ACUTE LIMB ISCHEMIA

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General Considerations

- Arteries are characterized by the presence of a collateral circulation, which under normal conditions is collapsed. This circulation opens whenever the blood flow in the main artery is inadequate for the tissue requirements.
- The term ***ischemia*** means relative diminished blood supply in relation to tissue demand.
- Ischemia may be acute or chronic according to the onset of arterial occlusion.
- **Acute limb ischemia** is a surgical emergency condition, which requires timely management and can be associated with high morbidity and mortality rates.
- The most common causes for nontraumatic acute limb ischemia include:
  - Embolism from the heart.
  - Thrombosis over an existing arterial plaque/stenosis.
  - Thromboembolism from arterial aneurysm.
  - Acute bypass graft occlusion (Vein or synthetic graft).

Effects of ischemia depend on

1. ***Type of artery:*** Some arteries have a very efficient collateral circulation to the extent that their ligature *may not* be followed by serious consequences e.g. subclavian artery. On the other hand, the popliteal artery has a poor collateral circulation.
2. ***Rate of artery occlusion*****:** Acute ischemia is much more serious than chronic ischemia as there is no enough time for the collateral circulation to develop.
3. ***State of the collateral vessels*****:** Healthy collaterals can compensate to some extent the ill effects of ischemia. If collaterals are atherosclerosed, ischemia will be severe & extensive.
4. ***General condition of the patient:*** Myocardial insufficiency or severe anemia will exacerbate the effects of ischemia.

Definition of Acute Limb Ischemia

Acute limb ischemia is any *sudden ↓ or worsening in limb perfusion* causing a potential threat to extremity viability.

Etiology

1. **Acute arterial embolism** (of a relatively healthy arterial tree).
2. **Acute arterial thrombosis** (of a relatively diseased arterial tree).
3. **Acute traumatic ischemia**: Arterial *trauma* either direct (stab) or indirect (blunt trauma or fracture bones) (Figure 1). It may be due to
   - Spasm of the vessel.
   - Sub-intimal hematoma.
   - Thrombosis of lumen.
   - Complete transection.

Figure 1. Brachial artery injury after fracture of humerus

Figure 2. Accidental intra-arterial drug injection causing acute ischemia & gangrene of the fingers

4. **Other causes**
   a. Accidental intra-arterial drug injection (Figure 2).
   b. Aortic dissection.
   c. External compression, e.g. a very tight tourniquet.
   d. Compartment syndrome: ↑ pressure due to hematoma or tissue edema in a closed space by bone, inter-osseus membrane & deep fascia resulting in ischemia (more in tibial plateau fracture).
   e. Extensive ilio-femoral DVT (phlegmasia cerulea dolens).

ARTERIAL EMBOLISM

Definition

- Embolus is originally a *Greek* word that means "*a plug or a stopper*".
- Embolism is the passage of a matter from one part of the circulation to another through a vascular lumen. ***Arterial embolism is considered the classical example of acute ischemia.***

Etiology

1. Thrombus

- The usual source of arterial emboli is a *thrombus* present, either in the left side of the heart, or in a major proximal artery.

***2. Cardiac* sources**

- Arrhythmia: Atrial fibrillation (AF) is usually associated with rheumatic mitral stenosis (MS) or with atherosclerosis that is complicated by a thrombus of *left atrium*. The latter is the source of emboli.
- Recent myocardial infarction (MI) that causes a mural thrombus.
- Bacterial endocarditis on top of rheumatic or congenital heart disease, or affecting a prosthetic valve.

3. Non-cardiac sources

- A thrombus in an aneurysm
  - Abdominal aortic aneurysms (AAA).
  - Cervical rib causes post-stenotic dilatation (subclavian aneurysm), which results in distal embolization.
- Platelet thrombi on top of an ulcerated atherosclerotic plaque, e.g. in the carotid arteries that → cerebral embolization → transient ischemic attack & even hemiplegia.

