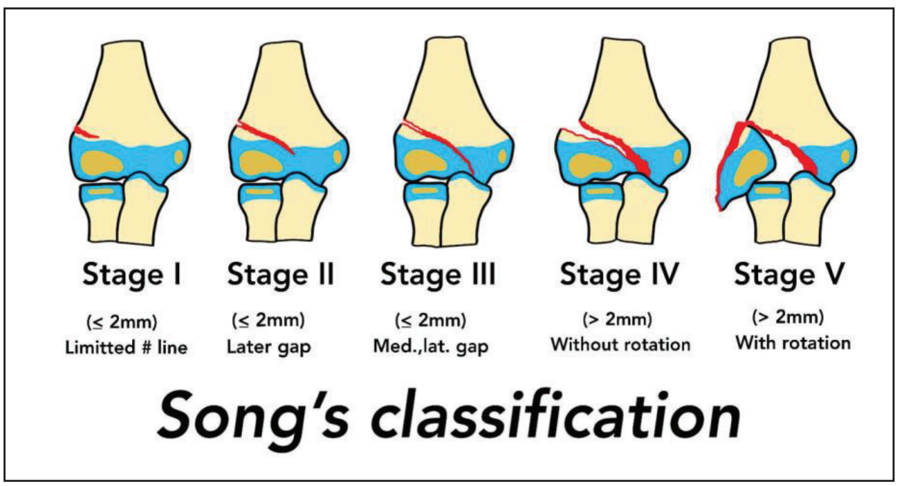
- **Type I**
  - Fracture passes through capitellum lateral to trochlear ridge, equivalent to Salter Harris type IV in children (through ossification centre of capitellum)
- **Type II**:
  - Fracture passes into trochlear notch, equivalent to Salter Harris type II in children (More common)
- **Plain Radiographs**
  - Internal rotation oblique views
- Arthrogram
  - Most accurately show maximum displacement and fracture pattern



Song classification

Based on classification in Xray view
More helpful to decide on treatment

Stage I	Fracture in metaphysic & undisplaced	Stable
Stage II	Lateral gap	Indefinable
Stage III	Lateral and medial gaps	Unstable
Stage IV	Displaced> 2 mm	Unstable
Stage V	Displaced > 2 mm & rotated	Unstable



Management

- **Children**
  - Closed reduction and 2 divergent K wires
  - Slow to heal – keep for 6 to 8 weeks - bury
  - Difficult reduction due to muscle force – open reduction
  - ORIF with compression screw for displaced fracture > 2mm - risk of non-union
  - Kocher approach
  - Intra-articular fracture - Confirm joint reduction anteriorly with arthrogram

Complications

- Cubitus valgus
  - Due to non-union or mal-union or premature physeal closure or delayed treatment
  - Consider osteotomy if deformity giving functional problems

(Courtesy of M Yousef)

- AVN
  - Posterior dissection during ORIF can damage nutrient artery
- Tardy ulnar nerve palsy
  - Slow, progressive paralysis of ulnar nerve
  - Caused by stretching seen with cubitus valgus. Occurs on average 22 years after injury
  - Treat with distal humeral osteotomy and ulnar nerve transposition
- Unsatisfactory appearance of surgical scar
- Lateral spur Does not affect ROM

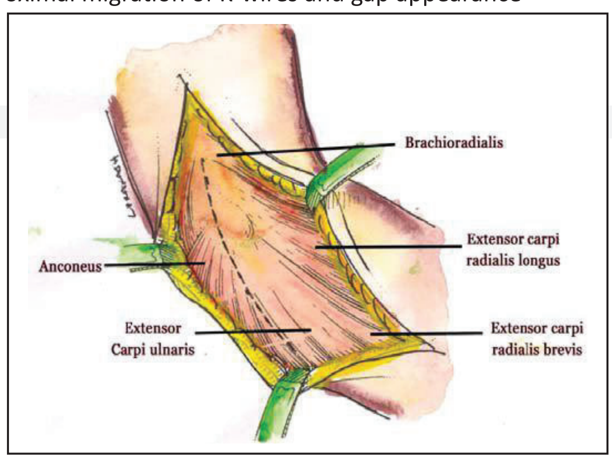
OLECRANON FRACTURES

- Triceps blends with olecranon
- Anconeus on lateral aspect, from lateral epicondyle to olecranon
- Displaced fractures of olecranon after trivial trauma in a child may be suspicious for Osteogenesis Imperfacta
- **Mayo Classification**
  - Type I: Undisplaced (Plaster)
  - Type II: Displaced stable (Tension band or intramedullary fixation)
  - Type III:
    - Comminuted or oblique (Plate)
    - Comminuted osteoporotic (Excision and triceps advancement)

Tension band wiring (TBW)

- **Principles**
  - Convert tensile forces into compression forces
  - Cannot use it in comminuted fractures – as there is no axial stability
  - Incise triceps aponeurosis
  - Between Anconeus & flexor carpi ulnaris
  - Stabilize oblique fractures first with interfragmentary screw/K-wire
  - Drill hole 4 cm distal to fracture site and 5 mm anterior to posterior cortex
  - 18 G (0.8mm) wire
  - Can use Vicryl tape in children
  - K-wire (1.6 mm) to pass as close as possible to joint
  - Iatrogenic AIN injury - protrusion of wire tips beyond anterior ulnar cortex should be no more than 1 cm
  - Intramedullary placement of wires results in proximal migration of K-wires and gap appearance

(Tension band principle)



Other treatments

- Tension Band using Sutures:
  - Orthocord instead of cerclage wire
- Intramedullary fixation:
  - Transverse fracture with no comminution
- Plate and screw fixation:
  - Comminuted fractures
  - Monteggia fractures
  - Oblique fracture that extend distal to coronoid
- Excision & triceps advancement
  - Elderly patients with osteoporotic bone and comminuted fractures or in non-union
  - Fracture must involve <50% of joint surface to fix
  - Salvage procedure that leads to decreased extension strength
  - Triceps tendon reattached with non-absorbable sutures passed through drill holes in proximal ulna
- **Complications**

- Symptomatic hardware (Most common)

RADIAL HEAD AND NECK FRACTURES

➢ Mechanism of Injury: FOOSH- axial load with a valgus force

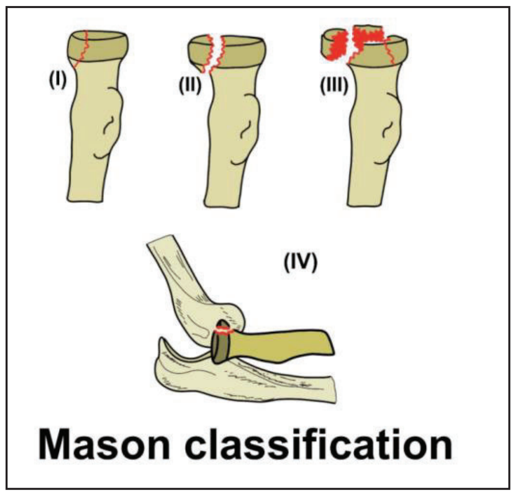
➢ Radial neck normally 15^0 valgus to shaft

➢ Radial head Biomechanics:
- Provides Valgus stability: especially if MCL deficient
- Longitudinal stability: aided by interosseous membrane
- Load Transfer: - 60% of load at elbow

➢ With radial head excision, load is transferred to ulno-humeral joint

➢ Increase risk of OA

➢ **Mason classification of radial head fractures**
- I Undisplaced
- II Displaced
- III Comminuted
- IV Associated with dislocation



(Courtesy of M Elgawadi)

➢ **Judet classification of radial neck fractures**
- I Undisplaced
- II Angulation < 300
- III Angulation 30-600
- IV Angulation $60\text{-}90^0$

➢ **Cochrane (2013)**
- Low quality evidence for radial head replacement for Mason III – as it provides better elbow function and less adverse effects

➢ **Chen et al International Orthop 2011**
Recommended using arthroplasty if >3 fracture fragments, better PROMs at 2 year follow-up.

➢ Dou et al, Orthop Traumatol Surg Res. 2015
Prosthetic replacement was found to result in significantly better post-operative excellent and good rates

<u>Essex-Lopresti</u>

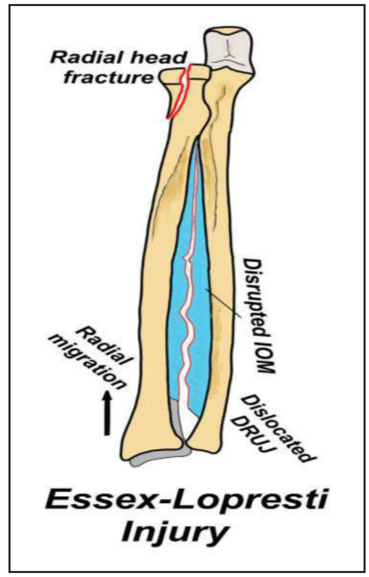
- Radial head injury with interosseous membrane disruption extending to DRUJ
  - Indicated by forearm pain
  - Must examine DRUJ in every radial head injury
  - Unstable relationship between ulna and radius leads to proximal migration of radius
  - Results in secondary DRUJ pathology and ulnocarpal abutment

➢ **X-Ray**
- Radiocapitellar (Greenspan) view

- Oblique lateral with forearm in supination and beam directed 45^0

➢ Treatment options

- Treat bony pathology (radial head or shaft)
- Pin DRUJ for 6 weeks in neutral to facilitate ligamentous healing
- Radial head excision contraindicated, Replace if necessary
- Central band of IOM is most important portion to be reconstructed
- Aspiration of joint haematoma and injection of LA
  - o Aids evaluation of mechanical block in type 2 or 3
  - o Facilitate function and early motion in type I



➢ **Closed/open reduction**

- if neck angulated > 30^0 or displaced > 4 mm reduced ROM
- MUA - Traction and varus pronate while elbow flexed to 90° and direct pressure on radial head
- Elbow in extension and apply traction and varus with forearm supinated while applying direct pressure over radial head
- K wire joystick technique (intrafocal) (risk of PIN injury!)
- **Metaizeau technique** retrograde insertion of wire/nail across the fracture site fracture reduced by rotating the wire/nail
- **ORIF** for type II with block 2 mm plates cause minimal loss of motion even when placed on radial neck

➢ **Safe Zone for implants:**

- Posterolateral portion of cartilage
- Appears yellow and thinner, non-articulating
- 90^o arc between radial styloid and Lister's tubercle

➢ **Indications for excision**

- Non-reconstructable radial head fractures
- Unsatisfactory outcome of ORIF if > 3 fragments

➢ **Contraindications for excision**

- Elbow joint unstable
  - Coronoid fracture
  - Collateral ligament rupture
- Injury to interosseous membrane or DRUJ (Essex-Lopresti) If annular ligament ruptured, repair with non-absorbable sutures

➢ **Radial head replacement**

- Vitallium prosthesis (Aseptic loosening)

- Silicon prosthesis (Risk of synovitis)
- Overstuffing joint lead to loss of extension – think of it as a spacer

- **Doornberg et al. Journal of Hand Surgery Am (2006)**
  - To prevent overstuffing, place radial head replacement 1mm proximal to lateral edge of coronoid articular surface
- Fragment excision (partial excision)
  - Fragments < 25% of surface area of radial head
  - Will exacerbate elbow/wrist instability
  - May result in proximal radial migration and ulnocarpal abutment

- Complications
  - Decreased range of motion(Loss of pronation more common than supination)
  - Radial head overgrowth (Usually does not affect function)
  - Osteonecrosis (Periosteal blood supply runs distal to proximal)
  - Synostosis (Most serious complication)

SURGICAL APPROACHES TO THE ELBOW

Medial approach

- **Indications**
  - Decompression and/or transposition of ulnar nerve
  - ORIF of coronoid process and medial humeral condyle
  - Debridement of common flexor wad for medial epicondylitis
  - Reduction of medial epicondyle fracture
- **Incision landmarks**
  - Curved incision 8 to 10 cm long on medial aspect of elbow
  - Centred over medial epicondyle
- **Internervous plane**
  - Proximally : Between brachialis (musculocutaneous nerve) and triceps (radial nerve)
  - Distally: Medial epicondyle osteotomy if needed to access joint
  - Or between pronator teres (median N) and brachialis

Anterolateral approach

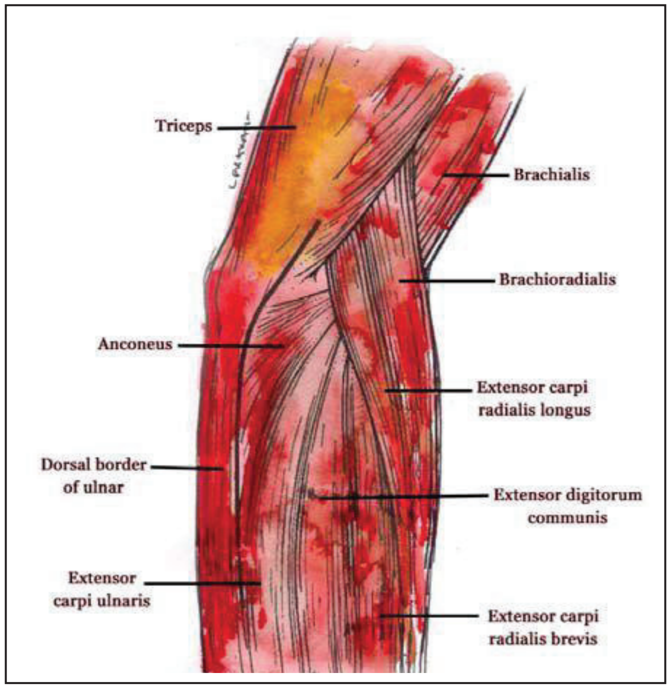
- **Indications**
  - Treatment of capitellum fracture or avascular necrosis
  - Excision of proximal radius tumour
  - Drainage of joint infection
  - Total elbow replacement
- **Landmarks**
  - Brachioradialis and biceps
  - Incision is made 5 cm above the flexion crease over the lateral border of the biceps muscle.
  - Follow the muscle laterally, curving as you cross the skin crease.
  - Then follow the medial border of brachioradialis
- **Internervous plane**
  - Proximally between the brachialis (Musculocutaneous Nerve) and the brachioradialis (Radial Nerve)
  - Distally between the brachioradialis and the pronator teres (Median Nerve)
- **Structures at risk**
  - Lateral cutaneous Nerve of the forearm
  - Radial nerve
  - The Posterior interosseous nerve
  - Recurrent branch of the radial artery
- **Cubital fossa contents**
  - Radial nerve, biceps tendon, brachial artery, median nerve (from lateral to medial)

Postero-Lateral approach - Kocher

- **Indications**
  - Access to radial head
  - LCL repair
  - Access to Coronoid
- **Landmarks**
  - 5cm longitudinal or gently curved incision based off the lateral epicondyle and extending distally over the radial head approximately
- **Internervous plane**
  - No true Internervous plane as dissection is between Anconeus (radial nerve) and extensor carpi ulnaris (posterior interosseous nerve)
- **Structures at risk**
  - PIN
    - If dissection extends beyond annular ligament
    - To protect, release the supinator posteriorly with arm in full pronation when access is needed distal to annular ligament
    - Careful placement of retractors to avoid injury to nerve
  - Radial Nerve

Kaplan lateral approach – more anterior than Kocher

- **Indications**
- Access to
  - Radial head
  - LCL repair (More difficult than Kocher)
  - Coronoid
  - Distal humerus
  - Capitellum
  - PIN decompression



- **Landmarks**
  - 4cm longitudinal incision from tip of lateral epicondyle distally towards Lister's tubercle

- **Internervous plane**
  - ECRB (radial n. or PIN) and EDC (PIN)
  - ECRB has variable innervation 50% PIN, 35% superficial, 15% radial N proper
  - Close annualr ligament to prevent instability
- **Structures at risk**
  - Posterior interosseous nerve (PIN): Protect by pronation of forearm
  - Radial nerve
  - Lateral antebrachial cutaneous nerve. Travels within subcutaneous fat at the distal aspect of the incision
  - Radial recurrent artery (recurrent leash of Henry)

CORONOID FRACTURES

- Rarely occur as isolated injuries, typically associated with elbow dislocations with risk for recurrent elbow instability
- Coronoid is the primary restraint to elbow subluxation/dislocation
- Anteromedial coronoid facet fractures may result in posteromedial rotatory instability
- Coronoid fracture with a stable elbow is amenable to non-operative management with a short period of immobilization and early elbow range of motion.
- Coronoid fractures with a stable elbow are amenable to non-operative management with a short period of immobilization and early elbow range of motion
- Coronoid fractures with elbow instability or current elbow pathology should undergo ORIF with a variety of techniques described pending the specific fracture pattern and associated pathology.
- Associated injuries/conditions
    - **Terrible triad of the elbow**
        - Coronoid fracture, radial head fracture, and elbow
    - Dislocation with LCL avulsion from humeral epicondyle
    - Olecranon fracture-dislocation
        - Often with a large coronoid fragment
    - Posteromedial rotatory instability
        - Varus force with fracture of the anteromedial facet of the coronoid and LCL disruption
    - Posterolateral rotatory instability: coronoid tip fracture, radial head fracture, LCL injury
- **Regan and Morrey Classification**
    - Type I: Tip fracture
    - Type II: Fracture ≤ 50 % coronoid height
    - Type III: Fracture > 50 % coronoid height
- **Anteromedial facet coronoid fractures**
    - Caused by varus posteromedial rotatory force

(Courtesy of M Yousef)

- **Treatment**
    - ORIF
        - If unstable, anteromedial facet fracture with posteromedial instability,fracture-dislocations, and terrible triad of the elbow
    - Options
        - Cerclage wire or suture fixation through drill, holes, retrograde screws, or plate fixation
        - Ligament repair as indicated
        - Early active motion in the postoperative period
        - Consider restricting shoulder abduction to prevent varus moment on the elbow
        - Hinged elbow external fixation
            - If poor soft tissues, poor bone quality, and complex revision cases
- **Complications**
    - Recurrent elbow instability
    - Elbow stiffness
    - Heterotopic ossification
    - Posttraumatic arthrosis

FOREARM FRACTURES

- Result from high-energy mechanisms, and are at risk for compartment syndrome
- Relationship of bicipital tuberosity and radial styloid should be 1800 on AP radiograph
- Relationship of coronoid process and ulnar styloid should be 1800 on lateral radiograph
- Radius rotates respective to ulna with axis of rotation from radiocapitellar joint to ulnar styloid
- Bony deformity will inhibit pronation and supination
- Require anatomical reduction

Monteggia fractures

- Fracture of proximal 3rd ulna with dislocation of radial head
- Rare in adults (more common in children)
- Line along radius should cut through capitellum in any view
- **Bado classification**
    - I: Anterior dislocation
        - Most common in children
        - Extension type – ulna apex anterior
    - II: Posterior dislocation (Most common in adults)
    - III: Lateral dislocation
    - IV: Both bones fracture with associated radial head dislocation
- **Equivalents**

(Courtesy of M Yousef)

    - Radial neck fracture and ulna shaft fracture
    - Radial head dislocation with plastic deformation of ulna
- **Mubarak sign**
    - Subtle ulna fracture & on lateral radiograph, ulna should be straight
- Can try MUA and see if adequate reduction and stability
- Reduce and fix ulna with plate or flexible nail and reduce radial head
- Radial head spontaneous reduction is common
- With anatomical reduction and length restoration of ulna, radial head usually reduces
- Failure to align ulna will lead to chronic dislocation of radial head
- Immobilization
    - In supination to relax biceps and in flexion > 90^0 to stabilize radial head in type 1
    - In type 2 – immobilize in extension
    - Mid-prone relax brachioradialis

- Open reduction through Kocher's approach to remove interposed annular ligament in radio-humeral joint
- Must repair annular ligament
- Ulna wedge osteotomy in plastic deformation when radial head will not reduce
- Most common complication is PIN injury
- Chronic/missed cases
  - Ulna corrective/lengthening osteotomy to reduce radial head
  - Multiple as it is multiple level deformity
- Annular ligament reconstruction
  - With (fascia lata)
  - Hold radial head with trans-capitellar K wire
  - Or excise radial head at skeletal maturity

Galeazzi

- Distal radius fracture with disruption of DRUJ
- Galeazzi fractures are unstable injuries that should undergo surgical fixation of the radius
- Distal 1/3 radial shaft fracture with associated DRUJ injury-
  - Incidence of DRUJ instability correlates with proximity of the radius fracture to the wrist.

