# MRI Technique

- **MRI Indications**
- **MRI Technical Background**
- **General MRI Terms**
- **MRI Sequences**

MRI technology is very complex and many books have been written about it. It is therefore impossible to discuss everything in detail.
This course focuses on practical MRI information. The first part will briefly address the underlying technology. Then some commonly used terms and MRI examinations will be reviewed.
The course concludes with a table outlining the reviewed MRI sequences.

## MRI Indications

MRI stands for **M**agnetic **R**esonance **I**maging and is based on magnetic resonance of hydrogen protons. Especially minor contrast deviations in soft tissues in the body can be imaged effectively using MRI. Therefore MRI is better at visualizing soft tissue pathology than CT scan.
Almost anything can be imaged with the MRI scanner. The list of indications is long and continues to lengthen with new technical developments. The following is an outline to give you some idea of the applications of MRI (fig. 1).

| MRI examination | Indications |
|---|---|
| Brain | Ischemia, sinus thrombosis, dissection, vascular malformations, temporal epilepsy, infection, tumors, multiple sclerosis (MS), dementia, congenital abnormalities, metabolic disease, pituitary pathology, internal auditory canal pathology |
| Spinal cord | Pre and postoperative HNP, radiculopathy, myelopathy, MS, infection, tumors |
| Musculoskeletal | Joints, muscles/tendons, cartilage, infection, tumors, arthropathies |
| Abdomen/pelvis | Characteristic hepatic/adrenal lesions, MRCP, pancreatic pathology, intestines (appendicitis, IBD (rectal carcinoma), prostate carcinomas, cervical carcinomas, perianal fistulas, endometriosis |
| Cardiovascular | Ischemia, cardiomyopathies, intracardial tumors, anatomy of large vessels (including aneurysmal screening), infection/inflammation (including myocarditis), vasculitis, sinus thrombosis |
| Mammography | Characterization & extent of tumors |
| Pregnancy | Fetal anomalies |

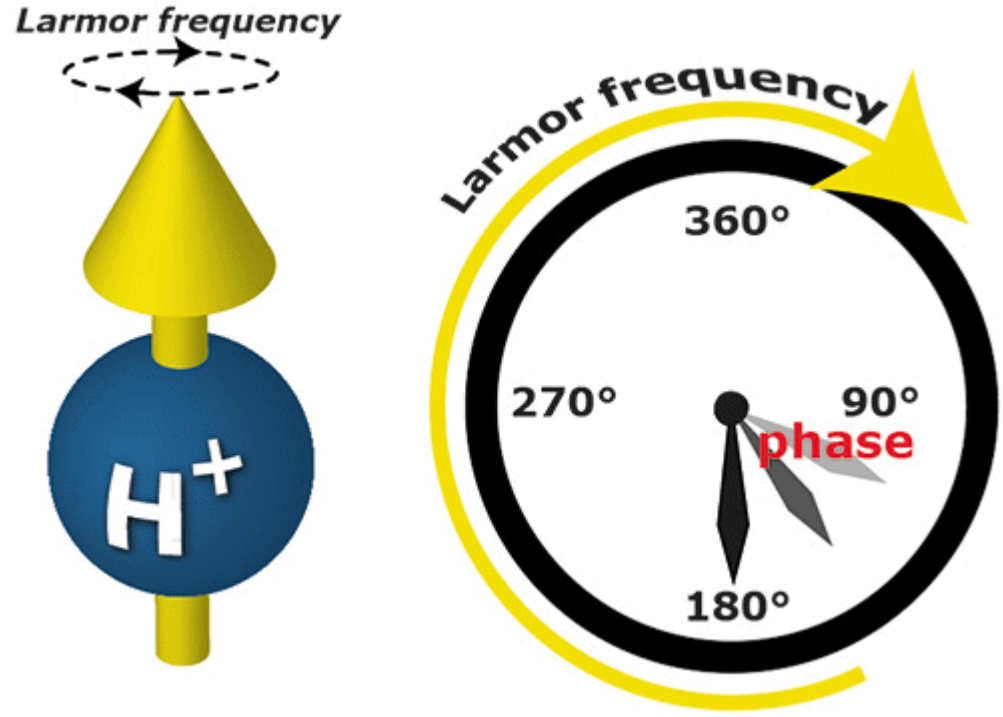
Figure 1. Summary of MRI indications. HNP = Hernia Nuclei Pulposi, MRCP = Magnetic Resonance Cholangio-Pancreatography, IBD = Inflammatory Bowel Disease.

## MRI Technical Background

- Excitation
- Relaxation

Excitation

The hydrogen proton is the most common atom in our body and can be found in substances including water (body consists for > 70% of water) and fat. Hydrogen protons are electrically charged (H+) and may be regarded as little magnets with a north pole & south pole. This makes hydrogen protons susceptible to external magnetic fields.
Each proton rotates 360° around its own axis (like a spinning top) and has a positive and negative pole. In order to understand MRI technology, you need to be aware that each proton spins with a certain speed, the so-called Larmor frequency (fig. 2). Because of its spin, the proton continually changes ‘phase’ (each phase is a snapshot, as it were). The relevance of this phase of the proton will be explained later in the course.




Figuur 2. Larmor frequentie en fase (‘momentopname’)

When hydrogen protons enter a strong external magnetic field (e.g. of the MRI scanner) most hydrogen protons will align themselves parallel to the strong external magnetic field. Most hydrogen protons will be aligned in the same direction.
The sum of direction & force of the parallel protons is represented on paper as a vector; the net magnetization. This is expressed with an arrow in the literature.
When a patient is placed in the MRI scanner, most protons will align themselves parallel to the magnetic field of the MRI device. In this resting phase, the net magnetization (vector) will always point towards the patient's head.

The Z axis represents the MRI scanner's magnetic field. This is also termed B0 (fig. 3).

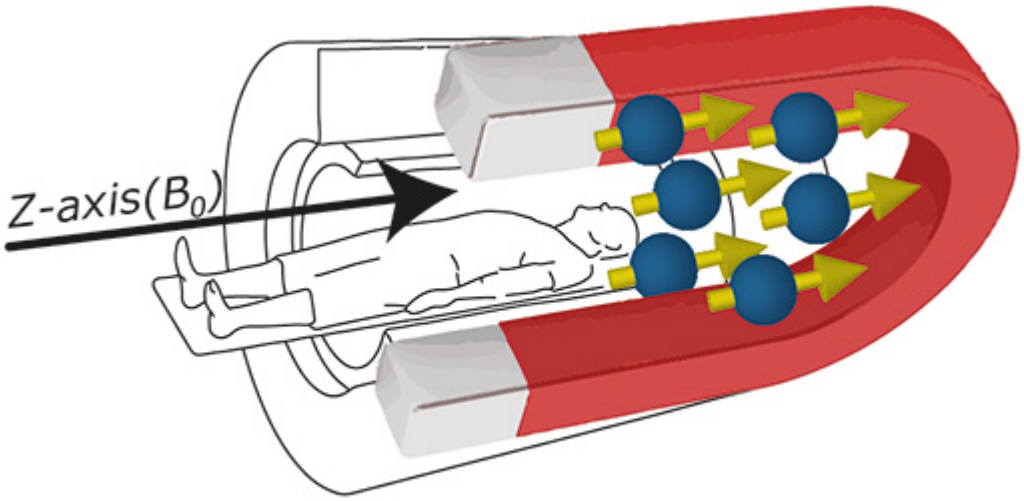



Figure 3. Protons align themselves parallel to the MRI device's magnetic field; the Z axis, also termed B0).

Despite the parallel alignment of protons in their resting phase, they will nevertheless have a different spin movement. In other words, the hydrogen protons do not spin synchronously, this is also termed ‘out-of-phase’. Hydrogen protons may be triggered by radiofrequent pulses with a specific frequency. When the frequency of the hydrogen proton (= Larmor frequency) matches the transmitted radiofrequent wave, resonance will occur. Energy is then transferred (as the opera singer breaking a glass). This is termed excitation. Excitation will cause all hydrogen protons to spontaneously spin simultaneously, the are spinning in-phase. The transmitted radiofrequent pulse will not only cause the protons to spin in-phase, but will also rotate their magnetization in a plane at a right angle to the Z axis; the XY axis (= the transversal plane). The X, Y and Z axes can be used to visualize the net magnetization vector (fig. 4).

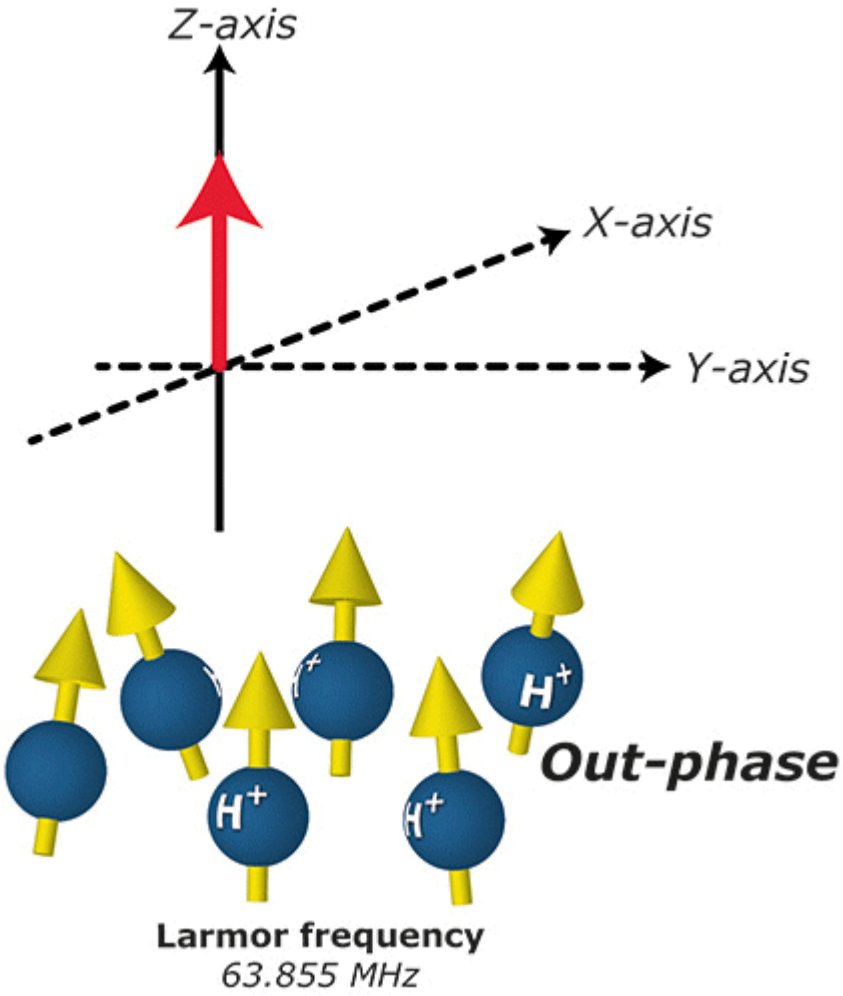



Figure 4. Excitation. A 90° rotation of the net magnetization to the transversal plane. The red arrow indicates the direction of the net magnetization. RF pulse = radiofrequent pulse.