4. Iatrogenic

- Mitral valvotomy.
- Valve replacement.
- After arterial puncture in arteriogram.
- In therapeutic embolization to treat bleeding (e.g. peptic ulcer).

Pathophysiology of Arterial Embolization

- It involves the following steps (Figure 3).
  1. Impaction of the embolus.
  2. Propagation.
  3. Muscle necrosis.
  4. Gangrene – venous thrombosis

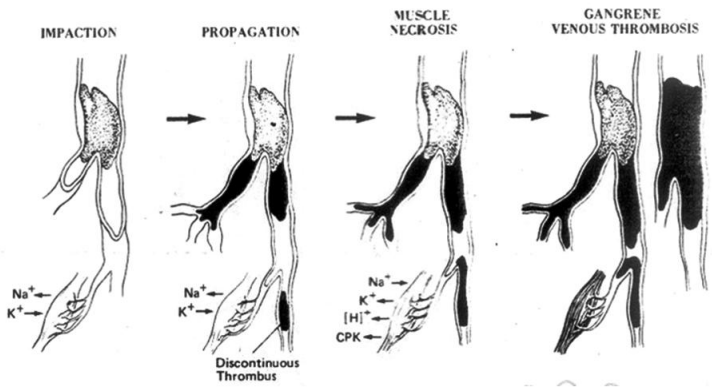


Figure 3. Pathophysiology of arterial embolization

Sites of Emboli

- An embolus in the arterial tree is usually arrested at the sites of *bifurcation of arteries* where sudden ↓ in the size of the arterial lumen occurs (Figure 3).
- The lower limbs (LLs) are more commonly affected.
- The commonest sites of arrest of emboli are:
  1. The bifurcation of the common femoral into superficial & deep femoral arteries (40%).
  2. Aortic bifurcation (*saddle embolus*) (Figure 4).
  3. Bifurcation of the popliteal artery.
  4. Bifurcation of the brachial artery.
  5. Bifurcation of common carotid artery (CCA)

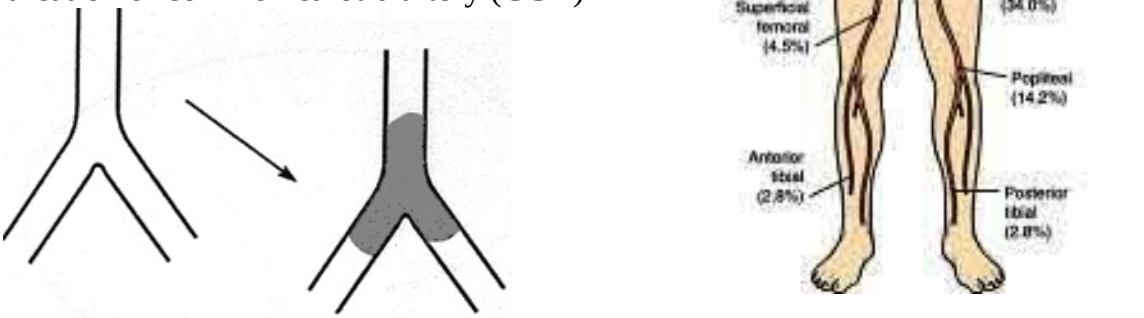


Figure 4. Embolism at aortic bifurcation (*saddle embolus*)

Figure 3. Sites of arterial embolism

ACUTE ARTERIAL THROMBOSIS

Definition

- Sudden occlusion of an artery by the formation of an adherent thrombus over a *diseased intima* e.g. ulcerated atherosclerosis.

Etiology

1. On top of chronic occlusive arterial disease eg atherosclerosis (commonest) or Buerger's disease
2. As a complication of arterial aneurysm.
3. As a result of traumatic contusion of vessels.
4. Arterial thrombosis may complicate febrile illness or gastroenteritis especially in children. Dehydration → hemo-concentration → thrombosis, heart failure & hypertension.
5. Blood disease that ↑ blood coagulation.
6. Drugs that ↑ blood coagulation e.g. corticosteroids, oral contraceptives.
7. Debilitating diseases.