(Courtesy of M Elgendy)

- DRUJ is most stable in supination
- **ORIF**
  - DRUJ reducible but unstable - reduce and pin in supination for 6 weeks Or fix large ulnar styloid fracture
- **Signs of DRUJ injury**
  - Ulnar styloid fracture
  - Widening/displacement of AP or lateral views
  - Radial shortening > 5 mm
- **Irreducible DRUJ**
  - Anatomic reduction is required
  - Interposed tendon or periosteum - ECU most common
  - Gap in fluoroscopy images
    - Requires open reduction to remove interposed material
    - Use dorsal approach to DRUJ
  - Always check wrist and elbow x rays
  - Immobilize in position of stability – usually in supination

(Courtesy of M Elgendy)

Both bones

- Functional results depend on restoration of radial bow
- Henry approach for middle and distal thirds
- Thompson approach for middle and proximal thirds
- Stabilize more difficult fracture
    - Tends to be radius first
- Longer plates preferred due to high torsional stress in forearm
- Absolute stability using 3.5 screws either through or separate from plate
- All both-bone forearm fractures should undergo ORIF
    - Utilize two-incision approach to decrease the risk of synostosis

Isolated ulna fracture

- Night stick fracture
    - Time to union greater in non-operative groups but clinical outcome equivalent
    - Isolated non-displaced or distal 2⁄3 ulna fractures with <50 % translation and <10° angulation are amenable to trial of non-operative management.
    - Isolated proximal 1⁄3 and distal 2⁄3 ulna fractures with greater displacement should undergo ORIF

Paediatric forearm fractures

- **MUA**
    - < 10 years   Angulated > 15 deg   rotated >45 deg
    - >10 years   angulated > 10 deg   rotated >30 deg
    - Bayonet apposition in > 10 years
- **ORIF**
    - Both bones at same level
    - Comminuted or oblique fractures
    - Proximal fractures
    - Failed MUA
    - Re-fracture
    - >13 years require anatomical reduction like adults
    - Below elbow well-moulded cast in anatomically reduced distal radius fracture would be adequate
- **Bohm JBJS, 2006 (RCT)**
    - Below elbow cast perform as well as above elbow casts in maintaining reduction of fractures in distal third of forearm in children
    - Higher risk of loss of reduction include combined radial and ulnar fractures and residual angulation of fracture after initial reduction
    - Increase stability with post-op plaster for 2 weeks
- **Cast index**
    - Sagittal/coronal cast width at fracture site
    - An index of good moulding and 3 points fixation
    - Ideal < 0.8
    - Increased index – risk of loss of reduction

- **Casting Thermal Injury**
  - Dipping water temperature > 24^0C
  - More than 8 layers of plaster used
  - During cast setting, limb placed on pillow
    - Decreases dissipation of heat
  - Fibreglass overwrapped over plaster

- **Flexible nailing of forearm fractures**
  - Age group: 7 -15 years old
  - Avoid in adults as healing slower which slows rehabilitation and less stable leading to non-union.
  - Nail always placed in retrograde approach in radius to avoid risk to PIN
    - Distal lateral incision
      - Risk of damage to superficial branch of radial nerve
    - Or Dorsal approach
      - Over Lister tubercle 2 cm proximal to distal physis
      - Risk to EPL
- In ulna nail can be inserted via antegrade (3cm distal to tip of olecranon on lateral side) or retrograde approach on radial side of ulna to avoid injury to ulnar nerve
- Nail diameter 2/3 of medullary isthmus
- Usually 2 mm in 7-11 years, and 2.5 mm in 11-15 years
- Start with more difficult fracture, usually radius
- Turn tips towards each other in supination to stretch interosseous membrane
- Removal at 4 - 6 months depending on full circumferential bone healing at fracture site
- **Complications**

	Synostosis	ORIF of both bones using single approach Treatment is excision then radiotherapy/Indomethacin
	Re-fracture	If removed < 18 months Needs protection for 3 months

- **BJJ, 1990** Removal of plates associated with complications in 40%
  - Wound sepsis
  - Poor scar,
  - Nerve injury,
  - Re-fracture
  - Growth arrest
- Colaris et al, AOTS 2013

Single-bone intramedullary fixation of unstable both-bone diaphyseal forearm fractures in children leads to increased re-displacement: a multicentre randomised controlled trial.

The single fixation groups cast immobilization period was longer (37 days vs. 22 days).

(HENRY) VOLAR APPROACH TO RADIUS

- **Indications**
  - ORIF radius
  - Decompression of superficial radial nerve

- **Internervous plane**
  - Proximally between BR (mobile wad) (radial N) and PT (Median nerve)
  - Distally between BR (radial N) and radial artery & FCR (Median nerve)

- **Incision**
  - From biceps tendon to radial styloid on ulnar side of Brachioradialis (BR)
  - Identify and protect lateral cutaneous nerve of forearm where it exits beneath lateral border of biceps
  - Superficial radial nerve & radial artery beneath BR
  - Supinate forearm to displace PIN radially
  - Incise supinator along medial edge
  - Ligate radial recurrent vessels as they can bleed when retracted
  - Pronate to detach the PT insertion of mid-shaft of radius
  - Release FPL from radial side as AIN supply come from medial

ULNA APPROACH

- **Indications**
  - Shortening procedures
  - ORIF
- **Plane**
  - Between FCU and Anconeus (radial nerve) proximally
  - Between FCU (ulnar N) and ECU (PIN) distally

FOREARM COMPARTMENTS

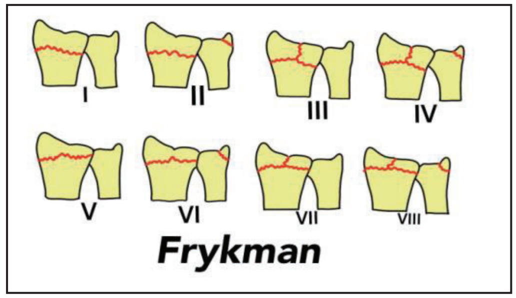
- **4 compartments**
  - Dorsal
  - Mobile wad (Henry)
  - Deep volar (Deep flexors)
  - Superficial volar (Superficial flexors)

- **Fasciotomy**
  - Volar incision
    - Starts radial to FCU at wrist and extends proximally to medial epicondyle
    - May extend distally to release carpal tunnel
    - Open fascia over FCU
    - Open fascia over deep muscles of forearm
  - Dorsal incision
    - Longitudinal incision 2cm distal to lateral epicondyle toward midline of wrist dissect interval between EDC and ECRB

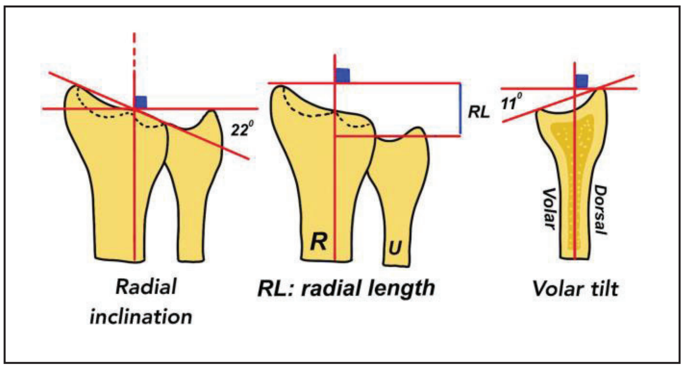
- **Post op**
  - Shoe lace technique for closure
  - VAC dressing when closure cannot be obtained
  - Follow with split-thickness skin graft

DISTAL RADIUS FRACTURES

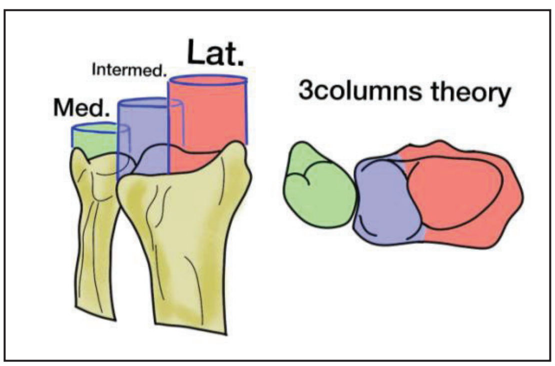
- **Classification**
  - Frykman



- **Radiographs** **Acceptable reduction (11-22-11)**
  - Volar tilt: Angle between horizontal line and line connecting volar to dorsal aspects of lunate fossa. Normal - 11^0, acceptable - neutral
  - Radial inclination: Angle between horizontal line and a line from ulnar aspect of distal radius to tip radial styloid. Normal - 22^0
  - Radial height: Distance between 2 horizontal lines, 1 at tip of radial styloid and 2nd at ulnar border of lunate fossa. Normal 11 mm



- Treatment guided by radiographic parameters, fracture pattern stability, patient age and functional demands
- **Acceptable angulation in children**
  - < 8years 20^0
  - >8 years 15^0
- **Describe 3 columns**



- **Barton fracture**
  - Displaced articular fracture of distal radius
  - Associated with carpal dislocation
  - Volar or dorsal

- **Hutchinson/Chauffeur fracture**
  - Oblique fracture of radial styloid
  - Dorsiflexion & abduction injury
  - Scaphoid forcibly impacts on radial styloid
- **Die punch fracture**
  - Depressed fracture of lunate fossa


(Courtesy of M Elgendy)

Management

- Aims
  - Restore distal radius alignment
  - Restore congruence of radiocarpal and distal radioulnar joints
  - Removable splints could be used for undisplaced fractures
  - Adequacy of reduction patient specific
  - Low demand patient experience no functional limitation even with considerable displacement
- Assessment of Instability Factors in Adult Distal Radius Fractures
  - **Nesbitt et al, J Hand Surgery 2004 (La Fontaine criteria)** (> 3 risk factors – unstable)
    - Dorsal angulation > 20^0
    - Dorsal comminution >50%, palmar or intra-articular comminution
    - Initial displacement > 1cm
    - Initial radial shortening >5mm
    - Ulna fracture
    - Osteoporosis
- At 4 weeks, 54% of those classified unstable failed to maintain adequate reduction
- Main risk of displacement is in elderly patients >60 years of age
- **The Management of Distal Radial Fractures (BOAST/BSSH Guidance)**
  - Document the mechanism of injury, skin integrity, assessment of circulation and sensation, should be documented at presentation
  - PA/Lateral views of the wrist
  - Manipulation using regional anaesthesia not local haematoma block
  - Early mobilisation in stable fractures using removable support once pain allows
  - If POP used, the wrist should be in neutral flexion with 3 point moulding - not forced palmar flexion. Consider removing the POP at 4 weeks.
  - >65 years, non-operative treatment unless there is a significant deformity / neurological compromise
  - <65 years, consider ulnar variance, intra-articular step, dorsal tilt and patient needs while considering surgical reconstruction
  - Volar displaced fractures are unstable and should be considered for ORIF
  - If fracture displacement is reduced by closed manipulation, consider K-wire fixation; if not, ORIF

- Surgery to be done within 72 hours of the injury for intra-articular fractures and within one week for extra-articular fractures
- If re-displacement following manipulation, surgery should be undertaken within 72 hours of the decision to operate
- Repeat radiographs of wrist between 1-2 weeks after injury (or manipulation) where it is thought that the fracture pattern is unstable AND when subsequent displacement will lead to surgical intervention
- Another radiograph when the POP is removed is not required unless there is a clinical cause for concern
- Patients should be assessed for falls risks and bone health, and referred to the fracture liaison services and or falls service where appropriate.
- All patients should receive information regarding expected functional recovery and rehabilitation, including advice about a return to normal activities

➢ **Indications for surgery - AAOS**
- Radial shortening >5mm (normal +10 to 15)
- Dorsal tilt > -10 degree (normal is +10 degree)
- Intra-articular displacement >2mm

➢ **Knirk, Jupiter et al. JBJS Am 1986**
- Fractures with **s**tep off $\geq$ 2mm in intra-articular fractures, caused 91% arthritis of radiocarpal joint (compared to 11% arthritis in congruent joint)

➢ **Principles**
- Articular reduction
- Restoration of anatomic relations
- Regain motion

➢ **MUA & K wiring**
- Intrafocal Kapandji
- Inter-fragmentary
- Bolster under wrist to maintain volar flexion while wiring
- For extra-articular and simple articular fracture with little dorsal comminution.
- Can lose position in fracture with dorsal/volar comminution

➢ **BMJ, 2014 RCT by Costa ML- DRAFFT (distal radius acute fracture fixation trial) study**

Multi-centre RCT of percutaneous K-wire vs. locking plate ORIF for dorsally displaced distal radius fracture (within 3cm of radiocarpal joint)

No difference in functional outcome in patients with dorsally displaced fractures of distal radius treated with K wires or volar plates including intra-articular fractures

Caveat:
- Excluded displaced intra-articular fractures and volarly displaced fractures
- Surgeon selection bias for randomization – cases were excluded from study if fracture can't be reduced closed or if surgeon though fracture might require ORIF
- Follow up of 12 months is not long enough to assess risk of arthritis

- **Ex-Fix**
  - From radius to 2nd MC
  - Bridging
  - 450 radially inclined in index MC to avoid extensor tendon
  - Aim concentrically to avoid fracture
  - Ligamento-taxis for fracture reduction
  - Can supplement with K wires
  - Over-distraction leads to stiffness
  - Radiocarpal joint should not be > 1mm wider than mid-carpal joint

(Courtesy of M Elgawadi)

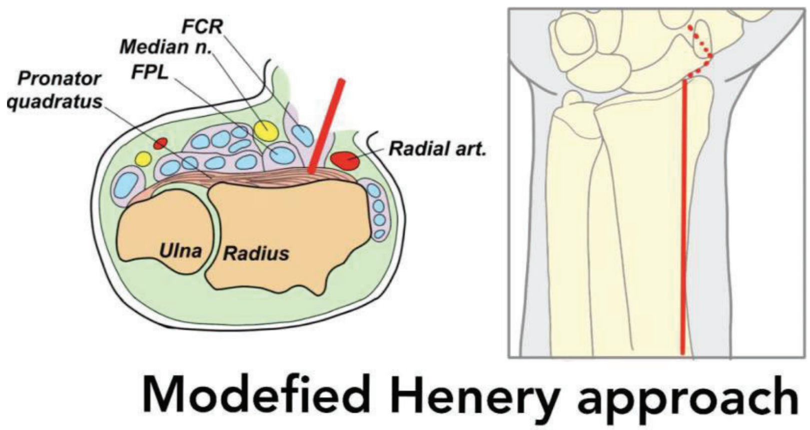
- **ORIF**
  - Variable Angle (Poly-axial) 2 column LCP
  - Can use K wire to correct radial inclination
  - Volar plating - Rupture of FPL most common complication
  - Associated with plate placement distal to watershed area (most volar margin of radius closest to flexor tendons)
  - Distal volar lunate fragment (site of origin of volar radio-lunate ligament)
  - Displacement volarly will allow lunate & carpus to subluxate volarly
  - Standard volar plate cannot capture this small distal piece without risking injury to flexor tendons - Fragment specific fixation
  - Dorsal plating (may cause extensor tendon rupture)
  - Keating et al, RCT on immobilisation post-surgery. JBJS Am 2018.
    RCT - Comparison of the effect of 1, 3, or 6 weeks of immobilization on function and pain after ORIF of distal radial fractures in adults
    1-3 week immobilization period following distal radius fracture improves early function vs. 6 weeks.