In rotation to the XY axis, the net magnetization of the protons changes from longitudinal magnetization (= Z axis) to transversal magnetization (= XY axis). The degree of rotation to the XY axis depends on the strength and duration of the transmitted radiofrequent pulse. This may vary from 1° to 180° and is also termed the 'flip angle'.
**In summary**: by giving radiofrequent pulses, protons will spin in-phase and ‘flip’ from the Z axis (=longitudinal plane) to the XY axis (= transversal plane). This process is termed excitation. When the protons are flipped to the XY axis, longitudinal magnetization will decrease and transversal magnetization will increase.
Eventually, the induced magnetic signal changes are registered by receiver coils and then processed into the MRI image (this will not be discussed further in this course).

**Important**: *Signals can only be received and processed if:*

1. The protons are in the transversal plane (= XY axis). Explanation: minor signal changes in the Z axis will be drowned out by the strong magnetic field of the MRI device (= Z axis/B0). In other words, you can only measure signals in the transversal plane.

   &

2. Protons must be in-phase. Explanation: when protons are not in-phase, the sum of all microscopic transversal magnetizations together will be negligibly small (protons 'neutralize each other' if they are not aligned).

Relaxation

When the radiofrequent pulse is switched off, the protons will return to their original resting phase; the XY axis reverts back to the Z axis. This is termed relaxation. Two separate processes take place during relaxation: longitudinal relaxation (T1 relaxation) and transversal relaxation (= T2 relaxation). Again, these two processes are independent and should be regarded as two separate processes.

**T1 relaxation**

In T1 relaxation, protons will return to their original position and the energy received from the radiofrequent pulse is transferred to their surroundings. T1 relaxation describes what happens in the Z axis (fig. 5).

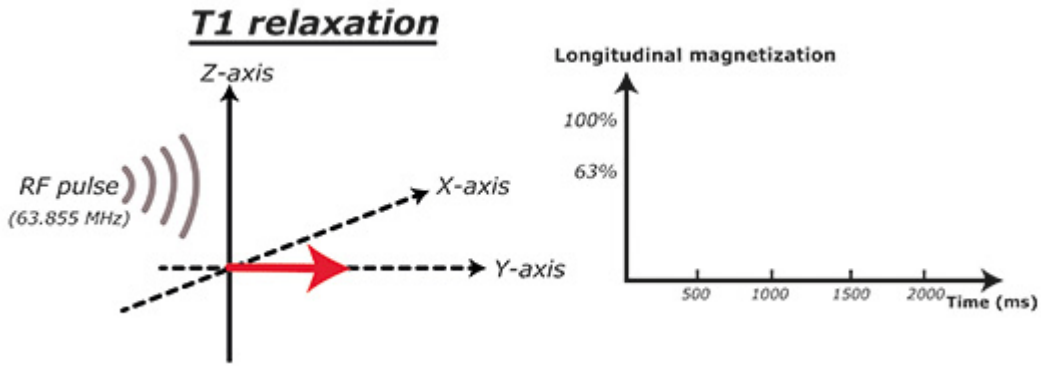



Figure 5. When the radiofrequent (RF) pulse is switched off, T1 relaxation occurs; longitudinal magnetization increases.

The T1 relaxation time is defined as the time needed to achieve 63% of the original longitudinal magnetization (in Z axis) (fig. 5). Each tissue has its own T1 relaxation time and curve (fig. 6).

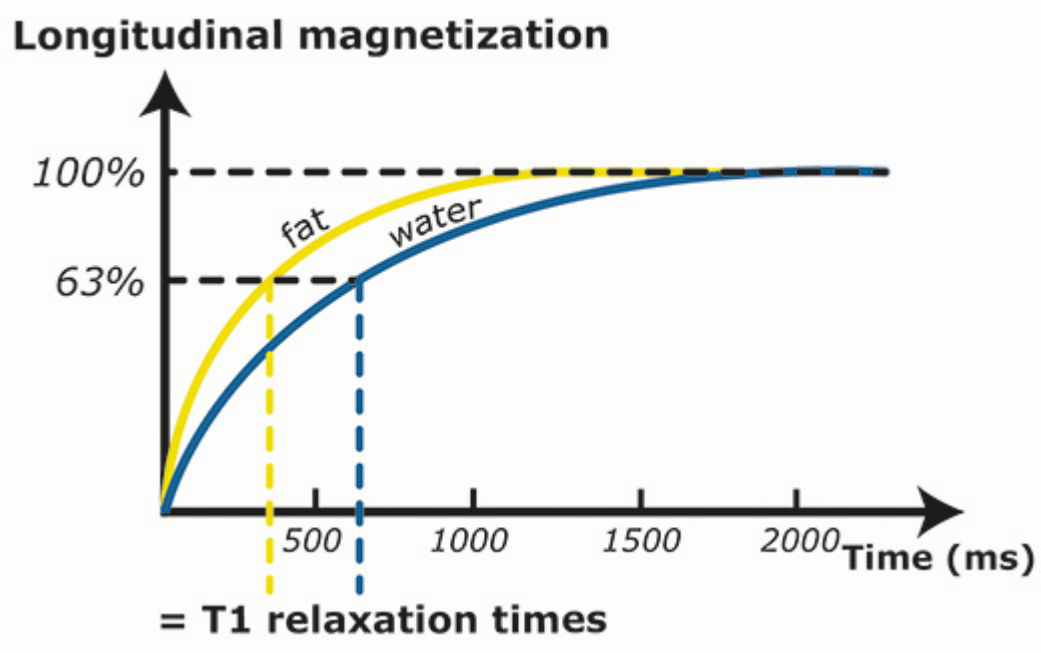



Figure 6. T1 relaxation times of fat and water.

Fat has a short relaxation time as compared to water because it can more easily transfer its received energy to its surroundings.

**T2 relaxation**

Simultaneously, something changes in the transversal plane; the protons spinning synchronously (= in-phase) will no longer spin synchronously once the radiofrequent wave has been switched off (= out-of-phase); this process is termed dephasing. Dephasing occurs because the magnetic field of the MRI scanner is no longer 100% homogeneous. The protons will be affected by irregularities in the magnetic field and no longer spin synchronously. Protons may be regarded as little magnets and thereby accelerate the dephasing process.
Explanation: consider in-phase protons as a group of soldiers marching synchronously. When the leader (‘radiofrequent pulse') stops giving commands to the soldiers (‘radiofrequent pulse is switched off'), the soldiers (‘protons') will no longer march synchronously. Only one soldier (‘proton') in the rank needs to trip to set off a rapid chain reaction of soldiers (‘protons') no longer marching synchronously.
Dephasing is an undesired phenomenon, seeing the protons must be in-phase for the receiving coils to receive the signal.

T2 relaxation describes what happens in the XY axis.
To avoid confusion: net magnetization consists of both a longitudinal component (Z axis) and a transversal component (XY axis). Together they constitute the net magnetization vector. Figure 7 illustrates the transversal component when the protons are in-phase.

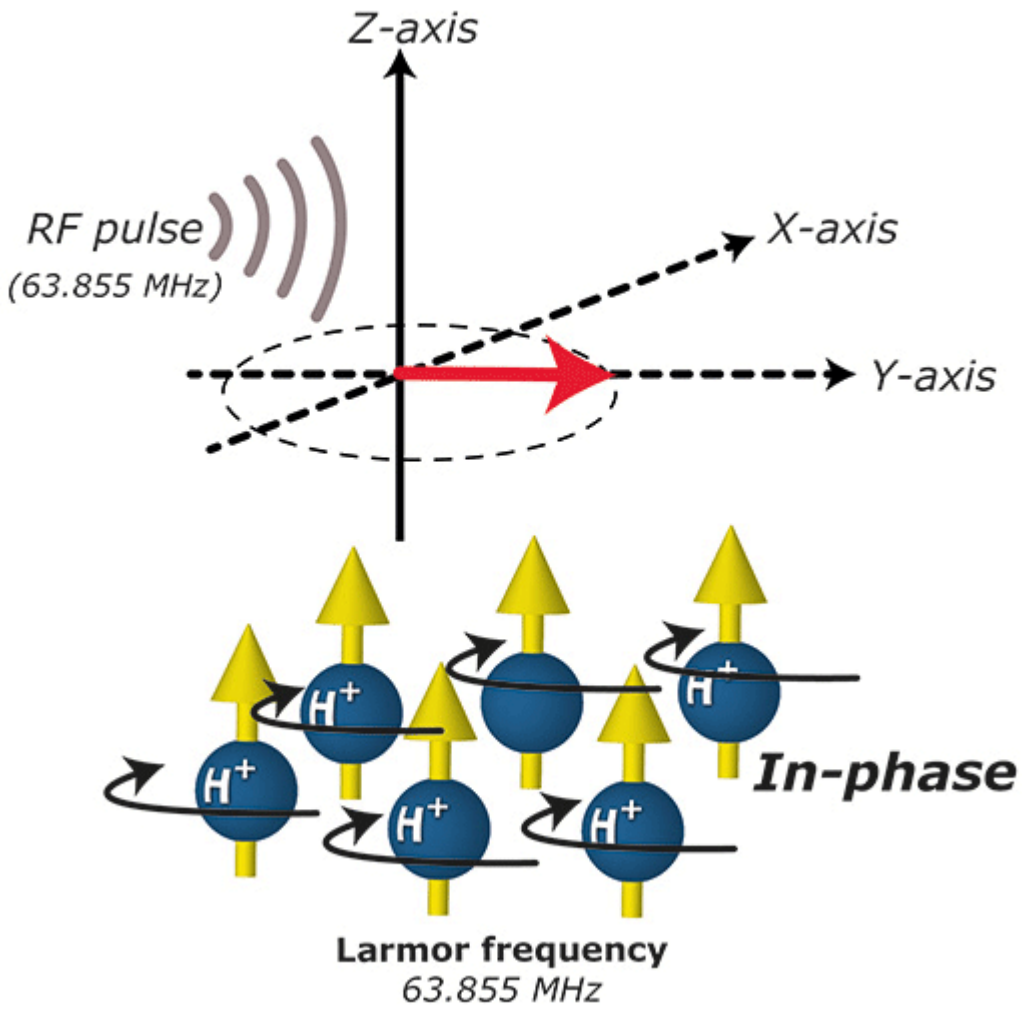



Figure 7. When transmitting a radiofrequent (RF) pulse, the protons in the transversal plane (XY axis) will be in-phase.