Factors predisposing to acute thrombosis

There are certain predisposing factors for development of thrombosis in a normal or diseased artery.

Predisposing factors for development of acute arterial thrombosis

Cause	*Example*
Dehydration	Hot weather, diarrhea, fever
Hypotension	Shock, sepsis, Myocardial infarction
Pressure	Prolonged sitting
Malignancy	Hematologic cancers
Hypercoagulable state	Thrombophilia

Pathological Consequences of Acute Ischemia

- After circulatory arrest, widespread distal intra-vascular thrombosis occurs. Thrombosis may also affect the artery proximal to the site of occlusion.
- *Ischemic muscles* get swollen & this, in turn, exaggerates the effects of ischemia by compression of the collaterals (***compartment syndrome***). This muscle compression is more apparent in the muscular compartments of the leg. Early "***fasciotomy***" of the muscle

Figure 5. Fasciotomy with muscle bulge due to high compartmental pressure

compartments can avoid this problem (Figure 5) i.e. longitudinal incision of the deep fascia of the leg in the affected compartment [anterior, lateral, posterior (superficial & deep)], either open, or semi-closed fasciotomy.

- If involving all compartments, ***fibulectomy*** is done.
- Consequences depend upon the etiology, site & duration of ischemia as well as the efficiency of treatment (Figure 6):
  1. Complete recovery (in small embolus with efficient collaterals).
  2. Gangrene, which is usually of the ***wet type***.
  3. Chronic ischemia.
  4. Volkmann's ischemic contracture.

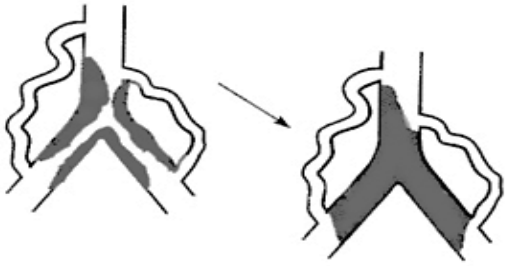


Figure 6. Consequences of vascular occlusion

Clinical Features of Acute Ischemia

- Severe acute ischemia → classic symptoms & signs **(6Ps)** (1 symptom "pain" + 5 signs)
  1. ***Pain*** (symptom)
  2. ***Parasthesia***
  3. ***Pulseless***
  4. ***Paralysis*** or paresis
  5. ***Pallor*** (color)
  6. ***Perishing coldness*** (temperature)

- ***Inspection (color)***
  - Initially the leg is marble *white* & the veins are empty (Figure 7). After 6-12 h, vasodilatation occurs & capillaries fill with stagnant deoxygenated blood → *cyanosis & mottled appearance*.
  - Later, capillaries rupture → fixed mottling & cyanosis (Figure 8), "irreversible changes", with tense calf, fixed plantar flexion (*rigor mortis*) & then, frank *gangrene*.

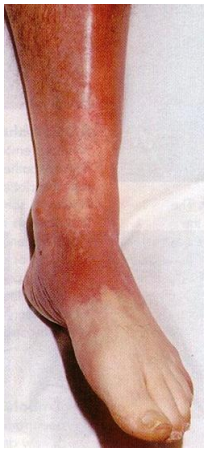


Figure 7. Pallor (foot) & empty veins (early changes)

Figure 8. Permanent mottling & cyanosis (arrow) (late changes)

- ***Palpation***

Pulseless

- Palpate arterial pulses (Figure 9). Compare with the other side.
- Slow capillary re-filling of the skin after finger pressure.

Temperature

- The limb is cold with a level of temp. change.

Parasthesia (loss of sensory function) occurs first

- Numbness will progress to anesthesia.
- The progress of sensory loss is in that order: light touch, vibration sense, propioception, deep pain & pressure sense (late).