- **Complications**
  - Mal-union
    - Radius shortening
    - Ulnocarpal abutment (Ulnar shortening osteotomy)
    - Dorsal angulation (Open wedge osteotomy with bone grafting)
  - CTS: 10%
  - EPL rupture
    - Watershed area at level of Lister tubercle damaged by dorsal fragments or screws
    - Primary repair not possible due to poor tissue quality
    - Transfer of EIP - Assess by asking patient to keep index extended while other flexed
  - CRPS (Prevent with 500 mg Vitamin C daily (controversial)
  - Stiffness
  - Superficial radial nerve injury (With K wires and Ex-Fix)
  - FPL rupture (Plate should be > 2 mm from watershed line)

VOLAR FCR (MODIFIED HENRY) APPROACH

- **Indications**
  - ORIF distal radius
- **Incision**
  - Along FCR tendon
  - Don't cross perpendicular to flexion crease
  - Standard Henry approach utilises interval between FCR and radial artery

- **Internervous plane**
  - FCR (Median nerve) & FPL (AIN)
  - Incise volar then dorsal FCR sheath – modified Henry approach
  - FPL underneath
  - Displace FCR radial ward to protect radial artery and FPL ulnar ward to protect median nerve



  - Elevate PQ from radial to ulnar
  - AIN supply comes from ulnar
  - Repair to protect FPL from plate
  - Extend incision obliquely in radial direction across flexor crease
  - Continue in line with thumb ray
  - Elevate thenar musculature off volar wrist capsule open capsule if necessary

- **Risks**
  - Palmar cutaneous branch of medial nerve which runs ulnar to FCR
  - Radial artery

DORSAL APPROACH TO DISTAL RADIUS

- **Indications**
  - Wrist fusion
  - PIN neurectomy
  - Proximal row carpectomy (PRC)
  - ORIF distal radius

- **Incision**
  - 8 cm incision midline (halfway between radial and ulnar styloid)
  - Centred on Lister tubercle
  - Incise extensor retinaculum
  - Between 3rd and 4th dorsal compartments
  - Excise extensor retinaculum over 4th compartment – EDC & EIP
  - Sub-periosteal dissection & use low profile plate to reduce extensor tendons irritation

- **Risks**
  - Extensor tendons irritation and rupture (EPL)
  - Closure of extensor retinaculum underneath extensor tendons may help protect tendons from plate

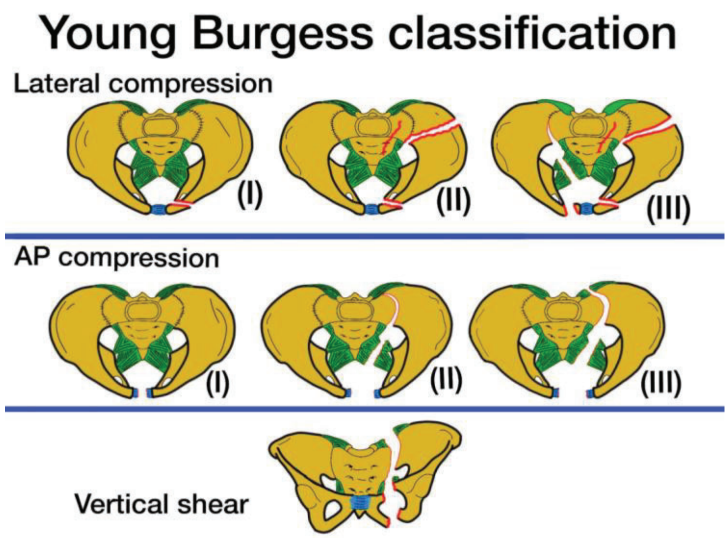
PELVIC FRACTURES

Approach

- **Examine**
  - ATLS
  - Skin
  - Neurology (Nerve root avulsion)
  - Urology
  - Vagina/rectum
- **Bleeding**
  - Venous 80%
  - Cancellous bone
  - Arterial superior gluteal (most common), cross SIJ into greater sciatic notch.
  - Internal pudendal
  - Obturator
- **Morel-Lavelle lesion**
  - Subcutaneous fluid mass indicative of subcutaneous de-gloving and fat necrosis in lumbosacral/trochanteric/thigh region
  - Risk of skin necrosis, surgical approach through it associated with high infection rate
- **Treatment**
  - Evacuate
  - Debride
  - VAC
  - Drain
  - Delayed closure
- **Pelvic ligaments**
  - Symphyseal
  - Sacrospinous (Both resist external rotation)
  - Sacrotuberous (Resists shear)
  - Sacroiliac (Strongest ligaments in body - most important ligaments for pelvic stability)
    - Anterior (Resists external rotation)
    - Posterior (Resists shear)
  - Interosseous
  - Iliolumbar
- **ASIS**
  - Origin of Sartorius and transverse and internal oblique abdominal muscles
- **AIIS**
  - Origin of direct head of rectus femoris and iliofemoral ligament (Y ligament of Bigelow)
  - Reflected head of rectus femoris from groove just above acetabulum

Classification

- **Young – Burgess (1990)**
    - **APC-Anterior Posterior Compression, Open book (Life-threatening haemorrhage)**
        - I
            - Stretching of anterior SI ligament
            - Symphysis diastasis <2.5 cm Protected W/B
        - II
            - Rupture of anterior SI, ST & SS ligament
            - Symphysis widening > 2.5 cm
            - Anterior plate Pfannenstiel approach
        - III
            - Rupture of anterior & posterior SI, ST & SS ligament
            - Rotationally and vertically unstable
            - SI screws
            - Safe zone in S1 body
        - More common in adults
    - **LC -Lateral Compression**
        - I
            - Rami & ipsilateral sacral ala fracture, protected weight bearing
        - II
            - I + ilium (SI fracture-dislocation/crescent fracture)
            - Risk of injury to internal organs/bowel entrapment - CT
            - Most common injury is head injury
            - ORIF of ilium with pelvic recon plate/ LC2 screw
        - III
            - I / II + contralateral APC
            - More common in the paediatric population
    - **VC -Vertical shear**
        - Vertical displacement of entire hemi-pelvis with anterior and posterior injury
        - Vertical fracture
        - Anterior & posterior stabilization
        - L5 transverse process fracture indicates vertical instability
        - Ischial spine fracture indicates rotational instability
        - Highest risk of hypovolemic shock
        - Skeletal traction to reduce - then SIJ screws to maintain reduction



- **Apophyseal avulsion**
  - In adolescent athletes
  - Ischial avulsion (Hamstrings)
  - ASIS avulsion
    - Sartorius
    - Smaller - Displaced anteriorly and inferiorly
    - TFL
    - Larger - Laterally displaced
  - ORIF if displaced (> 3 cm or non-union)
  - AIIS avulsion (Rectus femoris)
  - Iliac crest avulsion (Abdominal muscles)
  - If triradiate cartilage is open - iliac wing is weaker than elastic pelvic lig - bone failure before pelvic ring disruption

Radiographs

- **Judet**-To evaluate acetabulum
- **Inlet view** -For SI joint
- **Outlet view** -For vertical translation & sacral fractures
- **CT**-To define pelvic injury

Management

- BOAST guidelines (Cover pelvic and acetabular fractures)
- ATLS ABCDE
- Initial pelvic volume reduction
- Binder, sheet or external fixation
- **Pelvic binder**
  - Applied on GT to reduce pelvic volume & realign bone surfaces, venous haemostasis
  - Internal rotation of lower limbs also helped by bending knees
  - Can remain on for 24 hrs.
  - May cause skin necrosis if left longer and subsequent infection
  - Should be exchanged to Ex-fix

- **Tranaexamic acid**
  - IV within 3 hrs of injury (CRASH trial)
  - Bolus of 1gm over 10 mins, followed by a maintenance infusion of 1 g over 8 hours

- **Traction**
  - For vertical shear

- **Major haemorrhage**
  - Loss of more than one blood volume within 24 hours (>5 litres in a 70 kg adult)
  - 50% of total blood volume lost in less than 3 hours
  - Bleeding in excess of 150 ml/minute
  - If haemodynamically unstable - Activate major haemorrhage protocol with transfusion ratio of 4 RBCs: 1 FFP: 1 Platelets
  - Fibrinogen falls by 50% after 6 unites of RBCs transfusion
  - Pragmatic clinically based definition is bleeding which leads to systolic BP < 90 mm Hg or HR> 110 bpm
  - Activate via switch board 2222
  - Pelvic angiography and embolization for bleeding from internal iliac or obturator or superior gluteal arteries
  - Unstable patient shouldn't go to radiology
  - Bleeding from veins or bone can't be controlled by embolization and requires laparotomy (midline incision) and retroperitoneal packing (remove < 48hrs)
  - 3 large swaps each side placed round sacrum and posterior pelvis
  - No drain
  - I will take general surgeon with me to theatre
  - Haemorrhage is the most common cause of death

- **Urethral injury**
- **VTE**
  - Prophylaxis within 48 hrs
  - Multiple trauma patients (DVT 35-58%)
  - Pelvic fracture (DVT 20-60%)
- **Chest injury** -Most common associated injury

- **How to put ex-fix?**
  - 2 Schanz screws on each side
  - Iliac crest or supra-acetabular
  - Supra-acetabular pins don't interfere with future approaches to pelvis or acetabulum
  - Anterior can damage lateral cutaneous femoral nerve
  - Construct frame well up from abdomen
  - Should be placed before laparotomy

- Discuss with local pelvis fracture unit ASAP

- **Indications for ORIF**
  - SIJ or sacral fractures displacement > 1 cm
  - Pubic symphysis diastasis > 2.5 cm, Pfannenstiel approach
  - Open fractures
  - Consider diverting colostomy for extensive perineal or rectal injury
  - Displaced fractures in children > 2cm

- **Infix**: Anterior subcutaneous internal fixation

- **Malunion**: Pelvic asymmetry can lead to scoliosis
- Q Li et al, Injury 2016.

RCT - Retroperitoneal packing or angioembolization for haemorrhage control of pelvic fractures

In the treatment of uncontrollable haemorrhaging from pelvic fractures, mortality rates were similar between patients who received retroperitoneal pelvic packing and patients who received angioembolization therapy.

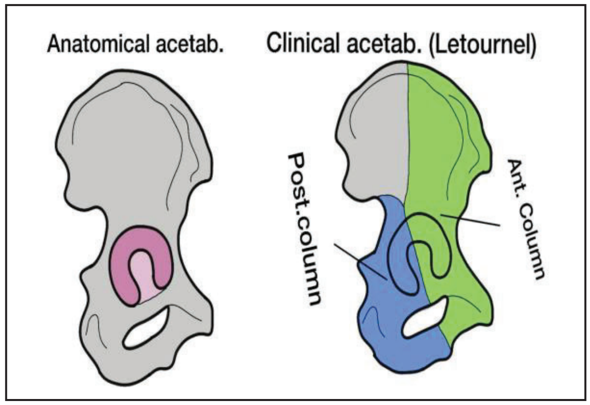
The amount of packed RBC units transfused, days in intensive care, and the postoperative complication rate were comparable between groups as well.

Pelvic external fixation

ACETABULAR FRACTURES

Anatomy and approaches

- **Inverted Y shape**
    - **Column theory – Letournel et al and Judet (2012)**
        - Posterior column (ilioischial line)
            - Quadrilateral surface (medial wall)
            - Posterior wall and dome, Posterior wall bigger on AP view
            - Ischial tuberosity
            - Greater/lesser sciatic notches
        - Anterior column (iliopectineal line)
            - Anterior ilium
            - Anterior wall and dome
            - Iliopectineal eminence
            - Lateral superior pubic ramus



- **Judet views**
    - 45^0 oblique views taken using wedge and centred on affected hip wedge
- **Obturator oblique**
    - Obturator foramen parallel to cassette – shows profile of obturator foramen
    - Shows anterior column and posterior wall
    - Spur sign in two column fractures - indicates intact part of Ilium
- **Iliac oblique**
    - Shows profile of iliac wing
    - (IOWA) Iliac Oblique Wall Anterior (and posterior column)
    - Anterior wall – trace inferior border of superior pubic ramus
    - Posterior wall – trace inferior border of inferior pubic ramus
- Dynamic fluoroscopic examination of affected hip under anaesthesia is best method of predicting hip stability

Classification

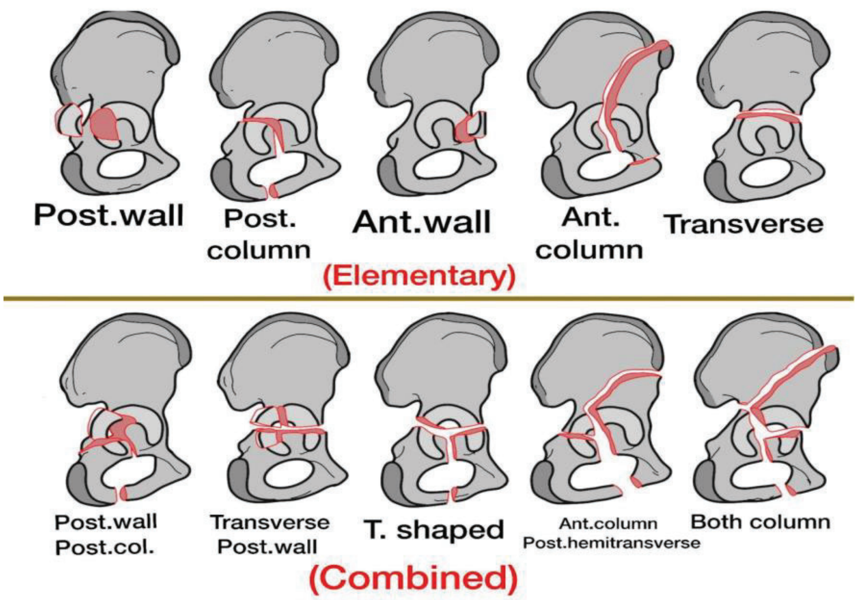
Judet – Letournel (2012)

- Elementary

Post wall	Post column	Ant wall	Ant column	Transverse
Most common	Superior gluteal NV bundle injury	More Common in elderly		The only elementary that involves both columns

- Combined

Post column + post wall	Transverse + post wall	T shaped	Transverse + anterior column/wall	Both columns
	Most common combined fracture			



Judet Letournel classification

Treatment

- **Non-operative**
  - Congruent joint (secondary congruence in elderly)
  - < 20% wall fracture
  - EUA to test stability
- **ORIF**
  - Iliofemoral approach is the only approach that allows visualization of both columns
  - Posterior (Kocher-Langenback) approach (posterior wall/column fracture)
  - Ilioinguinal approach (anterior wall/column)
- **THR** Comminuted fracture once healed can undergo THR
  Secondary OA
- **Chotai et al. Barts London (2018)**
  - Suggested radiographic parameters of poor outcome of acetabular ORIF
    - Dome impaction
    - Posterior marginal impaction
    - Femoral head damage
    - Displaced posterior wall >2cm
    - Poor post-op reduction
    - Osteopenia
- **Coccolini et al. World Society of Emergency Surgery (2017)**
  - **Grade I –** Haemodynamically and mechanically stable pelvis fracture
  - **Grade II / III –** Haemodynamically stable but mechanically unstable
  - **Grade IV –** Haemodynamically and mechanically unstable
- Pelvic x-rays and E-FAST scan to be used for patients who are not stable to go to Trauma CT (Monitor lactate and base deficit to guide resuscitation)
- Angio-embolization if positive blush on CT for WSES I-III
- Ex-fix + pre-peritoneal packing

Complications

- Postoperative CT scan is most accurate way to determine posterior wall accuracy of reduction which has greatest correlation with clinical outcome
- Functional outcomes most strongly correlate with hip muscle strength and restoration of gait
- Post-traumatic degeneration (most common complication)

BOAST 3 -Pelvic/Acetabular Fracture

- Initiate the Massive transfusion protocol (1:1:1), then either embolise/pelvic pack
- Binder initially. Change to Ex-fix if prolonged/transfer delay
- Early CT when stable
- Urgent urology input: CT/urethrography
  - If intra-peritoneal tears: Urgent repair
  - If extra-peritoneal tears: Urgent drainage
- Any open pelvic # needs cystostomy tube and diversion colostomy to upper quadrant
- Liaise with pelvic reconstruction team ASAP (definitive treatment in 5-7 days)
- Arrange for follow-up for sexual disabilities, etc.

- Hip dislocation ± acetabular fracture: reduce instantly and evaluate stability
  - Neurovascular status to be done pre- and post-skeletal traction
  - If still unstable, seek advice from a pelvic surgeon. CT within 24h, definitive treatment within 5-10 day. DVT prophylaxis within 48 hours

BOAST14-Management of Urological Trauma Associated with Pelvic Fractures

- All high energy trauma cases must have an examination of the external genitalia and perineum
- Single-pass 16F urethral catheter by an experienced doctor allowed, even if clinical or CT confirmed urethral injury – document presence of blood or not in urine
- Bloodstained urine mandates retrograde cystogram – involve urology if urethral or bladder injury confirmed
- Failure to pass urethral catheter require suprapubic catheter placed via Seldinger technique under USS-guidance using 16F silicon catheter – midline skin insertion, 3-4 finger-breadths above symphysis pubis (Or during emergency laparotomy)
- If urethral or bladder injury, then pelvic fracture should be treated like an open fracture with antibiotics for 72 hrs, and early fixation based on patient physiology
- Intra-peritoneal bladder rupture requires emergency laparotomy and direct repair
- Urethral injury in females and children need a tertiary referral as more complex
- Urethral repair is delayed for 3 months post-injury, EXCEPT: ano-rectal injury, perineal degloving, bladder neck rupture, penetrating trauma anterior urethra, massive bladder displacement (= early direct repair within 48 hrs)
- Patients with anterior displaced pelvic fractures or urethral injury should be counselled on high risk of sexual dysfunction – provide written guidance, and refer to andrological service

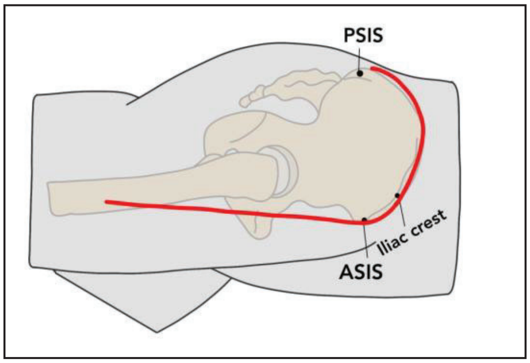
Anterior intra-pelvic (Stoppa) approach

- Access to quadrilateral plate to buttress comminuted medial wall fractures
- Insert Foley catheter to deflate the bladder
- 15 cm Transverse incision 2 cm above symphysis (Pfannenstiel)
- Split rectus abdominis along linea Alba or partially detach
- Allows middle window of ilioinguinal approach to be avoided, resulting in minimal dissection of inguinal canal, femoral nerve, and external iliac vessels
- Retropubic space (space of Retzius), extra-peritoneal space located posterior to pubic symphysis and anterior to urinary bladder
- Separated from anterior abdominal wall by transversalis fascia and extends to level of umbilicus
- Flex hip and knee to relax iliopsoas
- **Risks** To corona mortis (tie-off, otherwise it retracts), obturator nerve, bladder and iliac vessels

Iliofemoral approach

- **Indications:** Both column fractures (best approach), pelvic osteotomy, THR
- **Position:** Lateral
- **Incision:** PSIS to ASIS then in line with femur
- **Complications**
  - HO (Highest rate compared to other acetabular approaches)
  - Superior gluteal artery resulting gluteus medius necrosis

Ilioinguinal approach



- **Indications**
  - Anterior acetabular wall/column fractures
  - Both column fractures
- **Position**:
  - Supine
  - Urinary catheter
- **Incision**
  - Midline 4 cm proximal to symphysis to ASIS to anterior 2/3 of iliac crest
  - Divide aponeurosis of external oblique
  - Divide inguinal ligament and iliopectineal fascia
  - Release rectus abdominis
  - Release Iliacus muscle insertions from ilium subperiosteally to SIJ
  - Bluntly dissect plane between symphysis and bladder (space of Retzius)
  - Corona Mortis- retropubic anastomosis on lateral 3rd of superior pubic ramus
  - Ligate with Ligaclip
- **3 windows**
  - Lateral: Between iliac wing & iliopsoas (For SIJ and Ilium)
  - Middle: Between iliopsoas and external iliac vessels (For quadrilateral plate)
  - Medial: Between lymphatics/external iliac vessels & rectus abdominis (For pubis symphysis)
- **Risks**
  - Femoral nerve and artery
  - Lymphatics
  - Lateral cutaneous femoral nerve LCFN, exits under inguinal ligament
  - Spermatic cord
  - Inferior epigastric artery
  - Genitofemoral nerve

SACRAL FRACTURES

- Commonly comprise part of a pelvic ring injury
- Frequently missed
- 25% associated with neurological injury - most important factor in predicting outcome
- L5 nerve root runs on top of sacral ala
- S1-S4 nerve roots transmitted through sacral foramina
- S1 and S2 nerve roots carry higher rate of injury
- S2-S4 function
    - Anal sphincter tone / voluntary contracture
    - Bulbocavernosus reflex
    - Perianal sensation
    - Unilateral preservation of nerves adequate for bowel and bladder control
    - 25 % associated neurologic injury with increased risk in transforaminal, medial/spinal canal, transverse, and U-type sacral fractures.
- Stable injuries with incomplete sacral fractures can mobilize as tolerated
- Minimally displaced complete sacral fractures may be treated with protected weight bearing
- Unstable, displaced sacral fractures should undergo reduction and stabilization ± decompression with careful technique to avoid iatrogenic nerve injury

Denis classification

- I: (Lateral to foramina)
    - Ala fracture - most common
- II: (Through foramina)
    - Fracture with shear component - highly unstable
    - Increased risk of non-union and poor functional outcome
- III: (Medial to foramina)
    - Longitudinal, through spinal canal. Highest rate of neurologic deficit
    - Transverse, High incidence of nerve dysfunction