Dephasing in T2 relaxation is rapid, much quicker than in T1 relaxation. When the radiofrequent pulse is switched off, transversal magnetization will be lost (fig. 8/9).

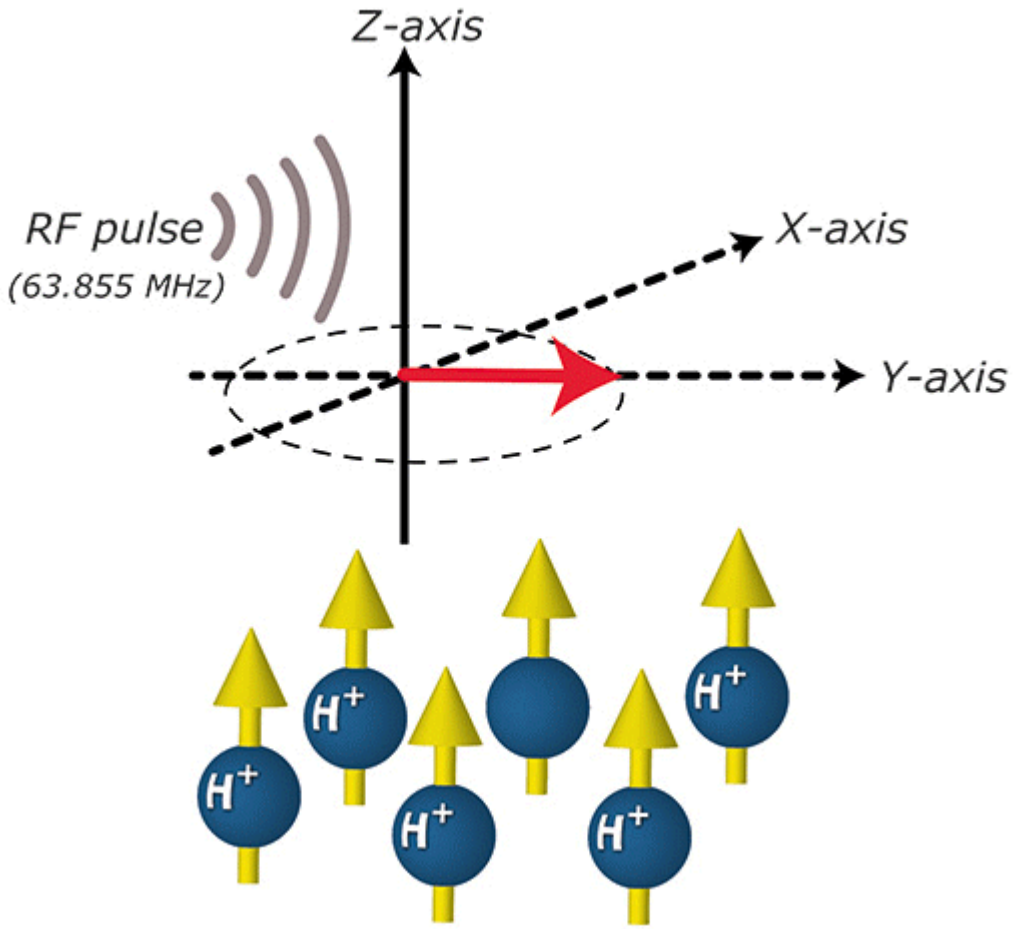



Figure 8. Dephasing occurs when the radiofrequent (RF) pulse is switched off.

T2 relaxation time is defined as the time needed to dephase up to 37% of the original value. Each tissue has its own T2 relaxation time and curve (fig. 9). In comparison with water, fat has a short T2 relaxation time and will therefore dephase quicker.

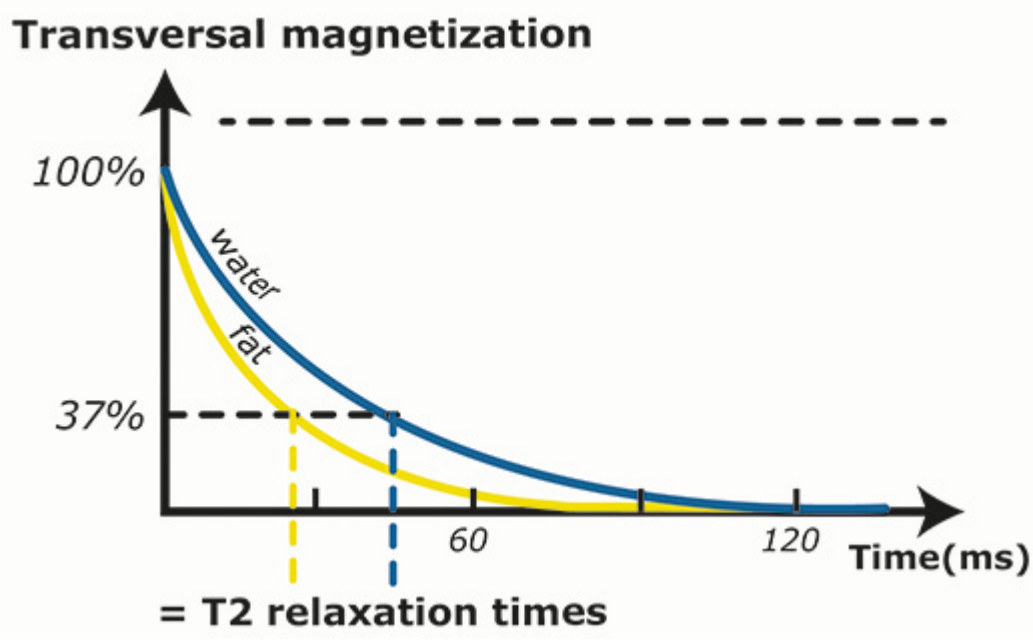



Figure 9. T2 relaxation times of fat and water.

# General MRI Terms

*Signal intensity:*
In MRI the terms low, intermediate and high signal intensity are used. Depending on the scan protocol, tissue is imaged as white (= high signal intensity), as a gray tone (= intermediate signal intensity) or as dark gray/black (= low signal intensity).

*Gradient:*
An additional magnetic field that may be added manually to the MRI device's magnetic field. This creates an additional subdivision in the 'total' magnetic field. Gradient coils are used among other things to determine the location of the protons in the X, Y and Z axis.

*Sequence:*
Combination of radiofrequent pulses and gradients (= 'added magnetic fields'), which together constitute the building blocks for an MRI series. For instance, the terms 'T1 weighted sequence' and 'T2 weighted sequence' are used.

# MRI Sequences

- T1 weighted sequence
- T2 weighted sequence
- PD weighted sequence
- Gradient & spin echo sequence
- Fat suppression
- MRI contrast
- Diffusion weighted image
- In/out-of-phase

Contrast differences are required to distinguish normal anatomy from pathology. Contrast is improved when two adjacent areas have high and low signal intensities. There are many different MRI sequences (>100) and all attempt to optimize tissue contrast.
Each MRI image consists of a T1 component and a T2 component (see also Relaxation section). It is possible to switch off most of one of either components, creating a T1 weighted or T2 weighted image respectively. A special form is the proton density (PD) weighted image. This sequence enables the visualization of the number of protons per volume. In order to achieve this, both the T1 and T2 components must be switched off.
The following briefly describes some commonly used MRI sequences.

**T1 weighted sequence**

The contrast created in the image is determined in particular by the difference in T1 relaxation times between fat and water. Fat has a high signal intensity (white) and water a low signal intensity (black).
Why does fat have a high signal intensity on a T1 weighted image?
*Answer*: fat has a shorter T1 relaxation time than water.
*Explanation*: by its short T1 relaxation time, fat will recover quicker from longitudinal magnetization (Z axis). When a second radiofrequent pulse of 90 degrees is given, water will not have fully recovered in the longitudinal plane. After the second pulse, fat will make a larger deflection than water and create more transversal magnetization (fig. 10). As a reminder, signals can be received and processed only in the transversal plane. The higher the transversal magnetization of the tissue, the more signal is received. When radiofrequent pulses are repeated, fat will contribute more to the final MRI image and therefore be represented as a high signal (white).