Figure 9. Palpation of arterial pulses

Paralysis / paresis (loss of motor function)

- Loss of motor function indicates advanced limb-threatening ischemia.
- Later → irreversible ischemia → muscle turgidity.
- Intrinsic foot muscles are affected first, followed by leg muscles.
- Detecting early muscle weakness is difficult because toe movements are produced mainly by leg muscles.

- ***Rutherford Classification of acute ischemia***

Rutherford Clinical Categories of Acute Limb Ischemia

		Findings		*Doppler signals*	
Category	**Description/prognosis**	**Sensory loss**	**Muscle weakness**	**Arterial**	**Venous**
I. Viable	Not immediately threatened	None	None	audible	audible
II. Threatened;					
a. Marginally	Salvageable if promptly treated	Minimal (toes) or none	None	(Often) inaudible	Audible
b. Immediately	Salvageable with immediate revascularization	More than toes, associated with rest pain	Mild, moderate	(Usually) inaudible	Audible
III. Irreversible*	Major tissue loss or permanent nerve damage inevitable	Profound, anesthetic	Profound, paralysis (rigor)	Inaudible	Inaudib

N.B Anterior tibial compartment syndrome

Definition

- Increased pressure due to hematoma or tissue edema in a closed space by bone, interosseus membrane & deep fascia resulting in ischemia (more in tibial plateau fracture) or in delayed cases of acute ischemia.

Clinical Picture

- At first, the pulse & skin circulation are normal, but the early manifestations are:
  1. Severe pain not proportional to the trauma.
  2. Marked muscle tenderness.
  3. Passive stretch of muscles causes severe pain.
  4. Loss of sensation in the 1st dorsal cleft of foot.

Treatment of Compartmental Syndrome

- Elevation of the leg.
- Drug to reduce edema.
- If progressive → *fasciotomy* of the affected compartment [anterior, lateral, posterior (superficial & deep)], either open, or semi-closed fasciotomy. If involving the 4 compartments, *fibulectomy* is performed

Investigations for acute ischemia

The aims of investigation are:

1. To diagnose the condition (which is usually diagnosed on clinical basis)
2. To define the etiology of the condition.
3. To evaluate co-morbidities of the patient that will have mostly a surgical intervention.

Imaging studies

1. ***Duplex scan*** localizes & identifies the presence of embolism or a thrombus.
2. ***Arteriography***. It is not done in a threatened limb. Its value is in cases of diagnosed acute thrombosis because it provides information that is essential before doing an arterial reconstruction. This information includes:
   - Site of occlusion
   - Proximal inflow, i.e. if there is another proximal arterial narrowing.
   - Flow distal to the occlusion, i.e. distal run-off.
3. ***Echocardiography*** detects cardiac sources of embolism.
4. ***Plain X-ray chest*** (cervical rib, aortic aneurysm), ECG, ECHO.
5. Trauma: ***Plain X-ray bone.***

Laboratory studies

1. ↑ blood urea nitrogen (BUN) & creatinine indicate intra-vascular hypo-volemia due to fluid sequestration in the limb.
2. Acidosis & ↑ CPK & WBCs indicate extensive muscle necrosis.

Differential Diagnosis

1. Low flow states (shock).
2. Acute occlusion of popliteal or femoral aneurysm.
3. Phlegmasia cerula dolens (PCD) (edema, cyanosis & tense calf muscle)
4. Aortic dissection.
5. Arterial spasm after trauma (ischemia improves by vasodilators)

Differences between Embolic & Thrombotic Acute Ischemia

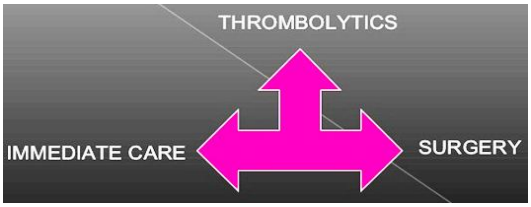
	Embolism	**Acute thrombosis on top of atherosclerosis**
History	Arrhythmia or recent myocardial ischemia	Intermittent claudication
Source of emboli	Usually present e.g. cardiac	Absent
Radial pulse	Usually irregular (AF)	Usually regular
Skin color	White	Dusky
Limb nutrition	Normal	Picture of chronic ischemia
Angiography	- Sharp cut-off - Minimal collaterals	- Tapering stenosis - Diffuse atherosclerosis - Extensive collaterals