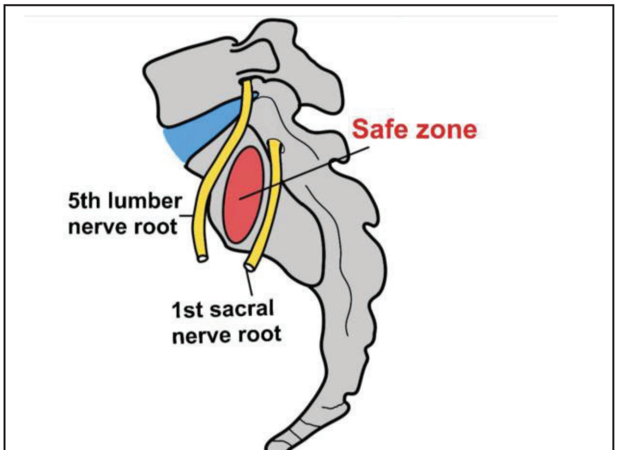
Radiographs

- Asymmetry of foramina
- Insufficiency fracture, Honda sign
- Outlet view - provides true AP of sacrum
- Lateral view for displacement of transverse fractures

Fixation

- Percutaneous SI fixation
    - Screws placed percutaneously under fluoroscopy
    - Beware of L5 nerve root as over compression of fracture can cause iatrogenic nerve dysfunction
- Posterior tension band plating (Posterior two-incision approach)
- Iliosacral & lumbopelvic fixation
    - Have greatest stiffness for unstable sacral fracture
    - Post-op CT to evaluate reduction and metal-work placement

- Vertical sacral fractures at increased risk for loss of reduction/fixation with resulting non-union, mal-union, and poor functional outcomes.
- Sacral U fractures are unstable injuries that represent spino-pelvic dissociation and require stabilization
- SI joint injury
  - Incomplete:
    - Posterior ligament intact
    - Rotationally unstable
  - Complete
    - Posterior ligament injured
    - Rotationally and vertically unstable
  - Fracture dislocation (crescent fracture)
    - Combination of vertical iliac fracture and
    - SI dislocation
    - Ilium remains attached to sacrum by posterior SI ligament
    - Ilium fragment termed crescent fracture



Safe zone for placement of iliosacral screw

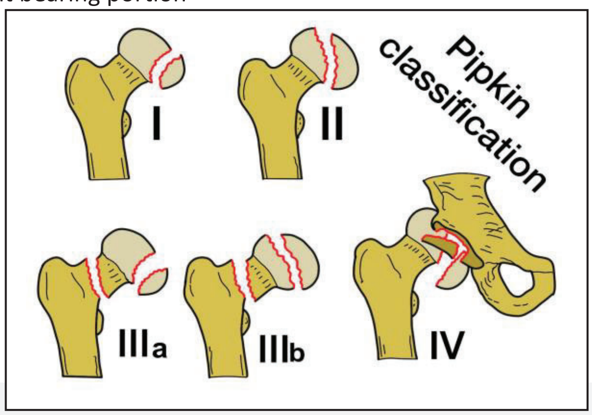
HIP DISLOCATION & FEMORAL HEAD FRACTURES

- **History:**
  - Dashboard injury
- **Examination**
  - PCL
  - Typically associated with hip dislocations
  - Position of the hip at the time of dislocation determines the location and size of the femoral head fracture
- **Types:**
  - Posterior (90%)
  - Anterior

Pipkin classification

Scrutinize femoral neck to rule out fracture prior to attempting closed reduction

- **I:** Below fovea (ligamentum teres), does not involve weight bearing portion
- **II:** Above fovea
- **III:** Head & neck fractures
- **IV**: Head & acetabulum fractures, usually posterior wall



Treatment goals

- Restore congruity of the weight-bearing portion of the femoral head
- Restore hip stability
- Remove incarcerated fragments
- Address associated femoral head and acetabular fractures appropriately

Management

- BOA guidelines (for acetabular fractures)
- Immediate reduction, prior to transfer to specialist unit
- Apply traction in line with deformity
- Screen to exclude femoral neck fracture, Closed reduction contraindicated if present
- Bigelow manoeuvre - flex, adduct, internal rotation with traction
- Recheck sciatic nerve
- Traction if unstable

- **Post reduction CT** to look for
  - Femoral head fractures
  - Loose bodies
  - Acetabular fracture
  - Non-concentric reduction-Explore to remove entrapped labrum, capsule, osteochondral fragment or ligamentum teres
- Open reduction should be done by hip & pelvic surgeon (BOA guidelines)
- Anterior (Smith-Peterson) and anterolateral
- (Watson-Jones) approaches provide best visualization of head in isolated fractures
- Or trochanteric osteotomy if associated with acetabular fracture
- Two or more 2.7mm or 3.5mm lag screws countersunk to avoid screw head prominence
- Add DHS for type III
- Excise fragment if small and not affect hip stability and not in weight-bearing dome
- For posterior wall fracture
  - Posterior approach dividing short external rotators and quadratus 1 cm from insertion to protect ascending branch of MCFA
- 2nd ilioinguinal or Stoppa approach for anterior wall
- Toe touch weight bearing creates lower JRF than non-weight bearing

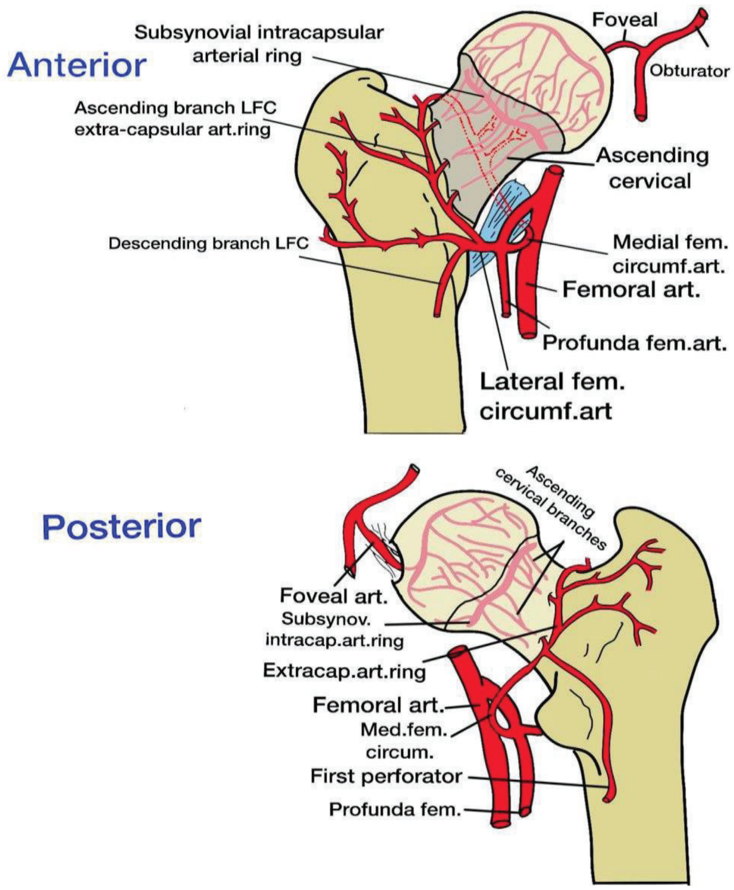
Complications

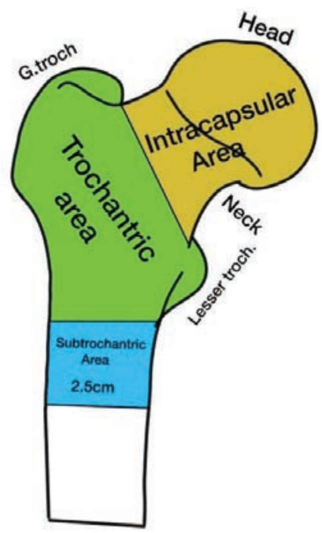
- AVN: Up to 40%, Increased with delayed reduction
- Coxa magna: In children, Not associated with functional limitation
- Arthritis: 20 %
- Sciatic N injury: 20 %, Traction injury

Take home message

- Smith-Peterson approach favoured when possible for not increasing the risk of AVN and providing good access to most femoral head fractures
- Risk of AVN greatest in Pipkin III fractures as related to the degree of displacement of the associated femoral neck fracture
- Increased risk of AVN with delay in reduction of associated hip dislocation
- May consider arthroplasty in older patients and multi fragmented fractures which are not amenable to primary reconstruction

INTRACAPSULAR HIP FRACTURES





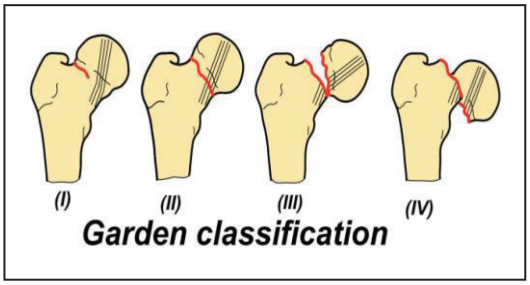
Blood supply of femoral head

- Medial epiphyseal artery from obturator artery via ligamentum teres
- Medial & lateral circumflex femoral arteries from profunda femoris, medial is the main one ,emerges from under the quadratus femoris and goes posterior to femoral neck
- Form extra-capsular arterial ring around base of trochanters giving off ascending cervical retinacular arteries
- Medial at risk when doing iliopsoas tenotomy, courses between iliopsoas and pectineus
- Intramedullary supply from shaft and metaphysis
- < 4 years All 3 arteries
- 4 – 10
    - Physis: acts as a barrier to metaphyseal and epiphyseal blood supply
    - Metaphyseal blood supply from extra-capsular arterial ring, ascending cervical arteries and sub-synovial intra-articular ring
    - Epiphyseal supply: from medial epiphyseal (from ligamentum teres, but still not developed enough between 4-10 years, to provide blood supply to prevent AVN) and lateral epiphyseal (from MCFA)
- Associated injuries
    - 5–10 % of femoral shaft fractures have an associated femoral neck fracture
    - ~30 % of femoral neck associated with femoral shaft fractures are missed upon initial presentation

- When clinically suspecting hip fracture but X rays not conclusive, request MRI (BOA/NICE guidelines)
- In young patient ask for full length femoral radiograph

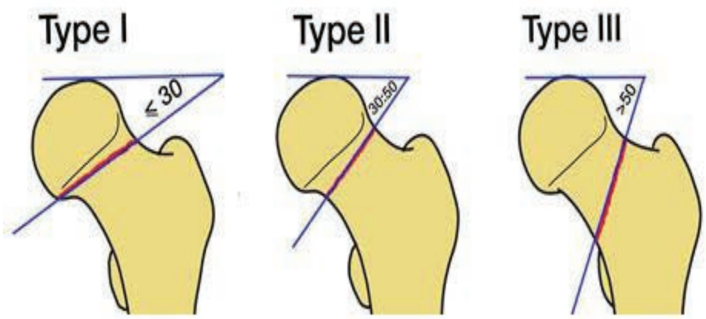
Garden classification Based on AP radiograph

- I: Incomplete, valgus impacted
- II: Complete, undisplaced
- III: Complete partially displaced
- IV: Complete, fully displaced



Pauwels classification (angle between fracture line and horizontal line)

- I: <30^0, Compressive forces
- II: 30 – 50^0
- III: > 50^0, Shear forces (Most unstable with highest risk of non-union and AVN)



- **NICE & SIGN Guidelines**
  - Patients should be nursed on alternating pressure air mattress
  - Protein & mineral supplements
  - Do not delay if patient on antiplatelet therapy
  - GA recommended if on dual therapy
- **Hip fractures BOA 2012**
  - MDT – anti-resorptive therapy, MRI, analgesia, comorbidities, AMTS, VTE, and NHFD

Hip fracture in adults (NICE) + Blue Book (2007) for standards of care for patients with fragility hip fracture

- Admit to acute orthopaedic ward within 4 hours of presentation
- Consider MRI if a fracture is suspected with negative X-rays. If MRI is not available within 24 hours or is contraindicated, consider CT
- Surgery on the day of, or the day after, admission on a planned trauma list (within 36 hours if medically fit)
- Manage correctable comorbidities immediately
- Assess and treat pain immediately upon presentation and regularly
- Offer choice of spinal or general anaesthesia as well as intraoperative nerve blocks
- Operate on patients to allow them to fully weight bear in the immediate postoperative period
- Consider arthroplasty in patients with displaced intracapsular hip fracture

- Consider THR in patients with displaced intracapsular hip fracture who were able to walk independently out doors with no more than the use of stick ,not cognitively impaired and fit for anaesthesia and procedure
- Consider an anterolateral approach in favour of a posterior approach in hemiarthroplasty
- Use extramedullary implants such as a sliding hip screw in preference to an intramedullary nail in patients with trochanteric fractures above and including the lesser trochanter (AO classification types A1 and A2)
- Use an intramedullary nail to treat patients with a subtrochanteric fracture
- Physiotherapy assessment and mobilisation on the day after surgery
- formal orthogeriatric assessment, rapid optimisation for surgery, early identification of individual goals for multidisciplinary rehabilitation, and to facilitate return to the pre-injury residence and long-term wellbeing
- If hip fracture complicates terminal illness, the MDT should consider the role of surgery as part of palliative care approach that minimises pain and considers patients' wishes about their rehabilitation end-of-life care
- Care should minimise the risk of delirium and maximise independence by actively looking for cognitive impairment, reassessing patients to identify delirium that may arise during their admission
- Early discharge if patient is medically stable and has mental ability to participate in rehabilitation and can mobilise short distances.

BOAST 1 Fragility Hip fractures

- MRI / CT within 24 hours if uncertain (Patient to be kept non-weight-bearing)
- Multidisciplinary Approach including members from the orthogeriatric, anaesthetic and physiotherapy teams
- Management of other medical comorbidities immediately
- Surgery to be done within 36 hours
- The main surgical goal of the selected surgical option is early Full weight-bearing
- Active early assessment and recognition of dementia/delirium
- Consider Hip fracture surgery as a part of palliative care in the terminally ill patient
- VTE and pressure sores prophylaxis

Data entry into the National Hip Fracture Database

- **Standards for Best Practice Tariff**
  - Admission to orthopaedic ward within 4 hrs
  - Surgery within 36 hrs and during working hrs
  - Assessment by orthogeriatrician within 72 hrs
  - Discharge on bone protection medication
  - Falls assessment prior to discharge
  - AMTS, Abbreviated Mental Test Score pre and post operatively
  - Fast track policy to transfer to orthopaedic bed within 2 hrs for patients without medical cause
  - Avoid opioid analgesia due to delirium
- **Leadbetter Manoeuvre**
  - For reduction of intracapsular NOF fractures
  - Flexion – adduction – traction – internal rotation – extension
- **Non-operative treatment**
  - For non-ambulatories or high risk of perioperative mortality
  - High risk of pneumonia, VTE, pressure ulcer or non-union
  - All patients should be offered surgery even for palliation

Internal fixation

- Fixation of impacted fractures gives superior results to conservative treatment
  - Earlier mobilization
  - Lower rate of displacement
  - Increased chance of union
  - Association b/w operative delay > 48 hours and higher 1 year mortality.
  - In patients with more > 3 medical comorbidities, medical optimization has greater impact on post-operative outcome than time to surgery
- **Cannulated screws fixation**
  - Fixation with implants that allow sliding can cause:
    - Shortening of femoral neck
    - Prominent implants
    - Affects biomechanics of hip joint
    - Lower physical function on SF-36
    - Risk of AVN higher
  - Anatomic reduction and placement of length stable devices decrease shortening
  - Displaced – open reduction via anterior approach to reduce and then 2nd incision (lateral) to fix
  - Threaded wire in head and Steinman pin in GT to Joystick fracture into satisfactory position
  - In the young, rapid surgery does not affect outcome
  - Most important factor is accurate anatomical reduction
- **Slobogean (Canadian paper). Injury, 2015**
  - **Meta-analysis** of 41 studies with 1558 patients to study complications of NOF fixation in < 60 year olds
    - 18% re-operation rate
    - 15% AVN
    - 9% non-union and 9% implant failure
    - 5% surgical site infection
- **FAITH trial – Fixation using Alternative Implants for Treatment of Hip fractures, (Lancet 2017)**
  - RCT 1108 patients (Sliding Hip Screw = 557, cancellous screws =551)
  - AVN more common in SHS group (9%) vs. cancellous screw group (5%)
  - 20% required re-operation in each group
  - Smokers, displaced or basicervical neck fractures might do better with SHS
- **Keating et al. JBJS 2006 – Multicentre RCT**
  - 298 patients in > 60 years
  - Rate of secondary surgery at 2 years – 37% in fixation, 9% in THR, 5% in hemi
  - THR best patient reported outcome at 2 years and provided better long-term results
- **Hopley et al, BMJ 2010 – Systematic review**
  - Primary THR vs. hemiarthroplasty for displaced intracapsular NOF in >60 years
  - Lower risk of re-operation with THR
  - Better functional outcome (Harris hip score)
  - THR shows slightly higher risk of dislocation and higher general complications

- **Meta-analysis by Damany, Parker et al. (Injury, 2005) – Warwick/Coventry**
  - Early or open reduction of these fractures may not reduce risk of non-union or AVN
  - Higher incidence of non-union following open reduction
  - 3 screws to reduce risk of subtrochanteric fracture insert proximal to lesser troch
- **Oakey et al (CORR, 2006) - Cadaveric study**
  - Inverted triangle has stronger fixation and higher load to failure
  - Superior apex associated with higher risk of subtrochanteric fracture
  - 4th screw for posterior comminution to maintain neck length
  - DHS for basicervical and vertical fracture pattern + de-rotation screw (Pauwels III)
- Decompressing intracapsular haematoma by means of capsulotomy or aspiration reduces intracapsular pressure, resulting in improved blood flow to femoral head and reduces ischaemia
- **Papakostidis, Giannoudis et al. (Leeds University) Injury (2015)**
  - **Systematic review and meta-analysis**
    - No significant association between timing of NOF ORIF and incidence of AVN
    - But odds of non-union increases with delay of fixation > 24 hours
- Non-union (Non-displaced 5 % & Displaced 30%)
- Osteonecrosis (Non-displaced 10% & Displaced 30%)
- Varus mal-reduction (Leads to increased shear forces and non-union)

Hemiarthroplasty

- Thompson (cemented), has narrow medial border which increase load on cement
- Austin Moore (uncemented) – fenestrated stem for bone graft impaction
- **Warwick Hip Trauma Evaluation Study (WHiTE 3), BJJ 2018**
  - Thompson hemiarthroplasty for displaced NOF shows no difference in outcome when compared to Exeter Hemi in > 60 years of age.
- **Arthroplasty J, 2020 – data from National Hip Fracture Database records**
  - Found that Thompson hip hemiarthroplasty are associated with higher dislocation rates
- Furlong (JRI) Bipolar & mono-polar options
  Polished, Tapered, collarless
  Stainless Steel
- Unitrax, 12/14 taper with V40 and C taper sleeve adjustment
- **Bipolar Vs mono-polar** hip hemiarthroplasty
  - **Imam et al Injury 2019**
    - Pooled analysis of 30250 participants. Bipolar hemiarthroplasty is associated with better range of motion, lower rates of acetabular erosion and lower reoperation rates compared to unipolar hemiarthroplasty. Both were similar in terms of mortality, and surgical or medical outcomes
- **Cemented versus uncemented hemiarthroplasty – RCT – Parker – BJJ – 2010**
  - Cemented hemiarthroplasty resulted in less pain and better mobility than uncemeted
  - Tendency to more peri-prosthetic fractures in uncemented group
  - More peri-op deaths in cemented group
- **Cochrane review (2010)**
  - Good evidence that cementing reduce post-operative pain and lead to better mobility
  - No evidence of difference in outcome between bipolar and unipolar
  - Some evidence that THR leads to better functional outcome than hemiarthroplasty

- Imam et al, Cemented versus uncemented hemiarthroplasty, Int Orth 2019
  Meta-analysis of 42046 hips demonstrated that contemporary cemented prostheses have less intra-operative and post-operative fractures, but longer operative time, more intra-operative blood loss.Otherwise, there were no significant differences between both groups.