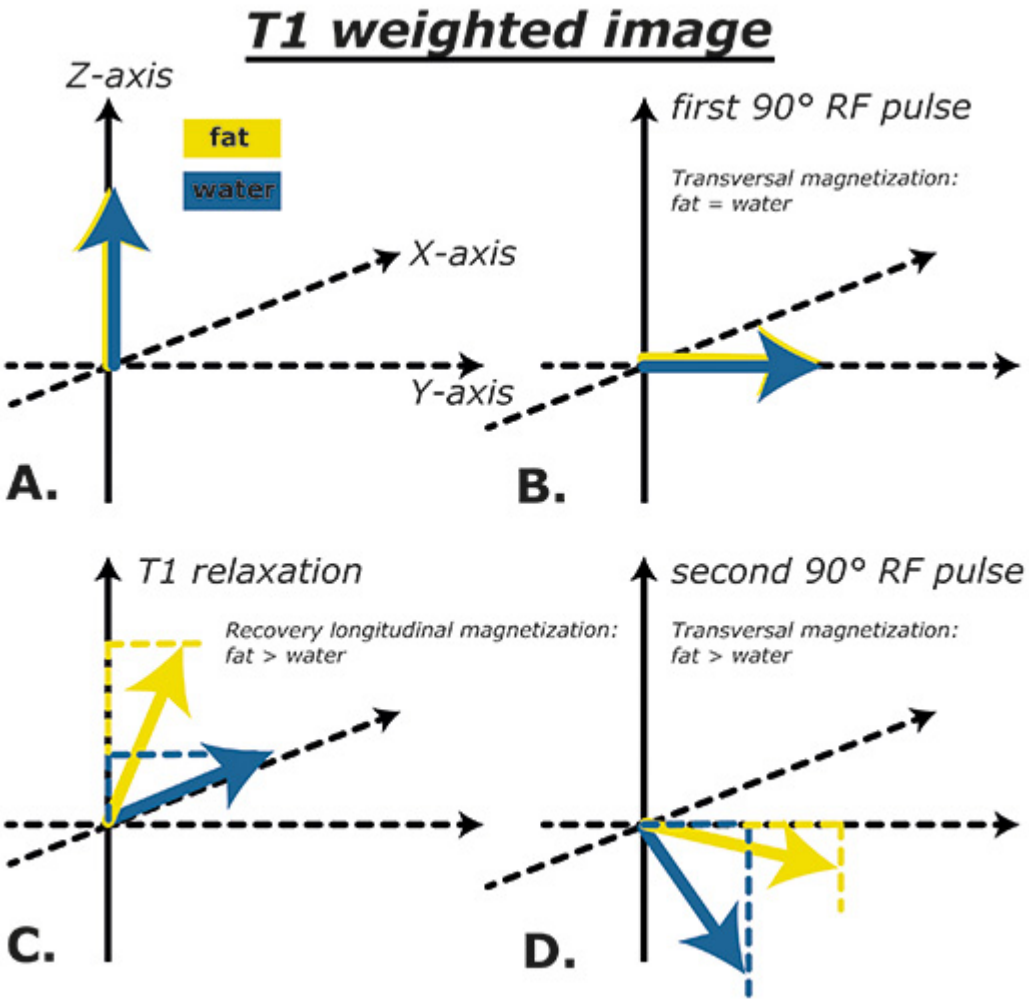



Figure 10. By repeating radiofrequent (RF) pulses, fat will have more transversal magnetization than water.

In practice, T1 weighted images are used mostly to evaluate normal anatomy.
Remember that only a few structures have a high signal intensity (= white) on a T1 weighted image: fat, blood, gadolinium (= contrast), melanin, protein (e.g. high-protein cysts). A high signal can also be seen in specific MRI artifacts and accumulation diseases (not discussed further in this course).
Water and collagenous tissue (ligaments, tendons, scars) have a lower signal intensity on a T1 weighted image (fig. 11).

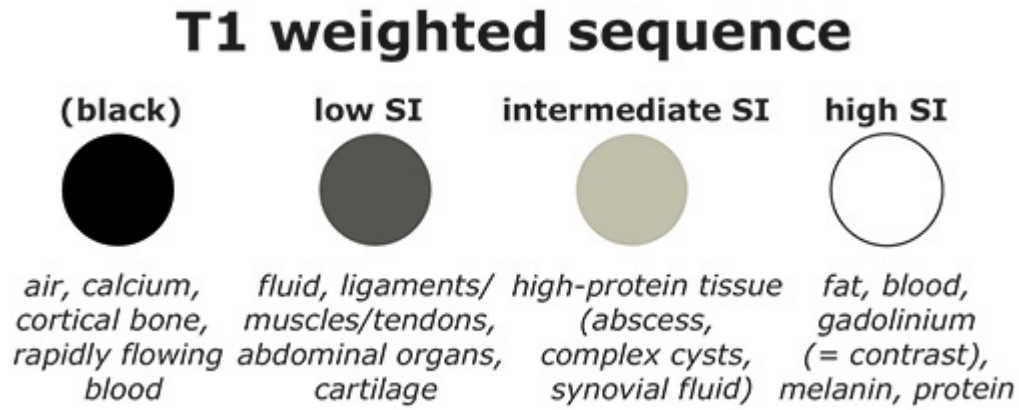


Figure 11. Signal intensities in T1 weighted image. Depending on protein content, the tissue may have an intermediate or high signal intensity (SI).

The spearhead of T1 weighted imaging is visualizing normal anatomy, particularly the musculoskeletal system (fig. 12). When the signal intensity of the fat-containing bone marrow (high on T1!) is replaced by a low signal intensity, beware of bone marrow edema or bone marrow infiltration (fig. 13/14).

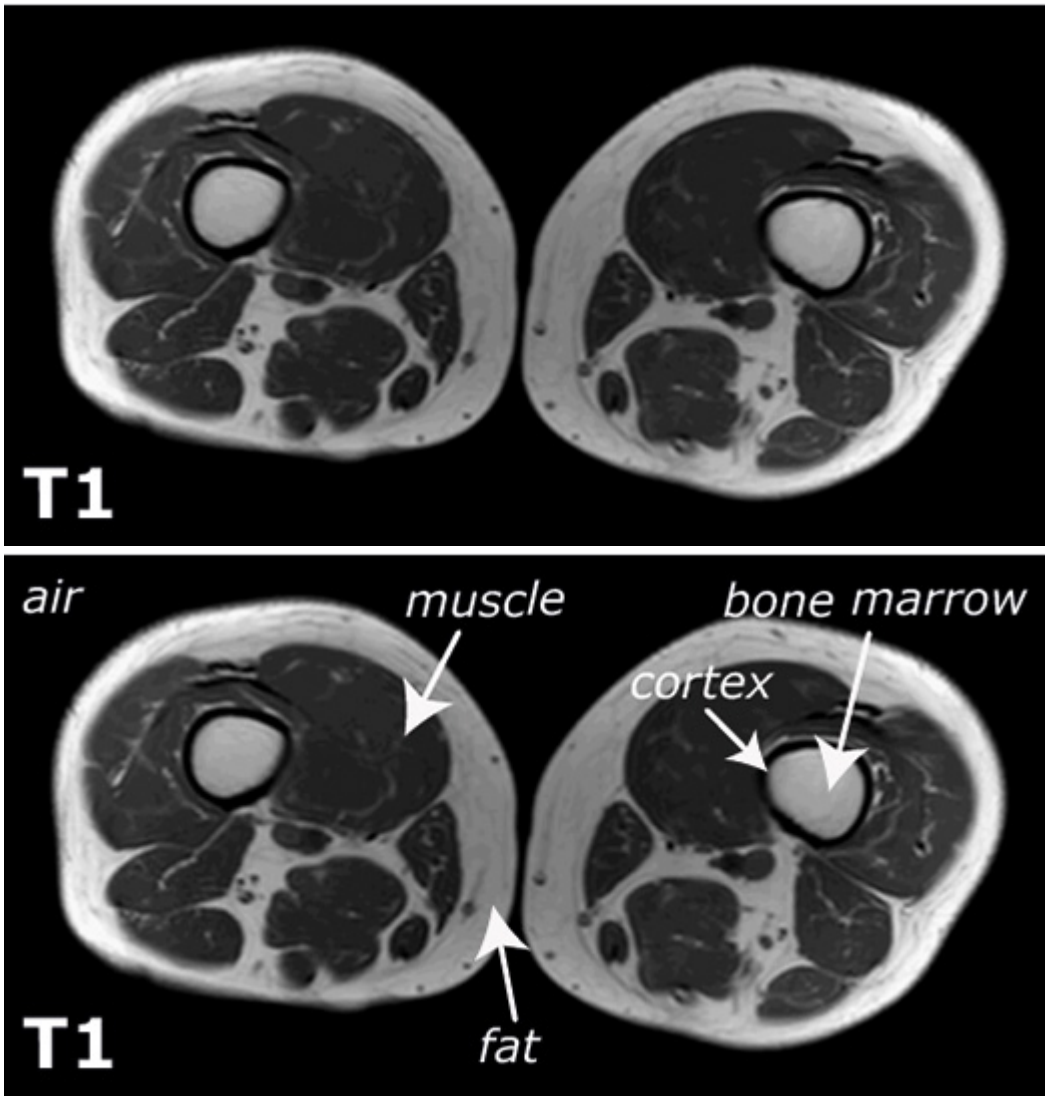



Figure 12. T1 weighted image in transversal direction of the upper legs. Normal anatomy.

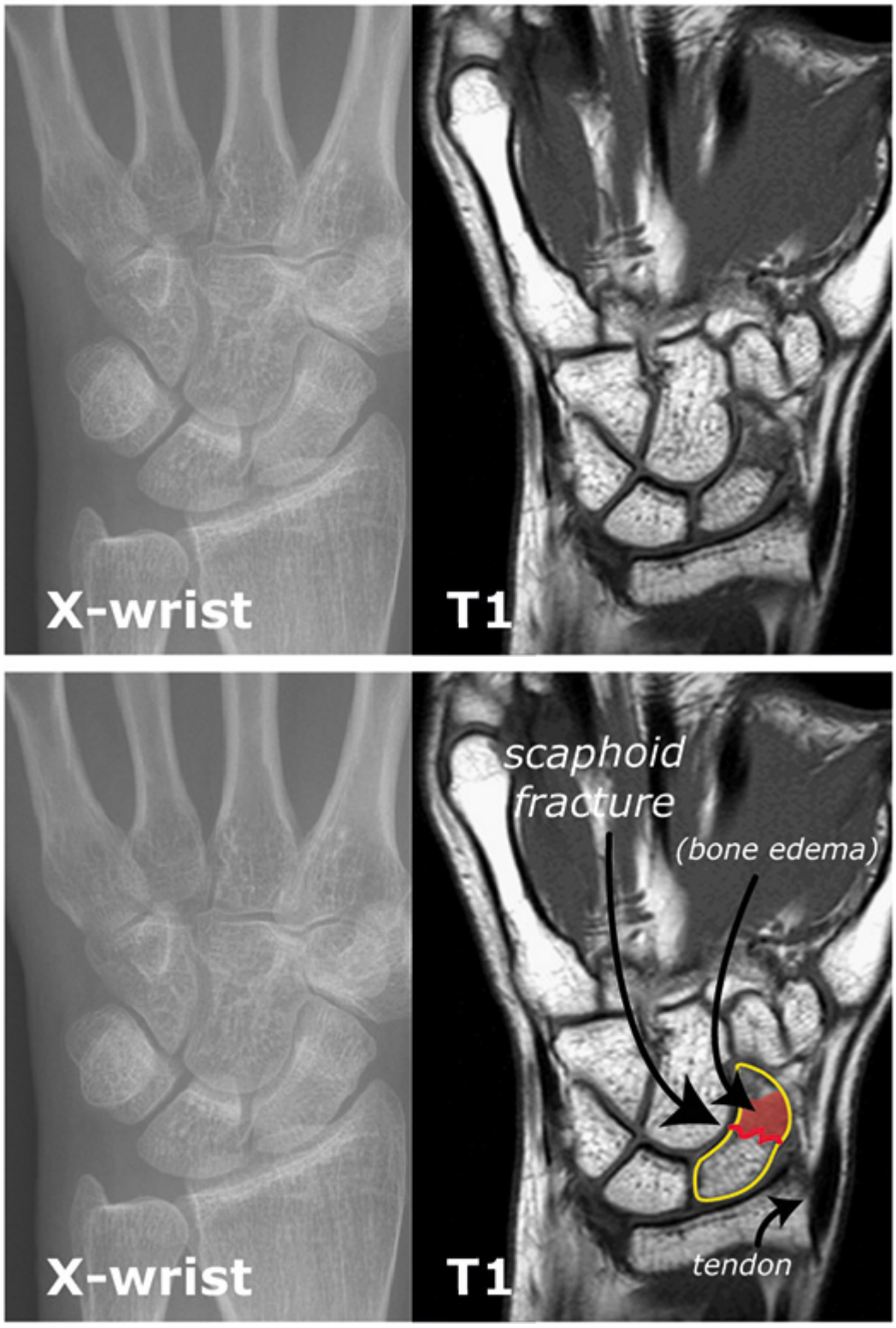



Figure 13. Wrist X-ray of the left hand: no abnormalities. T1 weighted image in coronal direction: fracture line midpolar in the scaphoid bone (red line) with reactive bone edema.