Differences between embolic and thrombotic arterial occlusion		
Parameter	*Embolism*	*Thrombosis*
Duration of symptoms	2–4 hours (sudden onset)	24– 48 hours (insidious onset)
Aggravation of symptoms	Rapid	Slow
Previous claudication	Absent	May be present
Cardiac disease	May be present	May be present
Contra lateral pulses	Present	May be absent
Multiple sites	Up to 15%	Rare
Angiography	Total occlusion, no collaterals	Collaterals noted
Artery on palpation	Soft, dark wall due to underlying clots	Hard, calcified
Extracted clots	Dark red, gelatinous	White, firm
Treatment	Embolectomy	Thrombolysis with angioplasty/Bypass

Differences between Acute & Chronic Ischemia

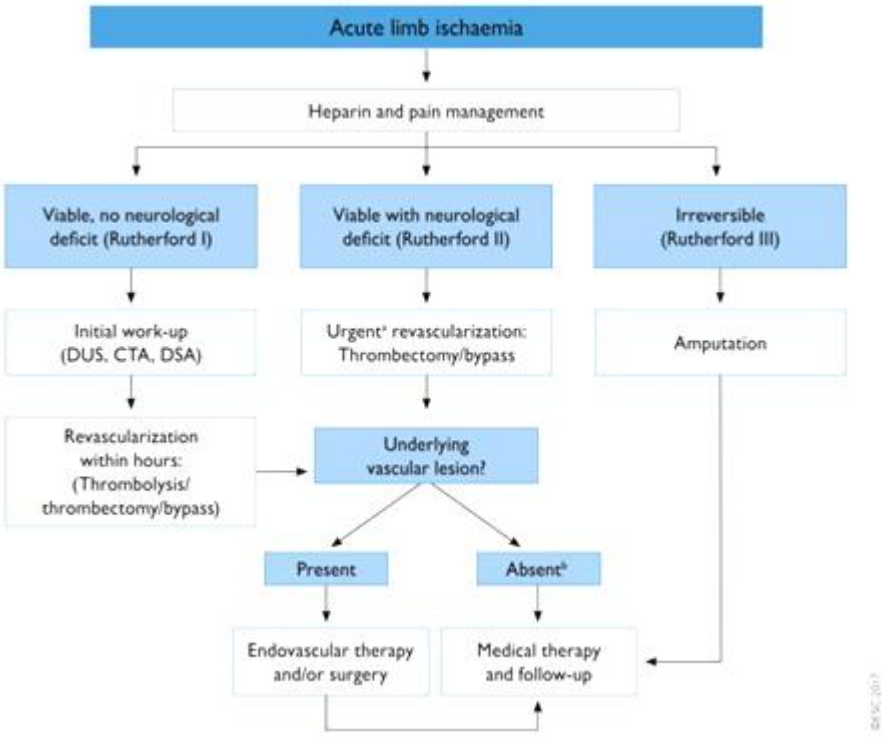
Criteria	Acute Ischemia	Chronic Ischemia
Age	Young	Old
History	Cardiac troubles or trauma	Other manifestations of atherosclerosis
Source of emboli	Present	Absent
Preceding claudication	No	Yes
Motor function	Absent (no collaterals).	Present.

Treatment of acute ischemia



***The aim is to*:**

1. Prevent further propagation of the thrombus
2. Correct general condition of the patient
3. Restore blood supply as fast as possible to the limb



- ***Immediate Care***

1. ***Anti-coagulation:*** IV Heparin. Start with 5000 to 10000 IU, followed by 3000-5000 IU/2 h. The dose is controlled by checking activated partial thromboplastin time (APTT) every 12 h, which should be maintained at 2-3 times the baseline level.
2. *Analgesics*: for pain.
3. *Measures to improve existing perfusion* + IV fluids to correct dehydration.
4. *R/ of associated cardiac condition*.