Total hip replacement

- **NICE guidelines**
  - Offer THR to pts with displaced intracapsular fractures who
    - Were able to walk independently out of doors with no more than use of stick
    - And not cognitively impaired
    - And medically fit for anaesthesia and procedure
- **Complications of intra-capsular hip fractures:**
  - Mortality
    - In elderly (5th die in first year & 4th need more care)
    - Albumin < 30 mg/L (Indicates poor nutritional status and corresponds with higher mortality)
    - Delay in operation beyond 48 hrs increases mortality
  - Non-union (Free vascularised fibula graft in young or valgus osteotomy and arthroplasty in old
  - AVN
  - VTE (NICE- Mechanical and chemical prophylaxis for 5 – 6 weeks)
  - Pulmonary complications

Hip fracture surgery safe for patients on antiplatelets - systematic review & meta-analysis

PERI-TROCHANTERIC FRACTURES

Classification

- Pertrochanteric
- Intertrochanteric
- Evans classification
  - Type 1 - 2 parts Undisplaced
  - Type 2 - 2 parts Displaced
  - Type 3 - 3 parts LT
  - Type 4 - 4 parts GT
  - Type 5 - Reverse oblique

Signs of instability

- Stability related to size and location of lesser trochanteric fragment and integrity of the lateral femoral cortex
  - Lesser troch comminution indicates comminution of posteromedial cortex (calcar)
  - Will collapse into varus and retroversion when loaded
  - Reverse obliquity
  - Subtrochanteric extension
  - GT fracture, Leads to medial translation of femoral shaft
  - MRI is the study of choice to evaluate for occult fracture

Treatment

- **Sliding hip screw**
  - Indicated in all except
  - Reverse obliquity fracture
  - Subtrochanteric fractures, and
  - Fractures with disruption of the lateral femoral cortex
- **Technique**
  - Lateral approach to femur, Risk to perforating branches of profunda femoris artery
  - Vastus lateralis, reflected anteriorly if bulky (Bleeding from perforating branches of profunda femoris). Or split longitudinally (if atrophic)
  - Position guide wire, AP (Caudal half of neck) & Lateral view (Center of neck)
  - In young patients with hard bone, best to use tap to precut thread for screw
  - Screw final position 10 mm short of subchondral bone in AP and lateral
  - Use short barrel plate only if screw is < 80 mm
- **TAD <25mm**
  - Sum of distances from tip of screw to apex of femoral head on AP & lateral X-rays
- **JBJS, 1995 - Baumgartner**,
  - Increased cut out with increasing TAD & Lowest risk of implant failure/cut-out with tip-apex distance <25 mm

- **In bilateral fractures**
  - Start with more stable one
  - Unstable (55% failure of DHS)
- **Intramedullary hip screw (PFNA, TFNA, Gamma nail)**
  - Reduced lever arm of implant
  - Resist medialisation
  - Load sharing
- **Trochanteric buttress plate**
- **Fixed angle device**
- **Arthroplasty**
  - Calcar-replacing prosthesis
  - Must attempt fixation of greater trochanter to shaft
  - When associated with OA – fix and replace when united

Complications

- Screw cut out
- Anterior perforation of femur
- Non-union (2 %)
- Left-sided unstable fractures at risk of malreduction rotational torque can cause anterior spike
- Mortality rates of 15–35 % at 1 year
- Delay to surgery >48 h associated with increased risk of mortality at 1 year
- ASA classification predicts mortality

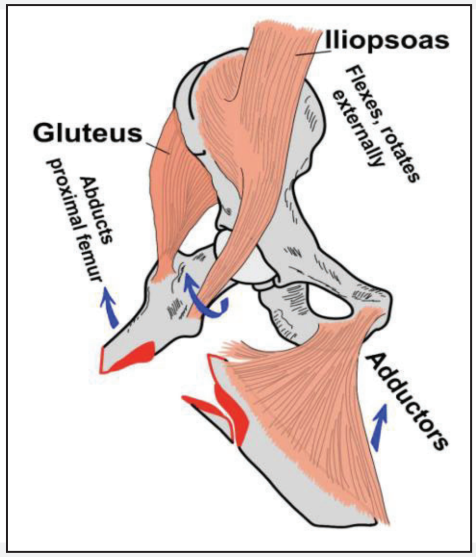
SUBTROHANTERIC FEMORAL FRACTURES

- Massive biomechanical loads through fracture
- Race between union and implant failure

Deforming forces

- On proximal fragment
  - Abduction (Gluteus medius & minimus)
  - Flexion (Iliopsoas)
  - Ext rotation (Short external rotators)
- On distal fragment: Adduction & shortening (Adductors)

(Courtesy of A Alali)

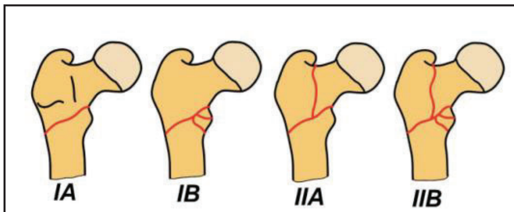


Atypical fracture

- Be aware of bisphosphonate induced atypical femur fracture
  - Prodromal symptoms of thigh pain
  - Associated with low energy mechanisms
- Characterized by
  - Beaking of the lateral femoral cortex
  - Transverse fracture patterns
  - Medial spike
- Treatment
  - Intramedullary nailing is the treatment of choice
  - Risk of delayed healing and revision surgery is higher than with a typical femoral fracture
- Consider screening and prophylactic fixation of the contralateral side in Bisphosphonate-associated fractures.

Russell - Taylor classification

- Type I: No extension into piriformis fossa
  - A: lesser troch intact
  - B: lesser troch fractured
- Type II: Extension into piriformis fossa
  - A: lesser troch intact
  - B: lesser troch fractured



- Ask for full length femoral X-rays to look for femoral deformities to plan surgery

Treatment

- Traction principles and application from Royal College of Nursing
- Thomas splint
  - 2 fixed points (at ischium and knot)
  - Measure oblique (1200) circumference of normal thigh just below ischial tuberosity – Allow for swelling (should be able to pass 1 finger to prevent pressure)
- Kendrick traction device (Used in pre-hospital setting)
- Russel Hamilton traction
  - Padded sling placed behind slightly flexed knee and skin traction applied to lower leg
  - Parallelogram of forces determines that upward pull of sling and longitudinal pull of skin traction create force in line of femur – limited to 5kg and might not be enough
  - Increased weight cause blisters - apply skeletal traction using proximal tibia
  - Steinmann pin
- **To reduce**
  - In line traction
  - Femoral distractor
  - Hold with Hey-Groves femoral clamp

Nailing

- **Type I**
  - Piriformis entry
  - Less likely to go into varus due to straight guide-wire trajectory
  - Higher risk of AVN and neck fractures
- **Type II**
  - Trochanteric entry
  - Gamma nail (Stryker) & PFNA (Synthes)
  - Load-bearing axis of nail is closer to hip joint than DHS
- **IM Nail Vs DHS**
  - Lever arm on implant & femur shorter
  - No lateral buttress required as for DHS
  - Nail will resist shaft medicalization
- **Techniques**
  - The canal should be reamed at least 2mm larger than diameter of nail
  - Check rotation and varus/valgus alignment
  - True lateral X ray with neck & shaft in-line to check cephalic screw position
  - If cerclage wires used – leave as much space as possible between them (5 cm) to preserve periosteal blood supply
- **Fixed angle plate**
  - When unable to perform nail – femoral deformity
  - Elevate vastus lateralis off lateral intermuscular septum
  - Longer lever arm – reduced mechanical stability – risk of fatigue failure
  - Problem   Weaker construct, increased risk of varus collaps

- **Matre et al, Injury (2013)** – Norwegian hip fracture database
  - 12 months postoperatively patients with transverse/reverse oblique trochanteric and subtrochanteric fractures operated with DHS had higher reoperation rate compared to those operated with IM nail

Complications

- Varus mal-positioning (most common complication), can lead to non-union
- Non-union
  - Due to unfavourable biomechanics
  - Increased risk in bisphosphonate fractures
  - Treat with reamed intramedullary exchange to bigger nail
- ARDS, No difference between reamed and unreamed nail.

FEMORAL SHAFT FRACTURES

Winquist & Hansen classification

- Based on degree of comminution and cortical continuity
    - Type 0: No comminution
    - Type I: Comminution <25 %
    - Type II: Comminution 25–50 %, >50 % cortical contact
    - Type III: Comminution >50 %, <50 % cortical contact
    - Type IV: Segmental fracture with no contact between proximal and distal fragments
- Traction through distal femur in presence of knee injury
- Fix within 24 hrs to reduce risk of ARDS & VTE except in head injury patients where hypotension can reduced CPP
- **Nail**
    - Piriformis entry,
        - Can damage blood supply to femoral head
    - Trochanteric entry
        - Minimise injury to abductors
        - Easier starting point
    - Reaming increases union rate
- For concomitant femoral neck and shaft fractures
    - Use 2 devices - screws or DHS for neck and retrograde for shaft
    - Priority is for neck fracture but fix femur 1st to be able to reduce neck
    - Or a Recon nail
- Examine knee at end of procedure as ligament damage could be missed
- For femoral neck/shaft and tibia fractures, nail tibia 1st to make hip operation easier
- Lateral femoral nail (Synthes)
    - In AP view entry point situated slightly lateral from greater trochanter
    - In lateral view entry point is in line with axis of intramedullary canal
    - Nail rotates approximately 90° during insertion
    - Close fracture gap in order to decrease incidence of non-union
    - To minimize chance of cross threading turn end cap counter-clockwise until thread of end cap aligns with that of nail
    - To remove broken nail, use extraction hook
    - Ream medullary canal 1.5 mm > nail diameter to clear path for distant nail

Complications

- Rotational mal-union
    - Use lesser trochanter /shape sign or cortical thickness/diameter sign
- Angular mal-alignment
    - Use cable technique
- Pudendal nerve injury, when traction table used
- VTE, NICE guidelines (for any lower limb fracture)
    - Mechanical and chemical prophylaxis until mobility not significantly reduced
    - **NICE guidelines -** Risk assessment
        - Age > 60
        - Active cancer
        - Acute infection
        - Obesity
        - Smoking
- Fat embolism 3-4% - avoid IMN of bilateral fractures
- **Pape, Tscherne et al, Journal of Trauma (1993)**
    - Primary intramedullary nail for femoral fractures could contribute to ARDS in presence of chest injury (33% ARDS in patients with chest injury vs 7.7% in patients without chest injury)
    - 21% mortality in patients undergoing early femur nailing with chest injury vs 4% in patients having nailing without chest injury
- **Bone, Giannoudis, JBJS Am 2011 (review article)**
    - Femur fracture can be nailed safely with chest injuries if patient oxygenation and hydration status is closely monitored and adequate resuscitation has been performed.
    - DCO is still advisable in unstable / in-extremis patient
- Non Union
    - Rare, <2 % of closed fractures
    - Increased risk in smokers and heavy postoperative use of NSAIDS
    - Exchange reamed nailing, conversion to plate fixation ± bone grafting

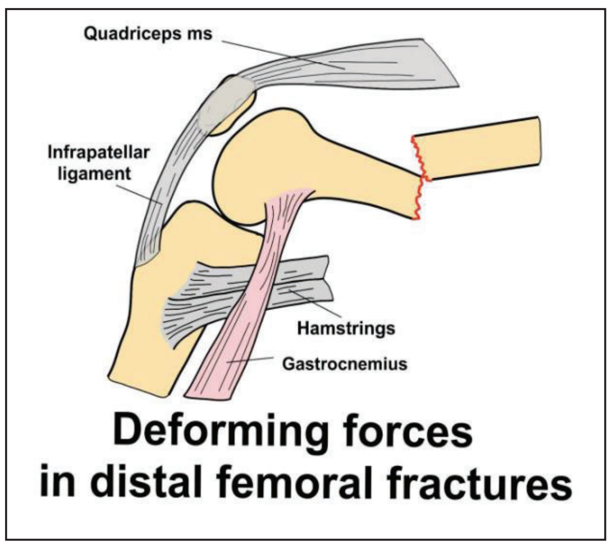
DISTAL FEMORAL FRACTURES

- From articular surface to 5cm above metaphyseal flare (rule of square – proximal and distal segment of long bone are defined by a square whose sides are the same length as the widest part of epiphysis, Muller et al, 1990)
- Distal femur is trapezoid – anterior part is 25% shorter that posterior part - internal view (30 deg)radiograph to assess screw length
- Obtain CT scan if concerned for intercondylar extension or to further characterize fracture with obvious intercondylar extension
- Hoffa fracture coronal split of posterior condyle
- More common on lateral condyle
- Coronal plane (Hoffa) fractures present in 30–40% ; 80 % of these involve lateral condyle
- Increased risk for vascular injury with increased fracture displacement
- Low threshold to initiate vascular work-up with asymmetric pulses, abnormal ABIs

(Courtesy of M Yousef)

Treatment

- **Plating**
  - LISS
  - Locking plate (better control of fragments)
  - For medial condyle – use ipsilateral proximal lateral tibial plate
  - Flex knee to 20 deg
- **Posterolateral approach**
  - Between vastus lateralis and intermuscular septum
  - Biceps (sciatic N) posterior
  - Perforators enter posterior aspect of vastus lateralis
- **Anteromedial approach**
  - Between rectus femoris and vastus medialis
  - Vastus medialis distal fibers insert on medial border of patella
  - For intra-articular fractures that can't be reduced percutaneously
  - Can cause muscle fibrosis and post-op stiffness
  - Meticulous closure to prevent lateral patella subluxation
- **Medial approach**
  - Between vastus medialis and Sartorius
  - Vessels behind Sartorius
  - Area distal to Blumensaat's intercondylar roof line must be avoided to avoid damage to cruciate ligaments
  - internal rotation
- **Hoffa fracture**
  - AP headless compression screw
  - 2 screws for rotational control



- **Retrograde nailing**
    - Indications
        - Supracondylar femoral fractures > 5 cm from joint
        - Diaphyseal femoral fractures in obese, pregnant
        - Ipsilateral femoral & tibial/femoral neck fractures
        - Periprosthetic
        - Bilateral
    - Midline incision
        - Medial parapatellar approach (arthrotomy)
        - Flex knee to 40 deg
        - Or infra-patellar/trans-patellar tendon approach
    - Entry point
        - In line with axis of medullary canal
        - Anterior to Blumensaat line (roof of intercondylar notch)
    - Cannulated drill to open canal sequential reaming
    - Reamed nailing allow use of larger diameter to provide greater stability
    - Check rotation
    - Use longest nail possible to prevent risk of peri-implant fractures
- **Dynamic condylar screw (DCS)**
- **Distal femoral replacement**

Traction

- Reduce pain
- Overcome deformity
- Keep fracture aligned and support movement while relieving pain
- **Types**
    - Skin
    - Skeletal
    - Fixed
- **Reduction Principles**
    - Use in the long axis of the limb
    - Align the fragment that can be controlled with the one that cannot be controlled
    - Reverse the mechanism that created the fracture
- **Skin Traction**
    - Applied over a large area of skin - spreads the load
    - Never more than 10lb (4.5 kg) or not more than 10% body weight
    - Contraindicated in vascular impairment, open fractures & marked shortening
- **Skeletal traction**
    - Used in lower limb fractures and cervical spine (Halo traction)
- **Fixed traction**
    - Force applied against a fixed point of the body
      i.e. ischial tuberosity
    - E.g.: Thomas splint and Hamilton Russell traction

QUADRICEPS TENDON RUPTURE

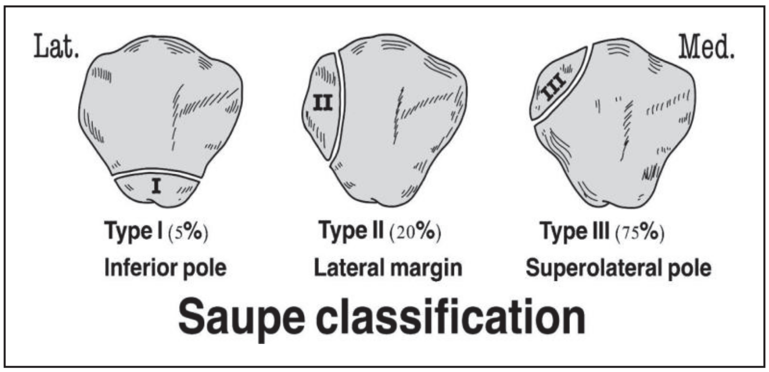
- Older than 40 years, Males > Females, Non-dominant leg> dominant leg
- Hypovascular area 1-2 cm superior to patella, thus, tendon rupture occurs most commonly ~2 cm proximal to the superior pole of the patella
- Occurs when foot planted and knee slightly bent
- **Risk factors**
    - Renal failure
    - DM
    - RA
    - Hyperparathyroidism
    - Steroids injections
    - Fluoroquinolones
- **Plain radiographs**
    - Assess for patella baja on lateral knee x-ray with 30° of flexion
    - Insall- Salvati ratio <0.8,
    - inferior pole of patella below Blumensaat's line
- **Repair**
    - Trans-osseous sutures through patella
    - Non-absorbable sutures in tendon in running locking fashion
    - Repair retinaculum with heavy absorbable sutures
- **Complications**
    - Weakness and knee stiffness are common complications

PROXIMAL TIB-FIB DISLOCATION

- Joint strengthened by anterior and posterior ligaments
- Comparison views of contralateral knee is crucial for diagnosis
- **Classification**
    - Subluxation
    - Posteromedial
    - Anterolateral
    - Superior
- **Treatment**
    - Closed reduction for acute dislocations
    - Open reduction and pinning vs. Arthrodesis vs. Fibular head resection
    - Chronic dislocation with chronic pain and symptomatic instability

PATELLA FRACTURES

- The biggest sesamoid bone
- Thickest cartilage in the body
- Most important blood supply to patella located at inferior pole, with anastomosis of medial and lateral SGA, IGA (Superior and inferior genicular arteries)
- **Functions**
  - Fulcrum for quadriceps
  - Protects knee joint
  - Enhances lubrication of knee
- **Radiologically**
  - Fracture displacement correlates with retinacular disruption
- The inability to actively extend the knee indicates a clinically significant extensor mechanism injury



Bipartite patella

- Anatomical variant
- Lack of assimilation of bone during growth
- Located on proximal lateral quadrant of patella in 75%
- Bilateral in 50%
- Can cause anterior knee pain following trauma or overuse or strenuous sports
- Radiograph shows rounded sclerotic lines rather than sharp edges of fracture
- CT to differentiate from facture
- Excise accessory fragment if painful > 6 months or fix if large