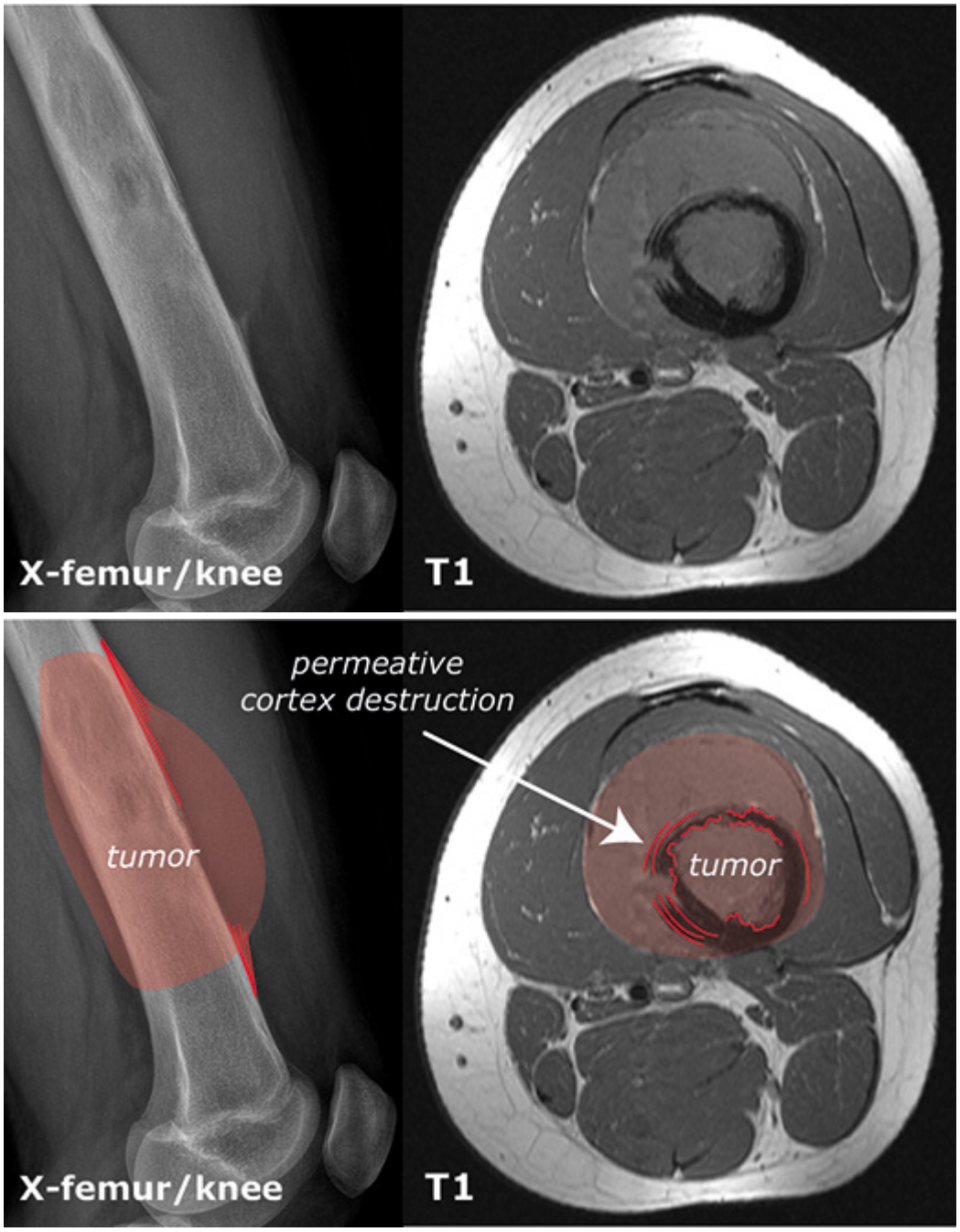



Figure 14. X-ray of left upper leg/left knee: lytic lesion in the femur with multilayered periosteal reaction and soft tissue mass (PA diagnosis: osteosarcoma). The T1 weighted image clearly visualizes the permeative cortex destruction and the breakthrough into soft tissues. Note also the abnormal low signal intensity of the bone marrow (fat has been replaced by tumor).

**T2 weighted image**

Characteristic of a T2 weighted image is the high signal intensity of water. Pathology is often associated with edema/fluid and therefore a T2 sequence is very suitable to detect pathology (fig. 15).

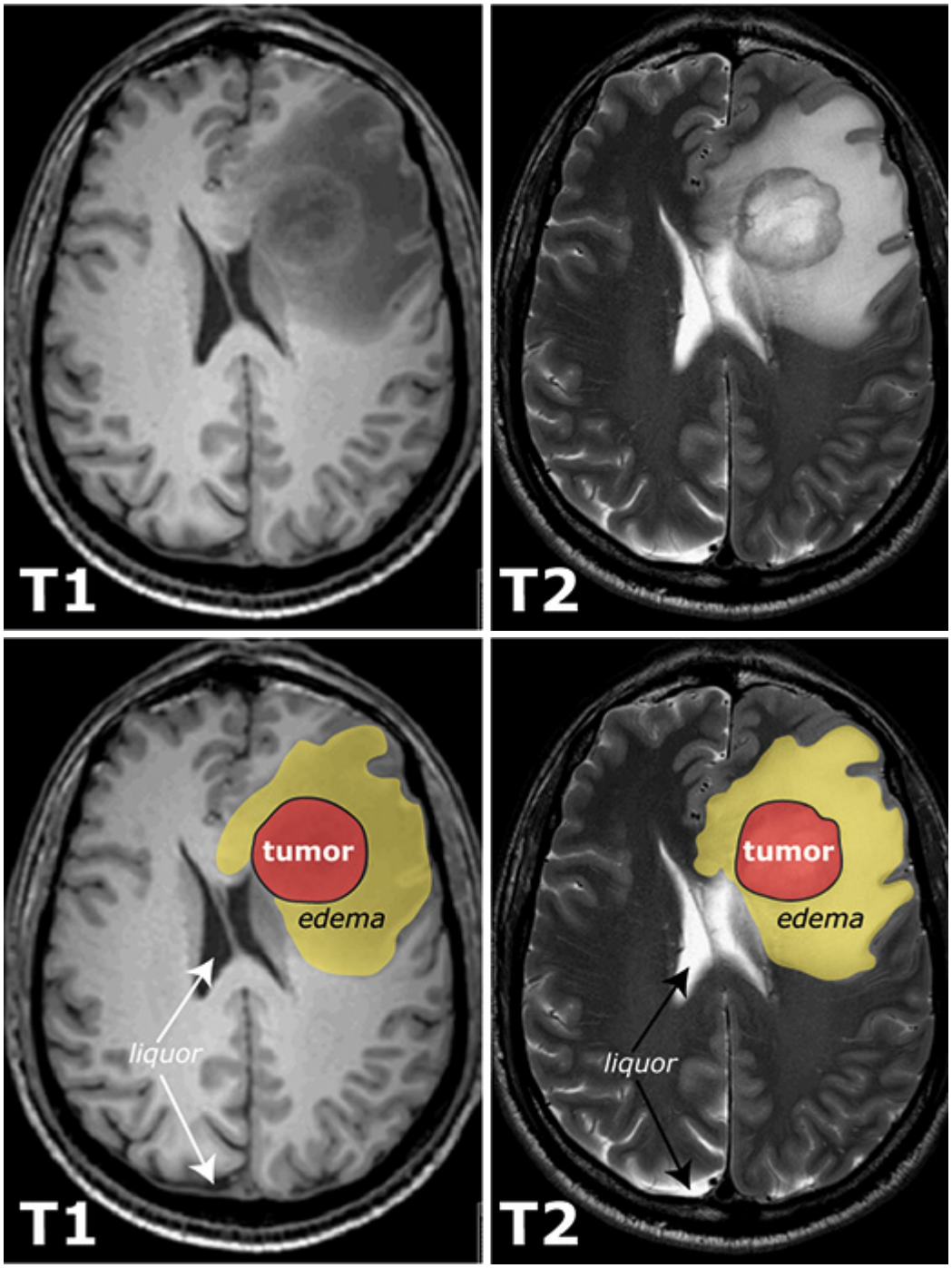



Figure 15. Brain tumor with surrounding (reactive) edema frontoparietal left. Both the tumor and the edema have high signal intensity on T2. PA diagnosis: lymphoma.

As in a T1 weighted image, air and calcifications have very low signal intensity.
Tip: you are unsure whether you are seeing air or calcifications? Try to find the structure on an X-ray/CT scan!