- ***Specific Measures***
  - ***Treatment of Embolism***

Emergency surgery is essential to remove the embolus "***embolectomy***". Urgent embolectomy using Fogarty balloon catheter is the standard method for removal of arterial emboli.

- The operation should be done as long as the limb is viable. The earlier the operation is done the better are the results because delay → occlusion of collaterals by propagated thrombosis & death of the limb.
- The operation can be done, under local, general or epidural anesthesia.

- ***Femoral artery embolectomy*** is done via a common femoral transverse arteriotomy.
- ***Aortic bifurcation embolectomy*** is done via bilateral femoral arteriotomy (Figure 10).
    - The Fogarty catheter is introduced through the femoral arteriotomy & is then passed up past the embolus in the lower aorta.
    - The balloon is inflated & the catheter is pulled out. The balloon sweeps the embolus out of the arteriotomy. The strong arterial blood flow will clear any residual fragments.
    - The Fogarty catheter should also be passed distally to extract any fragments of thrombi & propagated clots.

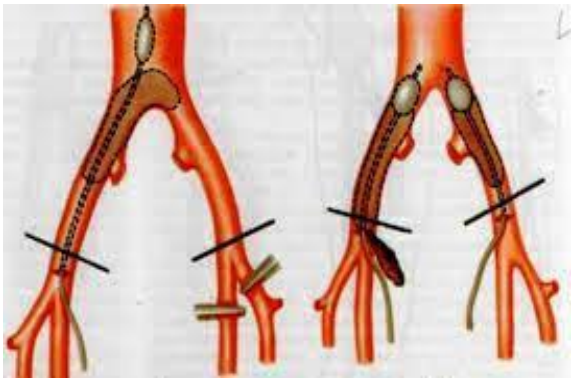


Figure 10. Embolectomy using Fogarty balloon catheter

- ***Brachial artery embolectomy*** is done via a brachial artery exposure.
- ***Arteriography*** is done on table to ascertain clearance of the arterial tree.
- ***Heparin*** should be continued post-operatively until the cardiac condition is assessed & the need for further heparin therapy is determined.
- **The *source of arterial emboli*** should be corrected if possible.
- ***Post-operative medical care:*** When you do embolectomy after a long period of ischemia, you need to do *fasciotomy* as the limb will swell (post-perfusion).

▪ *Treatment of Acute Thrombosis*

- ***Urgent arteriography*** is performed to plan for emergency "*revascularization surgery*".
- If there is time for the use of "*thrombolytic therapy*", elective revascularization surgery is done latter on.

1. *Thrombolytic therapy (CDT) Catheter Directed Thrombolysis*

Thrombolytic drugs

- Streptokinase may cause anaphylaxis.
- Urokinase is a direct plasminogen activator.
- Tissue plasminogen activator (TPA)

Technique

- At the completion of arteriography the tip of the arterial catheter is embedded in the thrombus. The thrombolytic drug is gradually introduced by drip for 6-12h until the artery patency & limb viability are assured.
- Heparin & oral anti-coagulants are then continued.

Complications

- Anaphylactic reaction with the use of streptokinase.
- Hemorrhage at the puncture site, GIT or cerebral.

Indications of catheter-directed thrombolysis

1. Viable or marginally-threatened limb (class I, IIa).
2. Recent acute thrombosis (not suitable for embolism or old thrombi).
3. Avoid patients with contra-indications

Contra-indications of catheter- directed thrombolysis

Absolute

1. Cerebro=vascular stroke within the previous 2 months.
2. Active bleeding or recent GI bleeding within the previous 10 days.
3. Intra-cranial trauma or neuropathy within the previous 3 months.

Relative

1. Cardio-pulmonary resuscitation (CPR) within the previous 10 days
2. Major surgery or trauma within the previous 10 days.
3. Uncontrolled hypertension.

2. Revascularization procedures

- Thrombectomy
- Bypass procedures.