Treatment

- **Non-operative management**
  - Non-displaced and minimally displaced fractures with intact extensor mechanism
- **Operative**
  - Mini-frag lag screw fixation for independent fragments
  - Tension band wiring - Figure of 8 wire
  - Longitudinal cannulated screws combined with tension band wires (Biomechanically superior)
  - Circumferential cerclage wiring for comminuted fractures
- Hinged knee brace 0-45^0 for 6 weeks
- Single loop and bury in retinacular tissue
- Partial Patellectomy
  - Superior/inferior pole fracture
  - Only if ORIF not possible due to comminution
  - Quadriceps or patellar tendon re-attachment
- Medial and lateral retinacular repair
- Total Patellectomy
  - Quadriceps torque reduced by 50%- so contraindicated

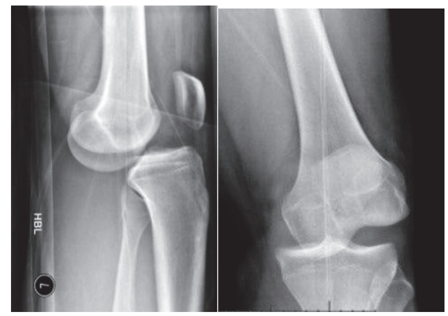

(Courtesy of H Hermina)

- **Complications**
  - Symptomatic hardware - most common
  - Failure of fixation (up to 20 %) (Technical error or Patient non-compliant)
  - Non-union <5 %
  - Arthrofibrosis
  - Infection
  - Osteonecrosis of proximal fragment (Observe; most spontaneously revascularize)

KNEE DISLOCATION

Classified according to direction

- **Anterior**
  - Most common type
  - Due to hyperextension injury
  - Usually involves tear of PCL
  - Arterial injury is intimal tear due to traction
- **Posterior**
  - Due to axial load to flexed knee
  - Highest rate of complete tear of popliteal artery
- **Lateral/medial**
  - Due to varus or valgus force
  - Usually involves tears of both ACL and PCL
  - Highest rate of peroneal nerve injury



(Courtesy of M.Imam)

Management

- **Surgical emergency**
  - Deal with life threatening injuries 1st
- **Urgent reduction**
  - **Howell from Bristol, UK – Injury 2011**
  - If ABI is <0.9 or examination is abnormal but limb is perfused, initiate further work-up with arterial duplex ultrasound or CT angiography
- **Prospective study** – **Stannard (JBJS, 2004)**
  - Selective arteriography based on serial physical examinations is safe and prudent following knee dislocation

- **ABPI**
  - Blood pressure cuff proximal to ankle and on ipsilateral arm
  - Systolic pressure determined with Doppler probe on DP or PT arteries
  - If concerned about vascularity after reduction and patient under GA – on table angiogram
  - Immediate surgical exploration if pulses are still absent following reduction

- **Surgical principles**
  - Shunt artery to save ischaemia time
  - Perform spanning external fixation
  - Excise damaged segment and repair with reverse saphenous vein graft
  - Always perform fasciotomies after vascular repair
  - Early reconstruction/repair when possible
  - Brace MCL for 6 weeks then reconstruct ACL/PCL

- **William Mook, Mark Miller et al. JBJS (Am) 2009**
    - Systematic review of timing of operative intervention in multi-ligamentous knee injuries
    - Simultaneous repair and reconstruction of ACL and PCL leads to ROM deficits that are unresponsive even to follow up surgeries
    - Staged procedures lead to best subjective outcomes with least ROM deficits which can be corrected by arthrofibrolysis
    - Acute treatment followed by aggressive rehabilitation may decrease complication

Complications

- Peroneal nerve injury 25%
    - Poor results
    - Neurolysis and tendon transfers are mainstay of treatment
- Rarely knee return to pre-injury state
- Vascular injury (18%)
- Arthrofibrosis (40%)

PATELLA TENDON RUPTURE

- Patella is sesamoid bone making this tendon, not ligament
- Injury usually happens in patients less than 40 years old
- Risk factors include
  - Patellar tendinitis
  - Diabetes
  - Rheumatologic disease
  - Renal disease
  - Corticosteroid injections
  - Fluoroquinolones

(Courtesy of M Elgawadi)

- May occur as an avulsion from the inferior pole of the patella (most common), midsubstance tear, or tibial tubercle avulsion (rare)
- Assess for patella alta on lateral knee x-ray with 30° of flexion: Insall- Salvati ratio >1.2, inferior pole of patella above Blumensaat's line

Surgical technique

- Midline incision (Risk to infrapatellar branches of saphenous nerve)
- **Techniques**
  - End-to-end repair
  - Transosseous tendon repair
  - Suture anchor tendon repair
- Suture any tears in lateral and medial parapatellar retinacula
- Krackow whip stitch Make holes in main fragment
- No.5 nonabsorbable transosseous suture
- Can be protected with cerclage wire between patella and tibial tuberosity
  Immobilize in full extension for 2/52 then in hinged brace to 90 degree for 8 weeks
- Treat partial tears with intact extensor mechanism with initial immobilization followed by progressive weight bearing and range of motion.

COMPARTMENT SYNDROME

Definition

- Increased pressure within osteofascial compartment that exceeds capillary pressure
- Osseo-fascial compartment pressure raises - decreases perfusion - irreversible muscle & nerve damage
- **Symptoms**
  - Pain out of proportion to clinical situation
  - Pain with passive stretch is most sensitive finding prior to onset of ischemia Paresthesia and hypoesthesia indicative of nerve ischemia in affected compartment
  - Sensation goes before paralysis because fibres carrying sensation more sensitive to increased pressure
  - Palpable tense swelling
  - Late findings: paralysis & absent pulses, recovery is rare
  - Pain, pain, pain, pain & pain

Diagnosis

- **Clinical**
  - Delta P - **McQueen BJJ 1996**
  - Difference between measured intra-compartment pressure and diastolic BP< 30mm Hg is diagnostic if taken prior to GA
  - More reliable than absolute pressure of > 30 mmHg (Mubarak et al.)
  - High CK may indicate muscle necrosis

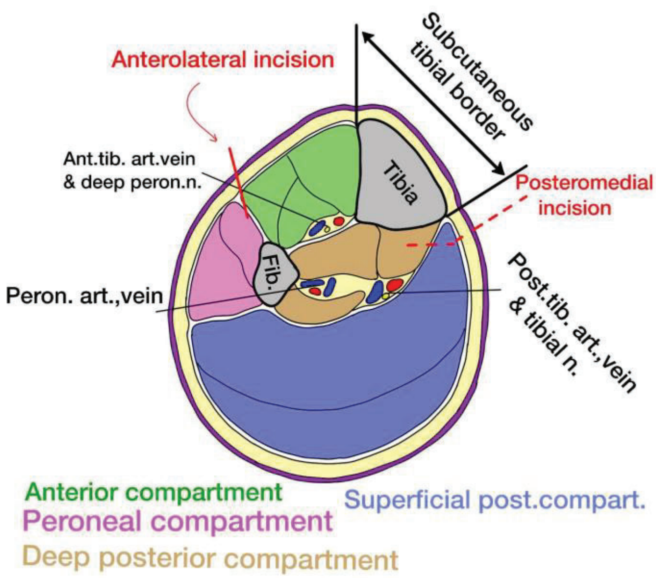
Compartment pressure measurements

- Prospective study – **BJJ, 1996 by McQueen**
  - Use of differential pressure of 30 mm hg as threshold for fasciotomy led to no missed cases of acute compartment syndrome
- **Indications**
  - Patient not alert/unreliable
  - Inconclusive physical exam findings
  - Unequivocal clinical findings should prompt emergent operation without need for compartment measurements
- **Technique**
  - Within 5cm of fracture site
  - Needle perpendicular to skin

BOAST -Compartment Syndrome

- Assess after all major injuries or prolonged surgery + clear documentation
- Pain on passive movement is key
- Neurovascular status should be documented too, but not a diagnostic essential
- Patients at risk should have hourly compartment nursing observations
- Avoid regional anaesthesia in high-risk patients
- If suspicious – release dressing to skin level, maintain BP ,keep limb at level of heart and reassess in 30 minutes
- Consider compartment pressure measurement (optional) – BUT all units should have access to compartment pressure measurement equipment
- Surgery within 1 hour once decision made – absolute pressure > 40mmHg, Delta P < 30mmHg, or convincing clinical signs

- Document compartments decompressed, debride necrotic muscle, 2nd look within 48 hours and early plastic surgery involvement
- Late presentation (>12 hours) has higher complication risk. 2 consultant decision to operate and non-operative management is an option
- **Two incisions Fasciotomy Technique** (15-20 cm wounds)
    - **Anterolateral incision**
        - 2 cm anterior to fibular shaft
        - Find and protect superficial peroneal nerve
        - Find anterior intermuscular septum
        - Release anterior compartment longitudinally ½ way between intermuscular septum and tibia
        - Release lateral compartment in line with fibula (danger to superficial peroneal nerve)
    - **Posteromedial incision**
        - 2 cm posterior to posteromedial edge of tibia
        - Incise posterior superficial compartment
        - Release posterior deep compartment
        - Cannot be done without proper elevation of soleus
        - Examine epimysium and incise when tight
        - Prevent retraction of skin edges with tensioned vessel loops weaved through staples (shoelace technique)



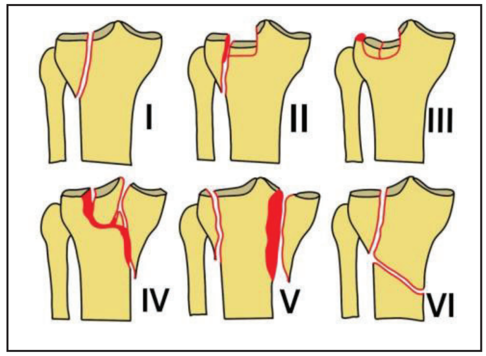
- **Post-operative**
    - Delayed primary closure or VAC or skin graft at 3-7 days

Neglected compartment syndrome

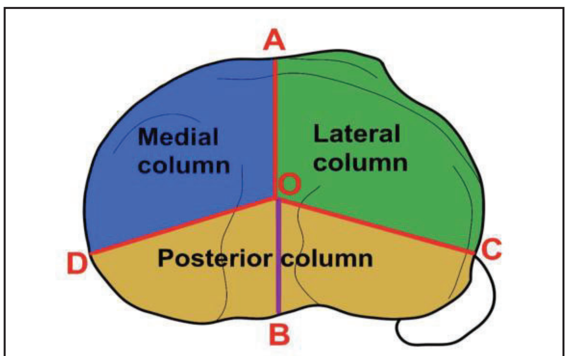
- Observe and do tenolysis later
- Decompression can kill patient from rhabdomyolysis

TIBIAL PLATEAU FRACTURES

- Usually occur with axial compression and varus/valgus loading
- Associated soft tissue injuries in 50–90 % of cases, meniscal tears most common, typically in the periphery, lateral > medial
- Blood supply to tibia is mainly from posterior tibial artery
- Periosteal circulation from anterior tibial artery
- Lateral convex and medial concave – medial more distal (aware when putting screws)
- Medial tibial plateau fractures should be considered knee dislocation equivalents
- 3 columns: Lateral, Medial & posterior
- **Schatzker classification**
- Radiographs – AP, lateral, and oblique, 10 degrees caudal (slope of tibia)
- CT
- MRI - For associated ligamentous injury
- Indications for ORIF
    - Depression of joint surface equal to depth of cartilage
    - Medial fracture - Can lead to varus collapse
    - Bicondylar fracture
    - Posterior fracture – instability in flexion
    - Varus/valgus mal-alignment
    - Condylar widening

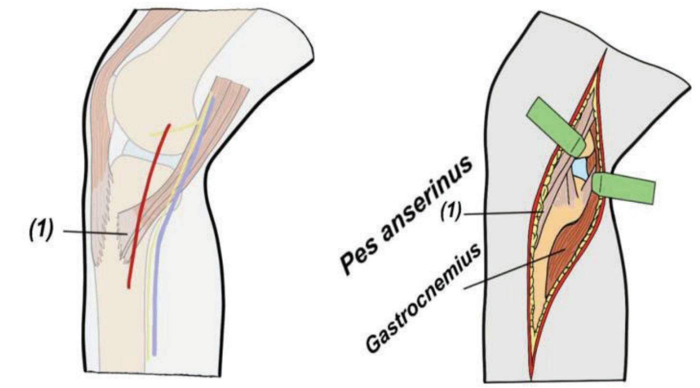


- **Principles of management**
    - Goal of treatment is to restore normal alignment and bicondylar width;
    - Restoration of the articular surface is of secondary importance
    - Soft tissue management
    - Anatomical reduction of articular surface
    - Restoration of length, alignment and rotation
    - Repair menisci
    - Early motion
    - Stabilization of the three columns



Three column theory of tibial plateau

- **Posteromedial approach**
  - Supine, sand bag beneath contralateral buttock
  - From medial epicondyle towards postero-medial edge of tibia
  - Interval between pes anserinus and medial head of gastrocnemius
  - Elevate popliteus with soleus to protect NV bundle
  - Fix with T plate in a buttress mode



Posteromedial approach of tibial plateu

- **Anteroateral approach**
  - Better soft tissue coverage
  - 1cm lateral to midline (just anterior to Gerdy tubercle) straight or hockey stick
  - Split tib ant from proximal tibia
  - Horizontal incision under anterior horn of lateral meniscus (submeniscal Approach) stay sutures in meniscus and elevate to expose lateral plateau to aid reduction

- **Midline incision**
  - Can lead to significant soft tissue stripping and should be avoided

- **Posterior approach**

- **Principles of fixation**
  - Restoration of joint stability is strongest predictor of long-term outcomes
  - Reduce from below – Anterolateral or medial metaphyseal window for pure depression
  - Temporary K wires
  - Bone graft or substitute defects – calcium phosphate has high compressive strength
  - Compress with Lag Screws - also act as subchondral raft to support reduced depression fracture
  - Repair associated ligament avulsions, Restore ligamentous stability
  - Preserve meniscus
  - Restore mechanical alignment of tibia
  - Bicondylar need double plating to prevent varus/valgus drift
  - Screws may be used alone for simple split fractures that were elevated percutaneously
  - Better to buttress if depression
  - Type IV usually associated with coronal split, require medial and posterior T plate fixation
  - Examine for stability after fixation

- **Ex – fix**
  - Ligamentotaxis improves position and reduces soft tissue compromise
  - 2 AP pins in distal femur
  - 2 AP pins in tibia distal to zone of injury on lateral aspect to avoid impeding plate fixation later

Complications

- Lateral meniscus injury (with type II)
- Medial meniscus injury (with type IV)
- OA worse with Condylar Widening, Mal-alignment, Instability
- Posttraumatic arthritis correlates with initial severity of injury, axial injury, and meniscal injury; quality of articular reduction does not directly correlate with development of posttraumatic arthritis
- ACL injury (with type V & VI)
- Common peroneal N and artery injury
- Compartment syndrome
  - Due to extravasation of fluid into soft tissue of leg during arthroscopy - avoid pressure pump
  - Arthroscopy
    - To assess reduction of articular surface
    - To check for soft tissue entrapment
    - To assess ligament damage
- MCL more likely to be injured than LCL due to direct insertion on plateau

TIBIAL SHAFT FRACTURES

- Tibia shaft fractures are the most common long bone fracture
- Associated soft tissue injury is critical to guiding treatment and risk of complications
- Fibula fracture at same level indicates high energy fracture pattern

Open tibia fracture

- Early antibiotic administration is the most important factor in decreasing the risk of infection in open tibia fractures.
- Management, according to BOAST and BAPRAS guidelines

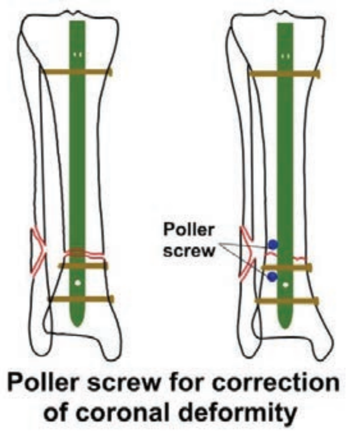
BOAST 4 Open Tibia Fracture

- Serial Neurovascular and compartment observation to be done and documented
- IV Co-Amoxiclav 1.2g within 3 hours of injury (Clindamycin 600mg if allergic)
- Gross contamination (agriculture/sewage) and vascular impairment - prompt surgery within 6 hours
- Compartment decompression via 2 incisions on lower leg for compartment syndrome
- Orthoplastic approach to all open fractures. early transfer if not available and primary debridement by non-specialist only if unfit for transfer
- Gross contamination removed to allow photography, saline-soaked gauze, impermeable dressing and splinting
- Primary debridement within 24 hours by senior plastic & orthopaedic surgeons together
- IV antibiotic cover that continues for 72 hours or until definitive closure
- VAC (Vacuum-Assisted Closure) dressing or antibiotic bead pouch if delayed definitive fixation or skin cover – ideally definitive fixation/cover within 3-7 days
- Paediatric tibial wounds are treated in the same way – but not necessarily the fracture
- **Stable fracture pattern**
    - < 5°varus/valgus, Risk of varus mal-union with midshaft fractures and intact fibula
    - < 10°pro/recurvatum
    - < 1 cm shortening, Risk of shortening with oblique fracture patterns
    - >50% cortical apposition
    - Place in above knee plaster, functional brace at 4 weeks
- **Wedging technique**
    - Mark level of fracture on cast
    - Cut opening < 90 % of circumference
    - Intact portion at apex of deformity
    - Lamina spreader, cork wedges
    - If displaced perform closed reduction under GA
- **WOLLF Randomized Clinical Trial, Matthew Costa et al, JAMA 2018**
    - For patients with severe open fracture of lower limb, use of negative pressure wound therapy compared with standard wound dressing did not improve self-rated disability at 12 months. This study does not support NPWT for severe open fra
- **WHIST trial, Matthew Costa et al, JAMA 2020**

- Incisional negative pressure dressing for surgical wounds associated with lower limb fractures from major trauma did not show any significant statistical difference in deep surgical site infection at 30 days.