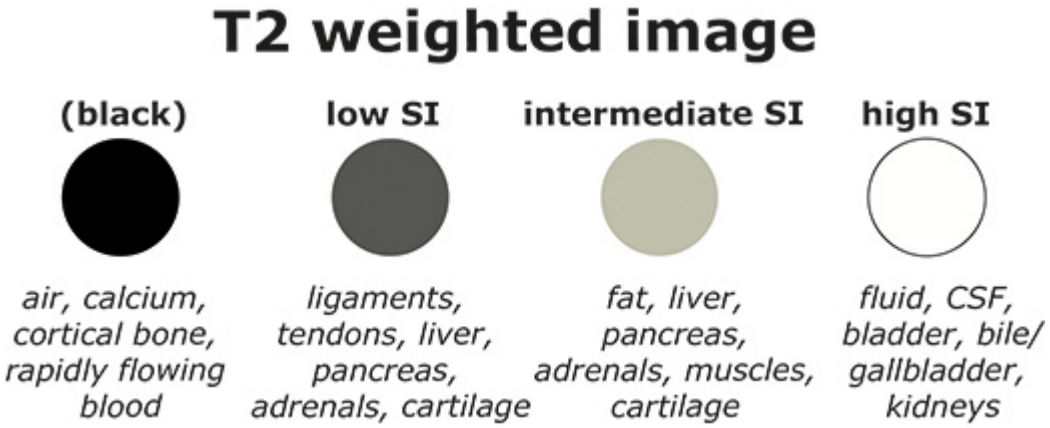



Figure 16. Signal intensities in T2 weighted image. Liver, pancreas and adrenals may have low or intermediate signal intensity (SI) caused by variation in individual fluid contents.

Tip: always look for fluid-filled structures (CSF, gallbladder, bladder) to decide whether you are looking at a T1 or T2 weighted image. Fluid has a high signal intensity on T2 weighted images. Note: fat is a less reliable marker to distinguish between T1 and T2 (especially in view of the development of new types of MRI sequences).

**PD weighted image**

The proton density (PD) weighted image visualizes the number of protons per volume. To achieve this, both the T1 and T2 components are switched off as fully as possible (for the sake of convenience, technical background is not discussed in this course).
Tissues with few protons have low signal intensity, tissues with many protons have high signal intensity.
Fat has a relatively high signal intensity, however, not as high as in a T1 weighted image. Fluid has an intermediate signal intensity rather than the high signal intensity as in a T2 weighted image.
A PD weighted image is used among other things to evaluate meniscal tears in the knee (fig. 17).
Additionally, a PD sequence can be useful in e.g. brain MRI to evaluate gray/white matter pathology.
Explanation: as opposed to a T2 weighted image, a PD clearly distinguishes between gray and white matter (gray matter has a higher signal intensity than white matter). The distinction between CSF and pathology is difficult on a T2 weighted image; both have a high signal. The contrast between CSF (intermediate signal intensity) and pathology (high signal intensity) will be better on a PD weighted image.

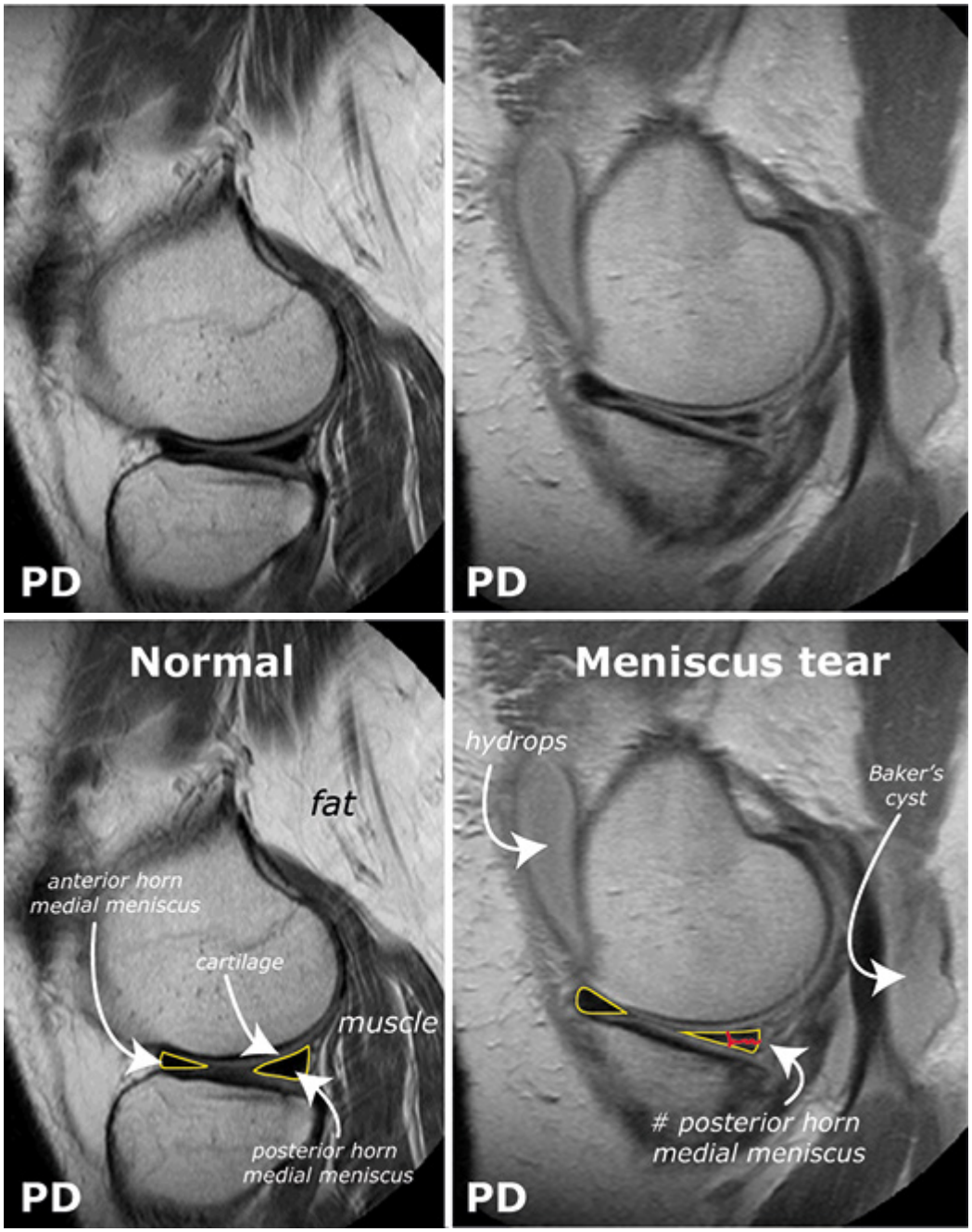



Figure 17. PD weighted image in sagittal direction of the knee in two different patients (at the level of the medial meniscus). Left shows an intact meniscus, at right there is a tear in the posterior horn of the medial meniscus. Note also that fluid (hydrops & Baker's cyst) have intermediate signal intensity on the PD.

**Gradient & spin echo sequence**

'Gradient' and 'spin echo' are common terms in an MRI context. Importantly, this is a technique that can be used on a T1, T2 and PD sequence. The gradient & spin echo technique may be regarded as two large families in which multiple variations are possible.
In summary: the gradient technique has a shorter scan time than the spin echo technique and is used among other things for angiography, brain, heart, abdomen and functional MRI. A significant drawback of the gradient technique is susceptibility to artifacts (hemoglobin in blood and prosthesis/osteosynthesis material).
Spin echo technique is an alternative option. The traditional spin echo was commonly used because of its many applications. Nowadays the spin echo has been developed into a faster sequence; the fast spin echo (FSE) and the single shot fast spin echo (SSFSE). Scan time has now been reduced to a few minutes, resulting in fewer

movement artifacts. Despite the fact that the spin echo is not as fast (as the gradient), the technique is used frequently because of its image quality. The fast spin echo sequences are used frequently to image the abdomen (e.g. MRCP), pelvis (urogenital) and musculoskeletal system (especially in prosthesis material!).
Practical tip:
- gradient is a good choice to detect blood products.
- spin echo technique has fewer unwanted artifacts in prosthesis and osteosynthesis material.

*Susceptibility artifact*
Magnetic susceptibility means that protons with their own internal magnetization interact with the external magnetic field. In other words: it is the degree to which tissue becomes magnetic as a result of exposure to a magnetic field. When two tissues with different magnetic susceptibilities are close together, local field inhomogeneities may develop. This disruption accelerates dephasing and will eventually lead to loss of signal or distorted images. These susceptibility artifacts develop with metals (depending on the metal type) and natural transitions such as air-tissue (sinuses-brain parenchym) and tissues surrounding bone. Also the blood product hemoglobin may cause susceptibility artifacts on a gradient echo sequence. Despite this undesired phenomenon, it can also be used to characterize lesions. A frequently used gradient echo is the SWI sequence (Susceptibility Weighted Imaging) (fig. 18).