Treatment of Trauma

- The vessel is exposed.
- Any tension or bone fragment is removed.
- The bone is better fixed by external fixator & damaged segment of the artery is resected & replaced with a reversed saphenous graft.

Complications of acute limb ischemia

These patients are at a high risk of myoglobinuria. The eventual requirement for amputation is also higher in these patients. Acute limb ischemia can lead to various loco-regional as well as systemic complications.

- ***Systemic***
  – Acidosis
  – Hyperkalemia
  – Myoglobinuria and acute tubular necrosis
  – Cardiac arrhythmias
  – Acute respiratory distress syndrome
  – Septic shock
- ***Local***
  – Compartment syndrome
  – Muscle necrosis
  – Muscle infarct
  – Causalgia (Reflex sympathetic dystrophy)
  – Gangrene

GANGRENE

Definition

- Macroscopic death of tissues caused by loss of blood supply.

Etiology

Ischemic	• Thrombosis • Embolism • Vasospastic
Neuropathic	• DM
Traumatic	
Physico-chemical	• Burns – Frost bite
Infective	
Venous	• Phlegmasia cerulae dolens

Cardinal signs of gangrene

- Loss of pulsations
- Change of skin color
- Loss of heat
- Loss of sensation
- Loss of function

Clinical types of gangrene

Dry gangrene

Due to slowly progressive vascular disease **(*Chronic ischemia*)**

Wet gangrene

In delayed ***(Acute ischemia)***

Gas gangrene

It develops deep in the body e.g. muscles caused by ***Clostridia*** infection

Specific types of gangrene

Necrotizing fasciitis

It is a rare infection of the deeper layers of skin & easily spreads within the subcutaneous (SC) tissue

Fournier Gangrene

It is a type of necrotizing fasciitis or gangrene affecting the perineum, usually the male genitals

AMPUTATION

INDICATION

- Peripheral vascular disease
- Diabetic limb disease
- Necrotising fasiitis
- Trauma (severe tissue damage) – traumatic amputation
- Infection (chronic disabling infection, Gas gangrene)
- Tumours (malignant)
- Nerve injury (traphic ulceration – insensitive limb)
- Congenital anomalies (e.g. extra digits) Gross deformity.

COMPLICATION

- Failure of healing
- Infection
- Phantom sensation: The patient feels that the amputated part is still present
- Telescoping: It is the sensation that the distal part of the amputated extremity has moved proximally up the arm.
- Phantom pain: The patient feels that the amputated limb is painful. It disappears with time
- Tens (trans cutaneous electric nerve stimulation)
- Contractures
- Neuroma

Criteria of ideal stump:

- Optimum length

Level	Site of Amputation	Stump not <
- Below knee	10-12 cm from the tibial tuberosity	8 cm
- Above knee	12 cm above knee joint	20 cm from greater trochanter
- Upper Limb	Stump should be as long as possible.	

- Smooth and rounded
- Normal Vascularity
- No projecting spur of bone
- The stump shouldn’t be under tension
- The scar should be away from pressure area
- Painless
- The stump is either; side-bearing (which is preferred) or end-bearing.

Levels of Amputation in the Lower Limb

Distal Amputation	
Toe amputation	In small vessel disease with good surrounding blood supply.
Ray-excision	Toe with part of the metatarsal bone
Trans-metatarsal amputation	Through the tarsal bones with long planter flap
***Chopart** amputation*	Leave the calcaneus & talus bones. Disadvantages are muscle imbalance leading to equinous deformity.

Major Amputation	
***Syme's** amputation*	Remove all foot & the limb stump is left on tibia & fibula & covered with skin of the heel. It is not suitable for ischemia but only for trauma.
Below-knee (BK)	A long posterior flap is made of the gastrocnemius muscle or equal flaps.
Above-knee (AK)	With equal flaps.
Through-knee	Via the joint.
Disarticulation	The whole limb is removed
Hind quarter	For malignancy, the LL & part of iliac bone are excised.