Tibial nail

- Consider ABx loaded tibia nail - PROtect Expert tibia nail
- Incision in line with central axis of intramedullary canal
- Incision can be suprapatellar, transpatellar, medial or lateral parapatellar
- Starts proximally at distal third of patella along patellar ligament to tibial tuberosity
- In AP view, the entry point in line with axis of intramedullary canal
- In lateral view, the entry point just below anterior articular margin of tibial plateau
- Proximal fracture reduction
    - Blocking screws
        - Place on concavity of deformity
        - Lateral to nail prevents valgus deformity
        - Posterior prevent apex anterior deformity (Procurvatum)
        - Can use wires instead
    - Unicortical plating
- Twisting movements to advance nail. Monitor nail passage across fracture, control in two planes to avoid mal-alignment Lock distally first, enables use of backstroke technique to prevent fracture gap
- No indication for dynamic interlocking acutely, contra-indicated in length unstable fractures
- Consider 3 interlocking screws in short segment of distal or proximal shaft fracture
- Deciding on weight-bearing
    - Fracture pattern & location
    - Condition of soft tissues
    - Quality of bone stock
- Suprapatellar nailing
    - Reduced incidence of anterior knee pain
    - Easier reduction, particularly in proximal and segmental fractures
    - Important to protect articular cartilage
- **COCHRANE REVIEW**
    - Reamed IM nailing has lower incidence of implant failure than un-reamed nailing
- **Bhandari – BJJ, 2000 meta-analysis**
    - Un-reamed nails reduce incidence of re-operations, infections and mal-unions, compared with ex –fix
    - Decreased time to union and to weight-bearing compared with non-operative



(Courtesy of M Elgawadi)

- **Complications**
  - Anterior knee pain
    - Up to 50%
    - Half of this improves with nail removal
  - Procurvatum/valgus malunion
    - With proximal shaft fracture
    - Add anterior tubular plate or polar screw or clamp
  - Mal-rotation

Ex-fix

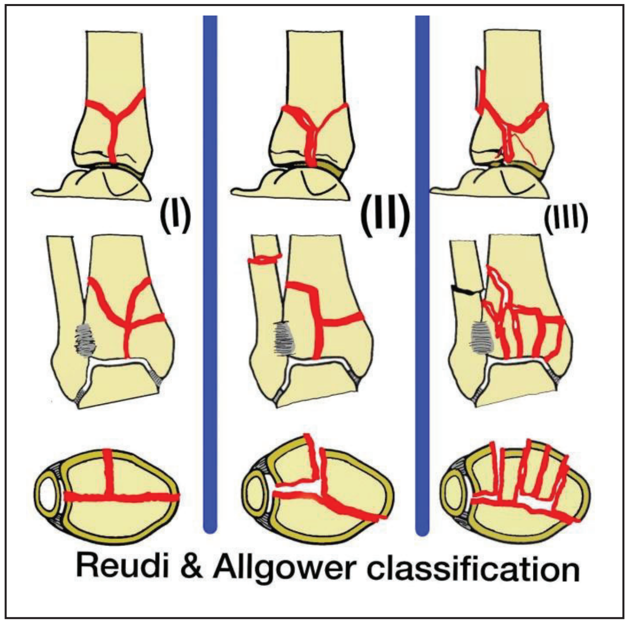
- Higher rate of mal-alignment compared to IM nail
- Indicated in children with open physis

Anterior approach to tibia shaft

- Longitudinal incision 1 cm lateral to anterior border of tibia
- Between Tibialis anterior and tibia
- Risks to long saphenous vein

PILON FRACTURES

- Most commonly occur with high-energy axial loading
- Reudi & Allgower classification
  - Non-displaced
  - Simple displaced
  - Comminuted

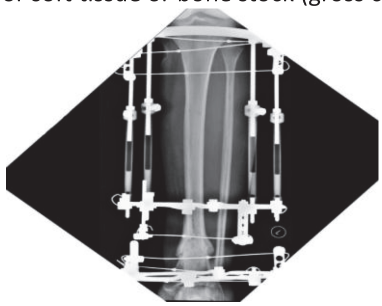


- Chaput fragment-AITFL-Called Tillaux in children
- Volkmann fragment-PITFL
- Three main fracture fragments: medial (attached to deltoid ligament0
  posterolateral/Volkmann (attached to posterior inferiortibiofibular ligament)
  Anterolateral/Chaput (attached to anterior inferior tibiofibular ligament)

Management

- Staged approach
  - Span (to reduce and immobilise) – scan (for planning) – plan (how to fix)
- CT to plan approach and fixation
- Delta frame
  - Bridging ankle ex-fix
  - With Steinman pin through calcaneum
  - 5 mm Schanz pins for tibia and 4 mm for MT
  - Oblique pin in 1st MT to avoid DP artery, away from injury zone
- Once soft tissues permit (recovered) (wrinkle sign) perform ORIF
  - Distal tibial contoured locking plate
  - Reduce and fix fibula 1st to restore length
  - Reconstruct articular surface with temporary K wires and then lag screws
  - 3 fragments (anterolateral, anteromedial, posterolateral)
  - Fill bone defect with graft or substitute
  - Reattach articular block to metaphysis and shaft

- Circular frame for patients with poor soft tissue or bone stock (gross comminution)



(Courtesy of M Imam)

- **Complications**
    - Wound breakdown and infection - 30%
    - Prevent with external fixation and delayed ORIF
    - Post-traumatic arthritis, need for arthrodesis 10%
    - Stiffness and reduced level of activity
    - Varus mal-union
    - High rates of wound breakdown: delay ORIF until soft tissue envelope improves, meticulous soft tissue handling; free flap may be required if soft tissue coverage required
    - Non-union
    - Risks - Anterior tibial A and deep peroneal N

Anterior approach to distal tibia & ankle

- Wait for swelling to go down, skin has to wrinkle
- Other indications – TAR
- Preserve > 5 cm Skin Bridge if also fixing fibula
- Incision starts 1cm lateral to tibial crest and follows medial border of Tib Ant, Curve medially 110^0 at ankle level
- Incise extensor retinaculum
- Intermuscular plane - EHL (deep peroneal nerve) & EDL (deep peroneal)
- Retract EHL and neurovascular bundle medially & Retract EDL laterally risks superficial peroneal nerve
- NV bundle is between EHL and Tib ant proximal to joint and between EHL and EDL distal to ankle joint
- Medial variation - 15cm incision anterior to medial malleolus
- Dissect tibialis anterior and neurovascular bundle and retract laterally
- Incise deep fascia to medial side of tibialis anterior tendon
- Deep peroneal nerve and anterior tibial artery
    - Above joint runs between EDL and EHL
    - Crosses behind EHL at level of the joint

Posteromedial approach to distal tibia and ankle

- Landmark: halfway between medial malleolus & Tendoachilles
- Plane between Tib post (tibial nerve) and FDL (tibial nerve)
- 10 cm longitudinal curved incision with concavity pointing anterior
- Structures at Risk: NV bundle (posterior tibial A. & tibial N.). Retract posteriorly with FDL and FHL

Anterolateral approach to distal tibia and ankle

- **Indications**
  - Distal tibia fractures
- **Incision**
  - Parallel to 4th MT distally and between tibia & fibula proximally
- **Internervous plane**
  - Between peroneus tertiuos (deep peroneal N) & peroneus brevis (superficial peroneal N) Superficial peroneal nerve crosses incision in subcutaneous tissue immediately under skin can be extended distally to talonavicular joint (Ollier approach)
- Retract extensor tendons, deep peroneal N, and dorsalis pedis artery medially
- Cannot access medial malleolus
- Use pre-contoured anterolateral plate

Anteromedial Approach to the distal tibia and ankle

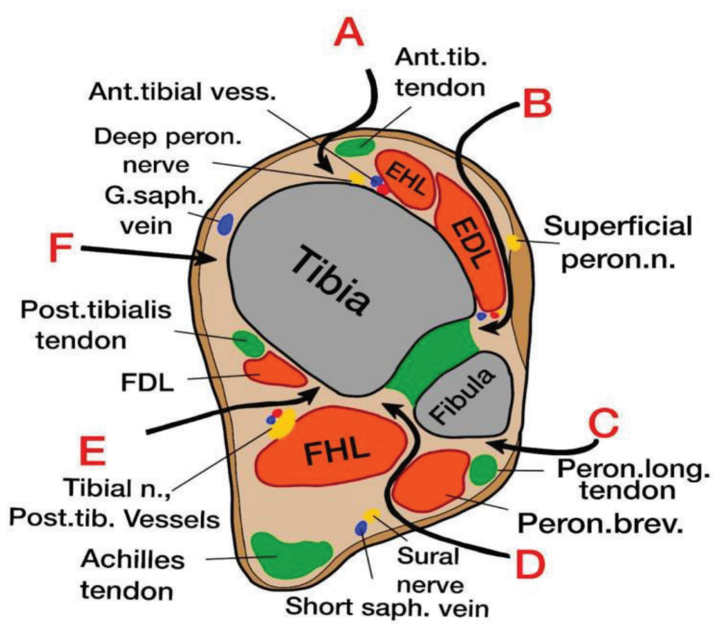
- Landmark: medial border of Tibialis Anterior
- Structures at Risk: NV bundle between Tib. Ant. and EHL
- Intermuscular: dissection medial to the Tib. Ant.

Lateral Approach to the Ankle:

- Direct approach to the posterior border of the fibula and can extend distally to
- Kocher lateral approach to the ankle and tarsus

Posterolateral approach to tibia & ankle

- Used to expose posterior tibia and for fibula antiglide plate
- Patient prone
- Incision along posterior border of fibula halfway between fibula and Achilles tendon
- Access tibia: Between Gastrocsoleus /FHL (tibial N) and peroneal muscles (superficial peroneal N)
- Access to fibula: obtained with posterior retraction of PL and PB
- Access to posterior malleolus obtained with anterior retraction of PL and PB
- NV structures (tibial nerve, posterior tibial artery, and peroneal artery) located between soleus and tibialis posterior
- Structures at risk :Sural nerve runs along with short saphenous vein



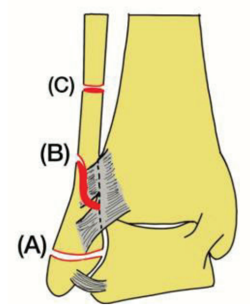
Distal tibia approaches

ANKLE FRACTURES

- Deltoid ligament (deep portion), Primary restraint to anterolateral talar displacement
- External rotation stress radiographs (helpful to determine instability)
- Medial clear space > 5mm is predictive of deltoid ligament injury
- Incisura fibularis - Concave surface of distal lateral tibia
- Mortise: recess cut to receive corresponding projection to lock parts together
- Tibio-fibular clear space between fibula and incisura
- Medial clear space < 5 mm, compare to tibio-talar joint
- Weight bearing x-rays - identify displacement in unstable fracture that is undisplaced

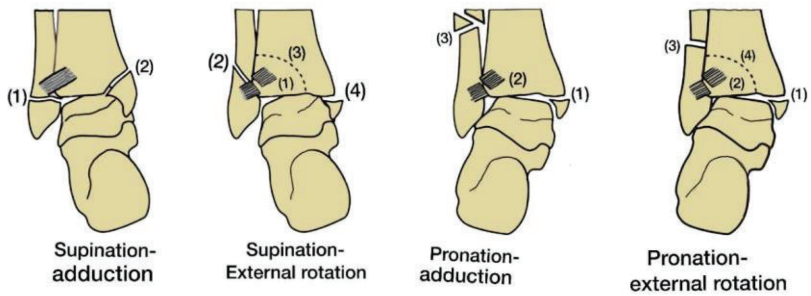
Weber classification

- Depending on level of fracture in relation to Syndesmosis - Immovable joint, bone bonded by fibrous tissue



Lauge – Hansen classification

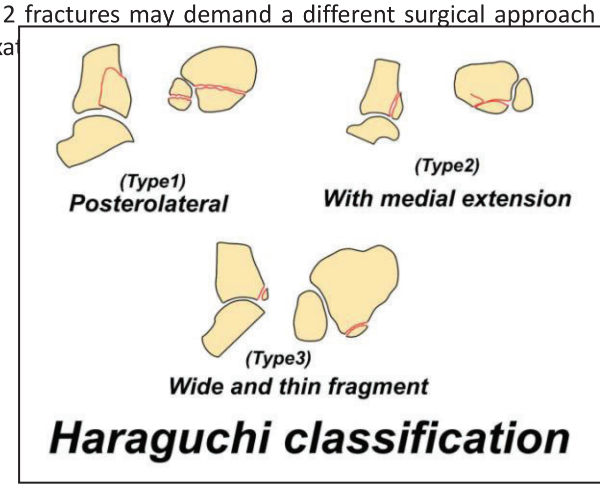
- Based on mechanism - position of foot at time of injury and direction of force applied
- **Supination – Adduction**
  - Vertical medial malleolus & transverse fibula
  - Fibula fails in tension – hence low transverse fracture
  - Associated with anteromedial marginal impaction
- **Supination – External rotation**
  - Lateral short oblique/spiral fibula fracture
  - In external rotation injuries fracture is spiral
  - Fibula fracture run from anterior inferior to posterior superior
  - Medial malleolus transverse fracture or disruption of deltoid lig
  - PITFL avulsion
- **Pronation – Abduction**
  - Medial malleolus transverse fracture or disruption of deltoid lig
  - In pronation injuries – medial injury 1st
  - Transverse comminuted fracture of fibula above syndesmosis (Weber C)
- **Pronation – External rotation**
  - Deltoid/medial malleolus – syndesmosis – fibula (Weber C)
  - Fracture could be as high as fibula neck (Maisonneuve fracture)
  - Examine entire length of fibula
  - Medial malleolus transverse fracture or disruption of deltoid ligament



- ➢ Wagstaff fracture: Avulsion fracture of anterior fibula by AITFL
- ➢ Bosworth fracture-dislocation: Posterior dislocation of fibula behind incisura fibularis
- ➢ Dupuytren fracture- Weber C

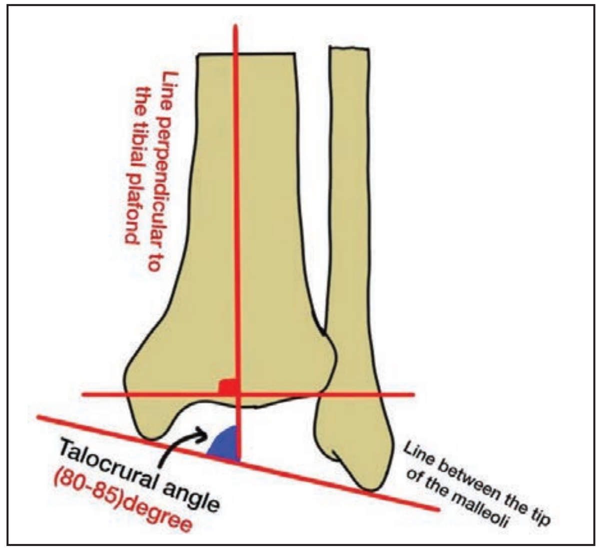
Haraguchi classification

- ➢ Three types of fracture in a CT study
  - Type 1 The most common, is a single posterolateral fragment
  - Type 2 Extension to posteromedial side of distal tibia
    There may be more than one fragment.
  - Type 3 Thin shell of bone
- ➢ The classification is useful, as type 2 fractures may demand a different surgical approach and type 3 fractures may be too small or thin to allow fixat



- ➢ **Indications for ORIF**
  - Talar displacement-**Ramsey and Hamilton et al JBJS 1976** – 1mm, talar shift causes increased contact pressure at tibiotalar joint by 42%)
  - Medial / lateral/posterior malleolus displacement
  - Open fracture
  - Posterior malleolus fragment > 25%
  - Functional bimalleolar - deltoid ligament
- ➢ **BOAST 2016**
  - Assess skin integrity and neurovascular status
  - Comorbidities- DM, peripheral neuropathy, PVD, osteoporosis, smoking
  - Urgent reduction and splinting
  - Recheck X-rays and NV status

- **Fibula (Lateral approach)**
    - 10 cm above tip of lateral malleolus, superficial peroneal nerve pierces fascia
    - Skin incision slightly anterior to aid lag screw insertion
    - Between peroneus tertius anteriorly (DPN) & peroneus L & B posteriorly (SPN)
    - Restore fibula length to provide lateral buttress to talus
    - Lag screw with neutralization plate – provides compression and torsional stability
    - Countersink to increase area of contact between bone and screw head
- **Ankle AP x-rays**
    - Check talocrural angle and Shenton line
    - Tibiofibular clear space < 5mm
    - Tibiofibular overlap > 10mm
- **Lateral plate**



- **Antiglide plate**
    - Posterolateral position
    - Advantages
        - Posterior position allows bicortical screws distally
        - Plate does not lie directly under wound
        - Biomechanically superior to lateral plating
    - Disadvantages
        - Peroneal tendon irritation
- **LCP distal fibula plate**
    - Osteoporotic bone
    - Distal fractures
- Mal-union can lead to tibio-fibular instability and post traumatic OA – requires lengthening fibula osteotomy
- **Medial malleolus**
    - Cancellous lag screws
    - Parallel to joint if vertical fracture (perpendicular to fracture line)
    - TBW
    - Antiglide plate
    - 2 K wires or mini fragment plate if fragment too small or comminuted

- **Medial approach**
    - Protect long saphenous vein & nerve anterior to medial malleolus
    - Split fibres of deltoid ligament to allow hardware to seat directly on bone
    - Explore medially if unable to reduce mortise

- **Syndesmosis – Injury**
  - Indicated by anterior ankle pain
  - External rotation stress radiograph
  - Cotton/hook test - Widening of syndesmosis with lateral pull on fibula
  - Lowest rate of false-positive results and smallest inter-observer variance
- **Literature review –Archives of orthopaedics & trauma, 2011**
  - Outcome similar in retained and removed syndesmosis screws
  - No adverse events from broken screws
  - Removal at 4 months if intact screw causes reduced dorsiflexion
  - Removal in < 8 weeks leads to tibiofibular diastasis
  - Direction from post to ant at 25–30° and parallel to tibial plafond
  - Tricortical screw just proximal to tibiofibular joint
  - 4 cortices easier to remove from medial side if broken
  - Not compression screw- thread must be tapped in both fibula & tibia
  - 3.5 mm or 4.5 mm cortex screw, Small fragment less prominent
  - Screws loosen in 15% or break in 15%
  - 2 small fragment screws in high fibular fractures, such as Maisonneuve injury
  - Foot position during positioning screw placement should be in neutral
  - Tightrope (Arthrex), No need for routine removal & Eliminates risk of broken screw
- **Posterior malleolus**
  - Fragment attached to distal fibula by PITFL
  - Fix when >25% or associated with syndesmotic disruption
  - Fix before fibula as fibular plate obstructs imaging to assess articular alignment
- **Calcaneotalotibial nail**
  - Used in frail elderly patients
  - Long nail to bypass isthmus

BOAST 12-Management of Ankle fractures

- Stable fractures should be treated with analgesia, splinting and patients allowed to FWB as tolerated.
- Where fracture stability is uncertain (but position acceptable), mobilise NWB but review within 2 weeks with weight-bearing x-rays to confirm alignment maintained.
- Always check syndesmosis stability during ORIF
- Surgical patients should be FWB as tolerated in a splint or cast – unless fixation is tenuous, soft tissues a concern, or those with peripheral neuropathy. Check x-rays within 6 weeks
- No consensus on the removal of syndesmosis screws or VTE prophylaxis
- Advise patients on functional recovery, rehab, and return to work/sports/driving
- **Nasell et al (Sweden) JOT 2011**
  - Ankle fractures treated operatively had increased postoperative complications in presence of following factors
    - Smokers – 6 times higher odds of deep infection
    - DM
    - Unsatisfactory 740reduction
    - More complicated fracture pattern

TRAUMA SCORING

- Requirements of any classification
  - Easy to remember
  - Guide treatment
  - Inter and intra observer reliability

Glasgow Coma Score

- **Best motor response**
  - 6 - Obeys command
  - 5 - Localizes pain
  - 4 – Withdraws from pain
  - 3 - Abnormal flexion
  - 2 - Abnormal extension
  - 1 - None (flaccid)
- **Verbal response**
  - 5 - Oriented
  - 4 - Confused conversation
  - 3 - Inappropriate words
  - 2 - Incomprehensible sounds
  - 1 – None
- **Eye opening**
  - 4 - Spontaneous
  - 3 - To speech
  - 2 - To pain
  - 1 – None