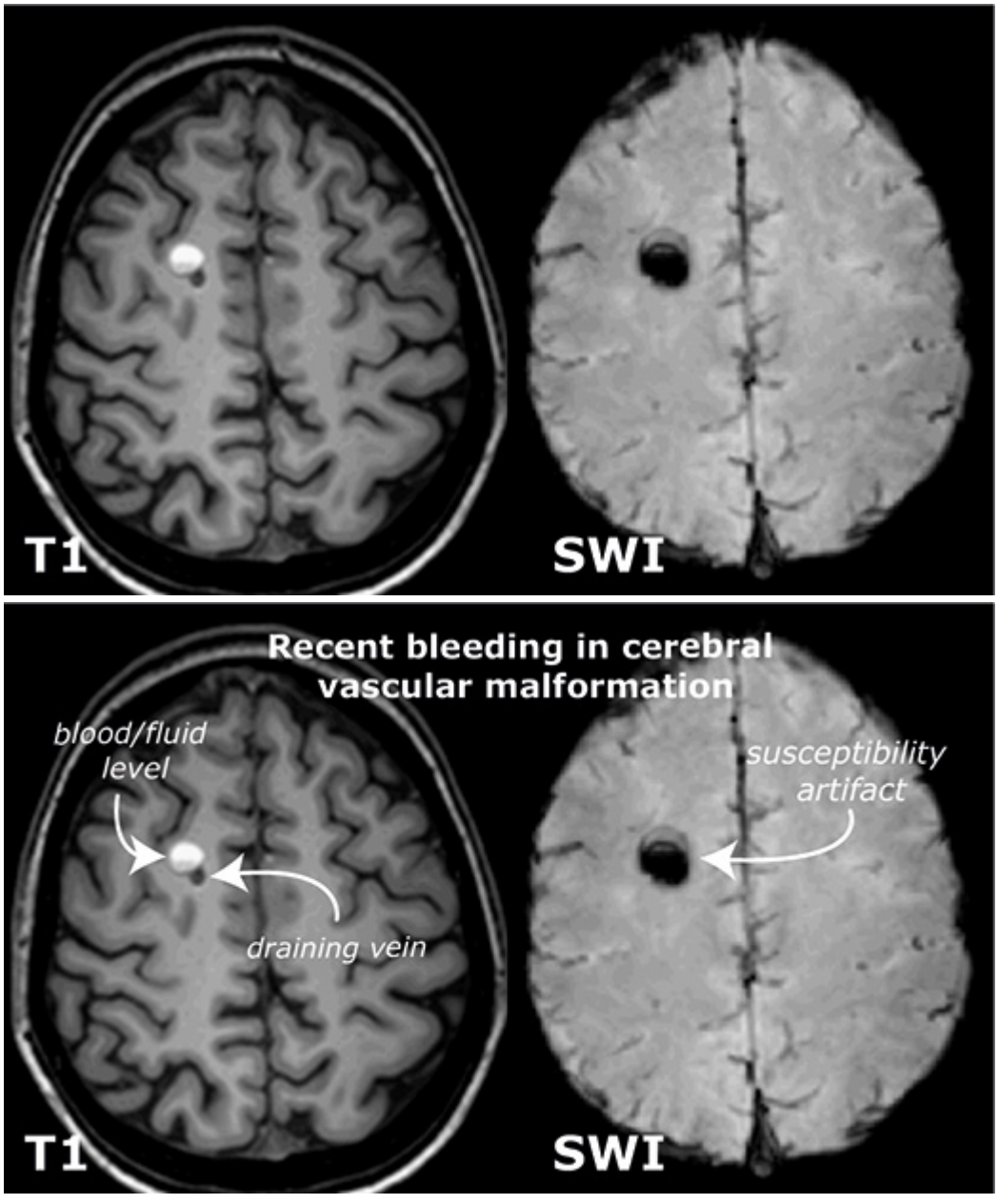


Figure 18. Recent bleeding in cerebral vascular malformation. SWI = Susceptibility Weighted Imaging.

**Fat suppression**

Suppression of fat tissue is one of the many options that can be used in an MRI sequence.
In virtually all abdominal MRI examinations, suppressing the fat tissue signal is advisable. The created low signal intensity of fat then contrasts more strongly with the vessels & pathology (high signal intensity!).
Also in skeletal imaging, it may be useful to make a sequence with fat suppression. Bone marrow contains fat and may mask bone marrow edema on a T2 weighted image.
There are several technical options to suppress fat tissue. Frequently used sequences are the STIR (short-tau inversion recovery) and the SPIR (spectral pre-saturation inversion recovery) sequences. Both are T2 weighted images.
You can also recognize fat suppression by the abbreviation FatSat, meaning Fat Saturation (e.g. T2wFatSat).
Tip: you can easily recognize fat suppression by looking at the subcutaneous fat (fig. 19). When it has a low signal, you are looking at a fat suppression sequence. The technique may be used 'as extra' in T1, T2 and PD weighted images.

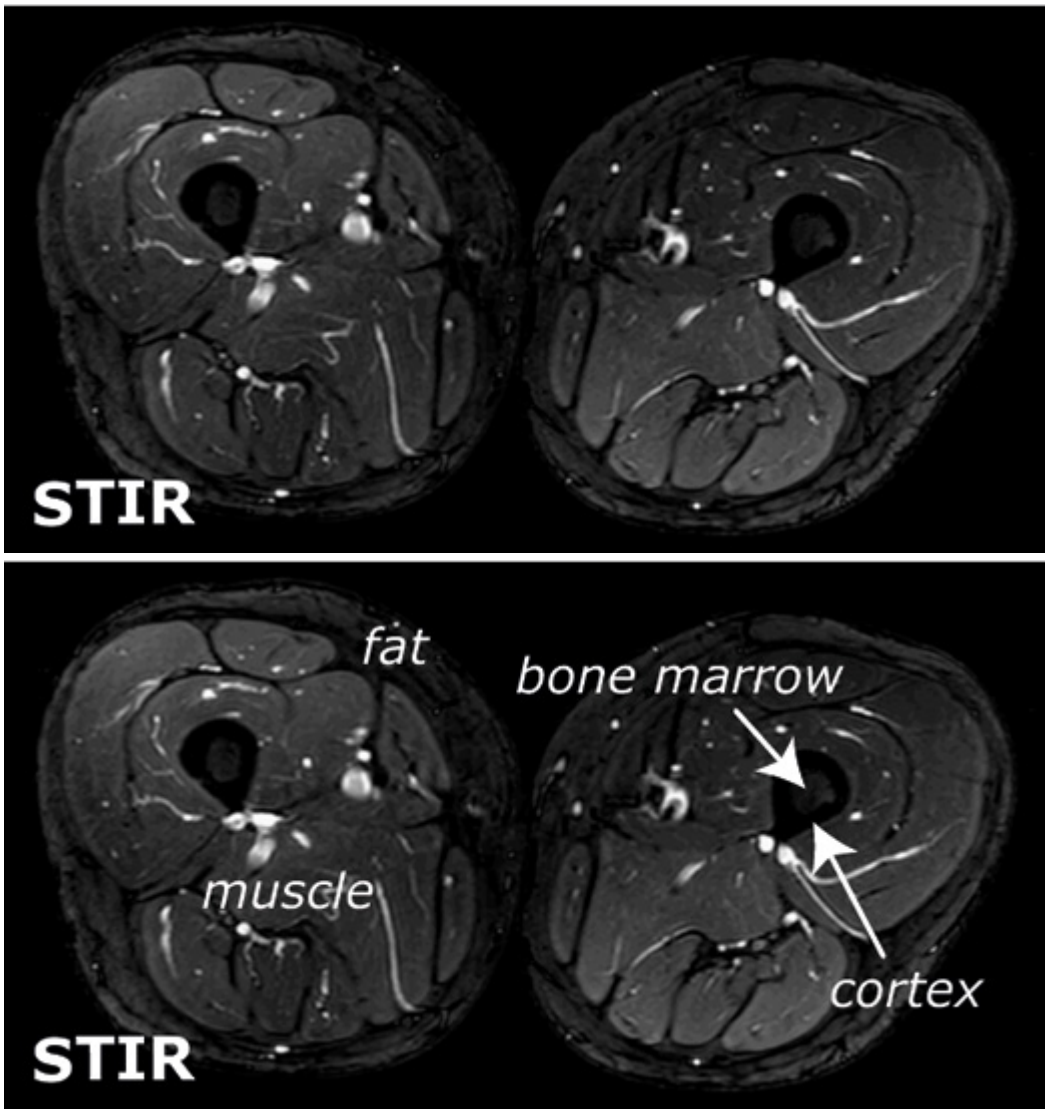



Figure 19. STIR sequence in transversal direction of the upper legs. Note also the good contrast with the vessels (fluid!).

**MRI contrast**

Frequent indications for MRI tests with contrast:

- Detect lesions (tumor/metastasis, abscess)
- Characterization of lesions (e.g. hepatic lesions)
- Imaging of vessels/vascular pathology (= MR angiography)

A contrast series is generally combined with a T1 weighted image. As pathology is often associated with fluid, the combination of contrast and a T2 weighted image has little value (Note: both fluid and contrast have high signal intensity).
There are multiple types of contrast agents available. A commonly used contrast agent is gadolinium (Gd). Gadolinium has paramagnetic properties and reduces the T1 relaxation time of the protons that absorb the contrast. Consequently, these protons will have higher signal intensity (=whiter). In addition to gadolinium, other types of contrast media are used (e.g. the liver-specific contrast agent Primovist). They are only used when indicated.
In order to correctly evaluate enhancement, a series should be made before and after contrast. A fat suppression technique may be used to avoid confusing the fat with enhancement (Note: fat has a high signal intensity on T1 weighted images).
Below is an example of a brain tumor (fig. 20) and an example of a classic enhancement pattern of an hepatic hemangioma (fig. 21). Additional details about enhancement patterns will not be addressed in this course.