ISS Injury Severity Score

- Used for mortality
- Based on anatomical criteria (9 anatomical regions)
- Each body system given score 1-6
- Sum of squares of AIS scores of the three most severely injured body regions
- Score > 16 is severe, considered poly-trauma - associated with 10 % mortality
- Modified ISS for paediatric - 5 regions

Tscherne classification

- Soft tissue injury in closed fractures
  - Grade 0: Minimal, indirect simple fracture
  - Grade 1: Superficial abrasion or contusion
  - Grade 2: Deep abrasion or muscle contusion, blisters
  - Grade 3: Extensive contusion, crush or degloving, compartment Syndrome

Mangled Extremity Severity Score MESS

- Tool utilized to help predict limb salvage success versus primary amputation at time of presentation
- Has high specificity but low sensitivity for predicting amputation
  - Score of 7 or more highly predictive of amputation
  - Skeletal & soft tissue injury (graded 1-4)
  - Limb ischaemia (graded 1-3)
  - Age (graded 0-2)
  - Shock (graded 0-2)
- **LEAP study (2001)** - Lower Extremity Assessment Project
  - Multi-centre study of severe extremity injuries treated with amputation or reconstruction at 2 years
  - High specificity but low sensitivity of mangles extremity scoring systems
  - Highest impact on decision making - severe soft tissue injury
  - Absence of plantar sensation not prognostic of long term functional outcome
  - Return to work was not statistically significant
  - Reconstruction patients had higher risk of re-hospitalisation & prolonged treatment
- **Akula et al. Injury (2011) –** Meta-analysis demonstrated lower limb reconstruction is more acceptable psychologically to patients, even though physical outcome for salvage or amputation was more or less the same
- **Sequence of salvage**
  - Shunt vascular injury
  - Ex-fix
  - Debridement
  - Formal vascular repair

AO classification

- Described by Muller et al 1979
- Formation of alphanumeric code
- Each long bone assigned number

1	Humerus	**2**	Radius/ulna
3	Femur	**4**	Tibia/fibula

- Each bone subdivided into segments

1	Proximal	**2**	Diaphyseal
3	Distal	**4**	Malleolar

- Morphology described as
  - **A:** Simple or Extra-articular or Extra-capsular (for hip)
  - **B**: Wedge or Partial (unicondylar) articular or intra-capsular (for hip)
    - Partial articular only part of joint involved while remainder remains attached to diaphysis
  - **C**: Comminuted or Complete (bicondylar) articular
    - Complete articular joint surface fractured and separated from diaphysis

Ganga hospital score

- To prognosticate limb salvage and outcome measures in Type IIIb open tibia fractures
- Factors
    - Covering tissues: skin and fascia
    - Functional tissues: Muscles, tendons and nerves
    - Skeletal structures: Bones and joints

Gustilo classification

- Grade I: < 1cm (puncture wound)
- Grade II: > 1 – 10 cm (moderate soft tissue damage)
- Grade III: High energy (Extensive soft tissue damage)
    - A: Adequate soft tissue coverage of bone after stabilization, periosteum intact
    - B: Inadequate coverage after stabilization, extensive periosteum stripping
        - Free or rotational flap required
    - C: Vascular injury requiring repair
- Prevalence of non-union and wound infection increases with higher grading
- ORIF if able to achieve soft tissue cover

Gustilo & Anderson's paper

POSSUM

- Physiology and Operative Severity Score for the enumeration of Mortality and Morbidity

TARN Trauma Audit and Research Network

- National organisation that collects and processes data on moderately and severely injured patients in England and Wales
- Allows major trauma centres, trauma units, ambulance services and individual clinicians to benchmark their trauma service with other providers across the country

GUNSHOT WOUNDS

- Exponential increase in injury with increasing velocity (kinetic energy)
- Kinetic energy proportional to mass and velocity (squared)

Classification

- Low velocity
  - <350 m/sec
  - Most handgun wounds
  - Comparable to Gustillo-Anderson Type I or II
- Intermediate velocity
  - 350-500 m/sec
  - Shotgun blasts
  - Variable depending on distance from target
- High velocity
  - >600 m/sec, military and hunting rifles
  - Wounds comparable to Gustillo-Anderson Type III regardless of size
  - Significant exit wound from massive transfer of energy
  - High risk of infection secondary to wide zone of injury & devitalized tissue

Treatment

- **Low-velocity with no bone involvement**
  - Wound care
  - Tetanus prophylaxis
  - Oral antibiotics
  - Primary closure contraindicated
- **Fractures**
  - Low velocity Internal fixation
  - High velocity External fixation
  - Intra-articular Remove (may lead to articular lead intoxication)
- Retained bullets in other anatomic locations do not warrant removal as no increased risk of infection even after penetrating the GI tract organs

DCO DAMAGE CONTROL ORTHOPAEDICS

- Aim to achieve haemodynamic stability with minimal orthopaedic intervention
- Rapid emergency surgery to save life/limb, whilst avoiding time-consuming and potentially traumatic reconstruction
- Involves staging definitive management to avoid adding trauma (2nd hit) to patient during vulnerable period
- Early stabilization and soft tissue management
- Patients at increased risk for perioperative complications such as ARDS and multi-system organ failure during acute period after polytrauma
- When to perform definitive surgery, (haemodynamic stability)
  - HR < 100 MAP > 60 (Indicators of adequate resuscitation)
  - Lactate (< 2.5 mmol/L)
    - Most sensitive indicator of adequate perfusion
    - Indicative of anaerobic metabolism due to inadequate perfusion
  - No coagulopathy; platelets > 95 000 & INR < 1.5
    - Inflammation causes Platelet dysfunction and accelerated fibrinolysis
  - Normothermia (Temp > 36)
  - Urine output (> 1ml/Kg/hr (sign of end organ perfusion)
  - Normal IL 6
  - Base deficit (Normal -2 to +2)
    - Indicative of metabolic acidosis
- Principles of surgery
  - Ex – fix of long bone fracture
  - Irrigation and debridement of open fractures
- 1st hit, produces inflammatory response (IL 6 & 10)
- Manage coagulopathy and metabolic derangements
- Hypotensive resuscitation - keep blood pressure low to avoid exsanguination while maintaining perfusion of end organs

ETC EARLY TOTAL CARE

- Definitive fixation of all long bone fractures within 24 hours of injury, once patient is physiologically stable
- Consider simultaneous surgeries with multiple surgeons to reduce operative time
- Long bones: restore length – alignment – rotation

Evidence for ETC, DCO or EAC (Early Appropriate Care)

- **Pape et al, J Trauma (2002)**
  - Showed DCO as adequate alternative for patients at high risk of developing post-traumatic systemic complications, e.g. ARDS and MODS
- **Pape, Giannoudis, et al. JOT (2005) – Differentiated trauma patients into 4 categories – Stable, borderline, unstable and in-extremis based on**
  - ETC for stable patients
  - DCO for unstable patients
  - ITU admission for in-extremis patients
  - ETC/DCO of borderline patients – depending on resuscitation status

TRAUMA CALL

- Trimodal distribution of death
- First peak
    - Seconds to minutes
    - Death from apnoea due to severe brain injury or high spinal cord injury or rupture of aorta
    - Prevention
- Second peak
    - Minutes to hours (golden hour)
    - Rapid assessment and resuscitation
- 3rd peak
    - Days to weeks
    - Sepsis and multi organ dysfunction

- **Basis of ATLS protocol is ABCDE**
    - Assessment of Airway (with C spine control)
    - Breathing (With oxygen)
    - Circulation
        - Haemorrhage control and IV fluid/blood
        - Pregnant women placed in left lateral decubitus position
        - Crystalloid, O –ve, Type specific, Cross matched blood
        - Tranaexamic acid (CRASH-II trial – loading dose 1gm over 10 mins within 3 hours followed by 1gm over 8 hours)
    - Disability (Neurological assessment/ Glasgow coma scale)
    - Logroll (Look for bruising and feel for step off)
    - Exposure (and secondary survey)
    - Trauma series (C spine, chest & pelvic X rays)

- **Cochrane**
    - No evidence that resuscitation with colloids reduces risk of death, compared to resuscitation with crystalloids in patients with trauma, burns or following surgery (<1L fluids)
    - Platelets should be transfused within 1 hours of leaving fridge, RBCs & FFP within 2hrs
- **TEG – Thromboelastograph (Haemostasis Analyzer)**
    - Allows accurate assessment of clotting function
    - Facilitate understanding of haemorrhagic or thrombotic risk
- Shock; clinical manifestation of inadequate organ perfusion and tissue oxygenation
- Septic shock
    - Usually by Gram negative (endotoxic shock) bacteria
    - Reduction in peripheral vascular resistance leads to vasodilatation
- Blood volume; Child (80ml/kg) & Adult (60ml/kg)
- Haemorrhagic shock classification 10th Edition ATLS

Parameter	Class I	Class II	Class III Moderate	Class IV Severe
Blood loss	<15% (<750 ml)	15-30% (759-1500 ml)	30-40% 1500-2000 ml)	>40% (>2000 ml)
Heart rate	Normal	>100	>120	>140
Blood Pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal	Decreased	Decreased	Decreased
Respiratory rate	Normal	Normal	N/Increased	Increased
Urine Output	>30 ml/hr	20-30 ml/hr	5-20ml/hr	<5ml/hr
GCS	Normal	Normal	Low	Low
Base deficit	0 to -2mEq/L	-2 to -6	-6 to -10	-10
Blood products	Monitor	Possible	Yes	Massive transfusion protocol

Triage

- Process of prioritizing patient treatment during mass-casualty event
- Based on patients' needs and available resources
- ATLS priorities
- Happens at scene of accident and in hospital
- Ensure own safety

The early management of patients with multiple injuries

TETANUS PROPHYLAXIS

- **Tetanus**
  - Caused by tetanospasmin
  - Exotoxin of anaerobic Gram +ve rod (bacillus) – Clostridium Tetani which is found in soil
  - Neuroparalytic disease
  - Toxoid is booster -TTB (inactivated vaccine) & IGg is active immunity

- **DOH guidelines**
  - Full course & booster <10 years — Nil if clean — TTB if dirty
  - Full course & booster > 10 years/non-immunised — TTB if clean — TTB if dirty

Clean wound is defined as wounds less than 6 hours old, non-penetrating with negligible tissue damage

AMPUTATIONS

Indications

- Irreparable loss of blood supply
- Severe soft tissue compromise
- Malignant tumours
- Congenital anomalies
- Insensate limb following trauma, prolonged ischemia time (2 consultants to make decision for amputation – involve plastics, vascular surgeons)
- Uncontrolled infection
    - Increased energy and O2 consumption
    - Inversely proportional to length of remaining limb
        - Hip disarticulation 100 – 150 %
        - AKA 60 % Bilateral 200%
        - BKA 20 % Bilateral 40 %
        - Syme 5 %

Principles

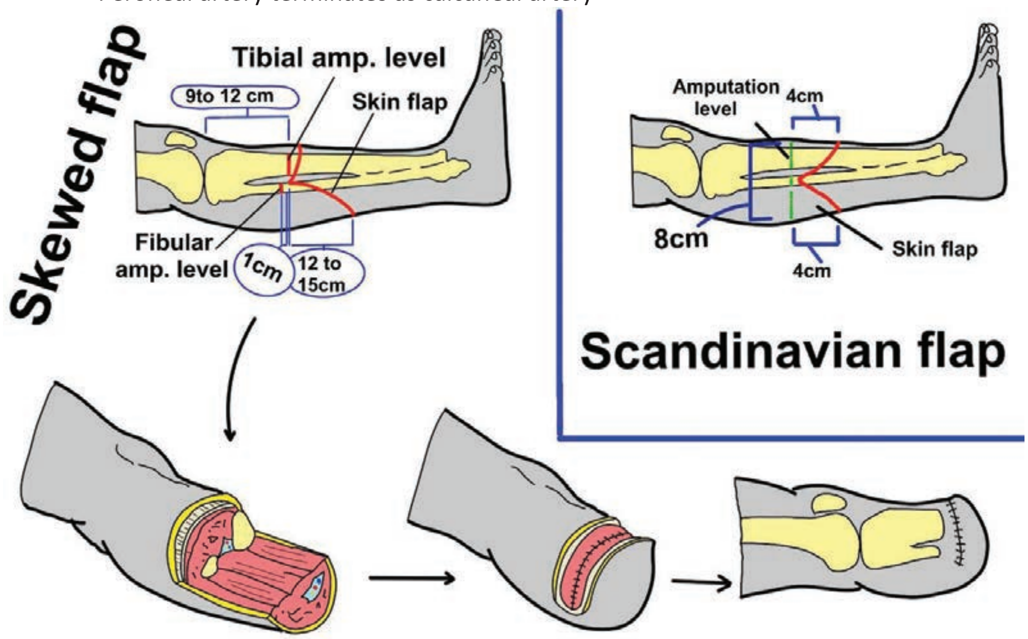
- Stump should be cylindrical or conical
- Disarticulation in children to prevent bone overgrowth
- Myoplastic (muscle to periosteum) or myodesis (muscle to bone) technique
- Gentle tension on nerves with sharp sectioning to allow burying to hide neuroma
- Bevel bone ends
- Drain to avoid haematoma
- Compression dressing
- Avoidance of joint contractures
- Early prosthetic fitting
- Physio and rehab
- Psychologist
- **Ideal stump**
    - Full ROM in proximal joints
    - Non adherent scar
    - Muscles to cover bone
    - Level balanced between preservation of useful limb and removal of non-functioning limb
- **Hindquarter**
    - Remove entire lower limb
    - Can't fit prosthesis
- **Transfemoral**
    - 12 cm above knee joint to allow prosthetic fitting
    - Adductor myodesis - Creates dynamic muscle balance
    - Provides soft tissue envelope that enhance prosthetic fitting
- **Through-Knee-Amputation (disarticulation)**
    - Worse pain and performance compared to AKA & BKA
    - Better sitting stability if bilateral
    - Bulbous shape assists suspension

Below knee amputation

- Good in children as there are less complications from overgrowth of BKA ,causing skin breakdown, pressure ulcers and difficulty with prosthesis fitting

➢ **BKA**

- 8-12 cm below knee joint minimum to retain tibial tubercle and patella tendon attachment
- Base of flap level with bone resection level
- Long posterior myocutaneous flap (Skew flap) in ischaemia as it has better blood supply
- Move incision away from weight bearing area
- Section fibula 3 cm proximal to tibia
- Ligate:
    - Anterior tibial artery
    - Posterior tibial artery (terminates as medial and lateral plantar arteries)
    - Peroneal artery terminates as calcaneal artery



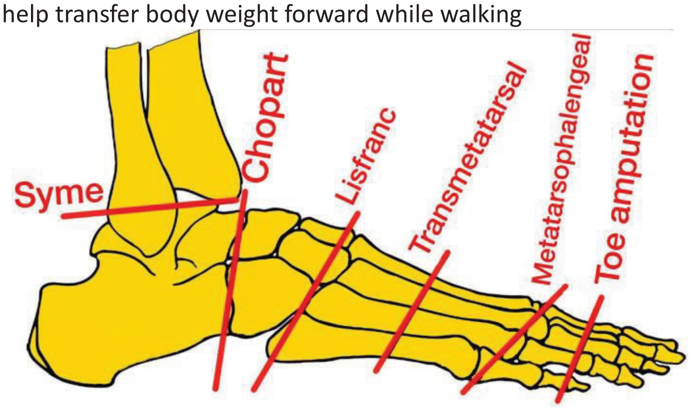
➢ **Syme amputation**

- Ankle disarticulation
- Remove malleoli
- Mobilise and stabilize heel pad to weight bearing area is most important step
- Viable heel pad critical for surgical success – should have palpable posterior tibial pulse
- More energy efficient than midfoot even though it is more proximal
- Symes socket bulky/need contralateral raise
- Fat pad migration

➢ **Chopart amputation**

- Avoid equinus by lengthening TA & transfer tibia ant to talar neck
- Avoid varus by transfer of tibia ant laterally
- Hindfoot amputation
- Through talonavicular and calcaneocuboid joints

- **Lisfranc amputation**
  - Equinovarus deformity
  - Caused by unopposed pull of tibialis posterior and gastroc/soleus
  - Prevent by maintaining insertion or transfer of peroneus brevis or TA
  - Lengthening
- **Transmetatarsal amputation**
  - Require Achilles lengthening to prevent equines
  - Rocker soles help transfer body weight forward while walking



- **Great toe amputation**
  - Preserve 1cm at base of proximal phalanx to
  - Preserve insertion of plantar fascia & Sesamoids & flexor hallucis brevis
  - Reduce amount of weight transfer to remaining toes & lessens risk of ulceration
  - Toe filler orthotic insole
- **Upper extremity amputations**
  - Wrist disarticulation Preserves radial styloid flare to improve prosthetic suspension
  - Improved pronation and supination (longer lever arm)
  - **Trans-radial** Easier to fit prosthesis
3 cm distal to biceps insertion
  - **Trans-humeral**
  - **Shoulder disarticulation** (Retain humeral head)
  - **Forequarter** (Poor cosmesis and difficult to mount Orthotic)

Complications

- Haematoma
- Infection
- Skin breakdown
- Flexion contracture-Splint if at risk
- Phantom limb sensation and pain
- Weight gain
- Increased energy demands
- Painful neuroma
- Back pain
- Psychological

Amputations for the FRCS

HEAD INJURY

- **Concussion** Transient impairment of neurologic function
  Headache, dizziness, memory loss
  Can last up to 10 days
  Second impact syndrome, second minor blow to head before initial symptoms resolve might
  Result in diffuse cerebral swelling, brain herniation and death
  Post-concussion syndrome – headache, confusion

- **Extradural haematoma** Biconvex
  Do not cross suture lines as dura adherent to cranium
  Usually associated with fracture
  Result of damage to anterior part of middle meningeal artery
  Lucid interval in 20%
  Life threatening

- **Subdural haematoma** Concave/crescent-shaped
  Both extradural and subdural haematomas could lead to rise in ICP

- **Basal skull fractures** frontal skull # can cause anosmia due to damage to cribriform plate (olfactory nerve)
  Visual defects by damage to orbit and optic chiasma
  Discharge from nose or ear may indicate leakage of CSF
  Blotting paper test Fluid placed on blotting paper
  CSF forms yellow ring (halo) around blood
  Bruising over mastoid bone, retro-auricular ecchymoses - Battle sign
  Peri-orbital ecchymosis, racoon eyes

- **Early stages of head injury**
  - Non-linear relationship between expanding haematoma and elevation of ICP
  - Haematoma may expand without any significant rise in ICP
  - Once this early compliance lost, pressure will rise rapidly severely jeopardises cerebral perfusion
  -

Cerebral perfusion pressure (CPP) equal to mean arterial blood pressure minus ICP
Normal CPP 70 mmHg
Normal ICP 10–15 mmHg
Critical to avoid peri-operative hypotension and hypoxemia when fixing other injuries

- **Monro–Kellie hypothesis** sum of intracranial volumes of blood, brain, CSF is constant
  Increase in any must be offset by corresponding decrease in another, or else ICP rise

In multi-trauma with head injury, don't start VTE prophylaxis until head bleeding excluded