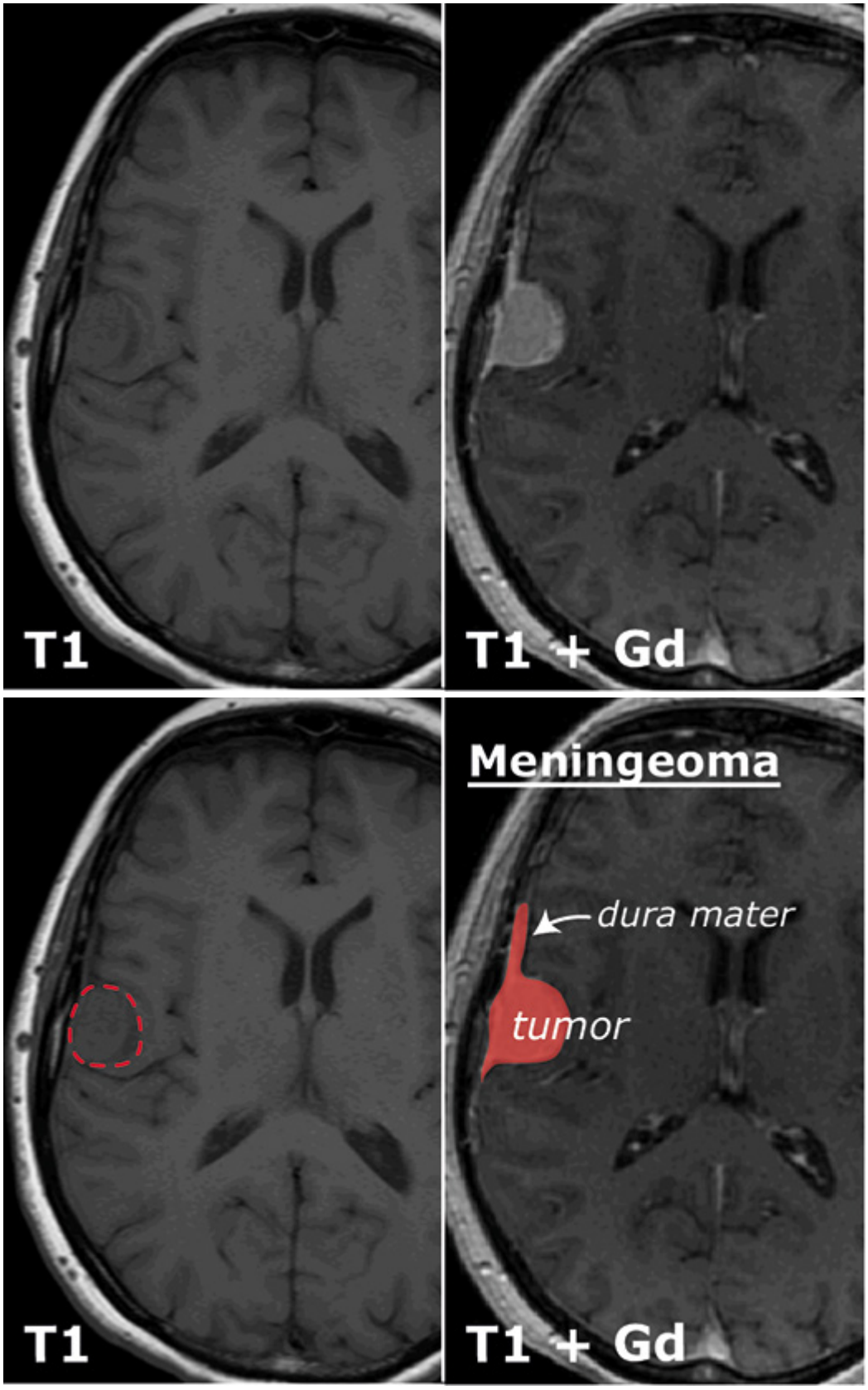



Figure 20. Tumor in the right hemisphere, with good visualization after gadolinium administration. The tumor originates in the dura mater. PA diagnosis: meningioma.

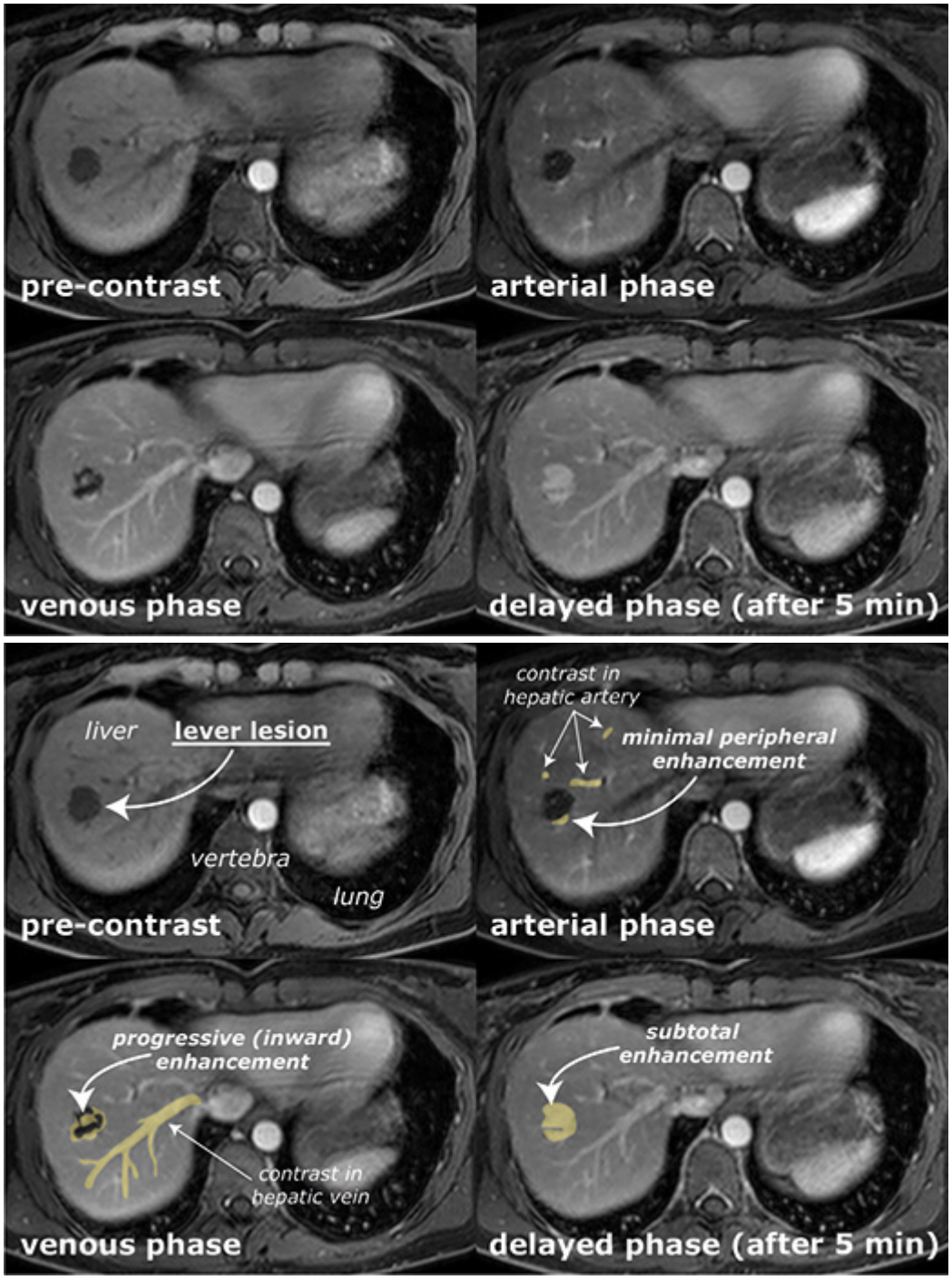



Figure 21. T1 + Gd sequence: liver series in the transversal direction. The images show the typical enhancement pattern of a hemangioma (slow progressive filling with contrast from the periphery).

**Diffusion weighted image**

Diffusion weighted imaging (DWI) is currently indispensable in radiology.
Diffusion means the random movement of molecules in a substance; the Brownian motion.
Diffusion weighted imaging is a very fast technique where the diffusion behavior of hydrogen molecules is determined under different field strengths. The diffusion images obtained are T2 weighted images.
The degree of proton motion depends among other things on (fig. 22):

1. Cellularity of the tissue; many vs few cells (in cell-rich tissue there is relatively lower diffusion)
2. Integrity of the cellular membrane. In an infarction, the ion pump of the cell membrane will break down and ions & water will stay in the cell (= cytotoxic edema). This will increase intracellular pressure, leading

to reduced intracellular diffusion.

3. Blockage of fluid; large vs small molecules. Tissues with large molecules have relatively lower diffusion.

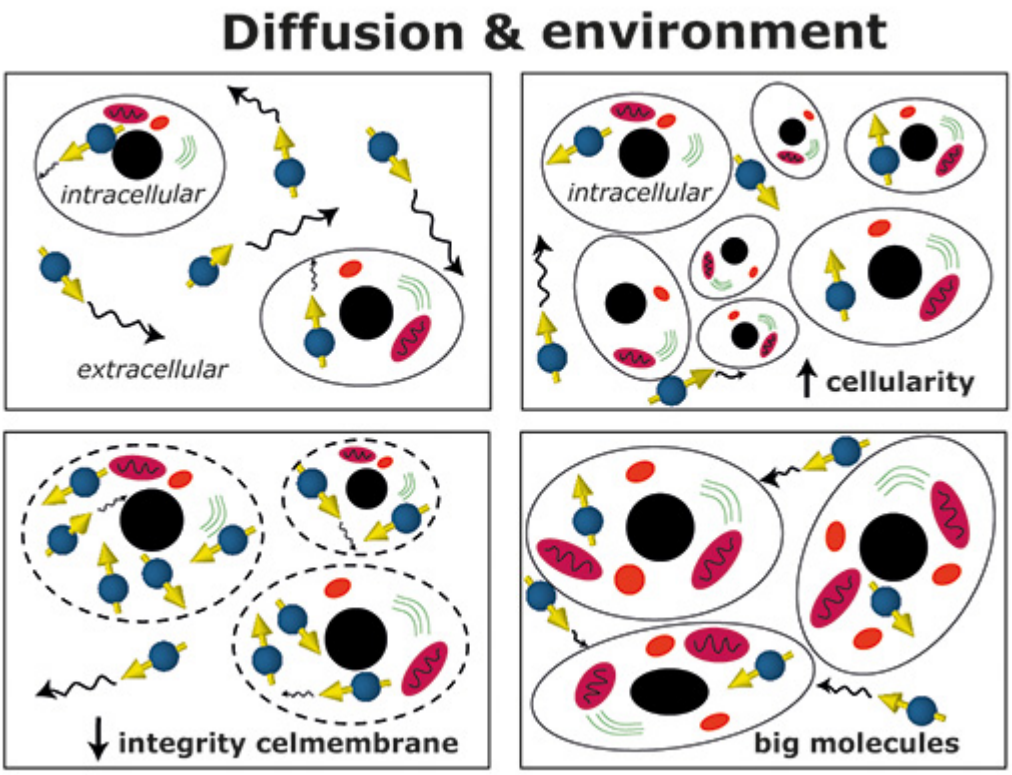



Figure 22. Degree of diffusion (protons + arrows) in various situations.

When protons can move freely and therefore diffuse away, signal loss will occur in DWI. This can be seen e.g. in CSF. Background information: in order to obtain a signal, the proton must receive two pulses. If the proton does not receive the second pulse (because the moving proton is now in a different position), signal loss will occur.
In reduced diffusion (= diffusion restriction), there is limited movement of protons, shown as a high signal intensity on DWI. This can been seen in disorders including cytotoxic edema and inflammation.
Importantly, DWI is a strong T2 weighted image. As a reminder: tissues with a high water content have high signal intensity on T2 weighted images. To be sure that tissue diffusion has been reduced, we need to filter the T2 effect out. To this end a quantitative calculation of diffusion is made; the so-called ADC map (apparent diffusion coefficient). The ADC map filters out the T2 effect and produces inverse images. Diffusion is reduced when the tissue has high signal intensity on DWI and low signal intensity on ADC (fig. 23).
When both DWI and ADC have high signal intensity, we have a T2 effect without diffusion component. Better known as the T2 shine-through. An example is (reactive) vasogenic edema. In vasogenic edema there is more free moving water in the extracellular space. This may develop in response to a tumor.

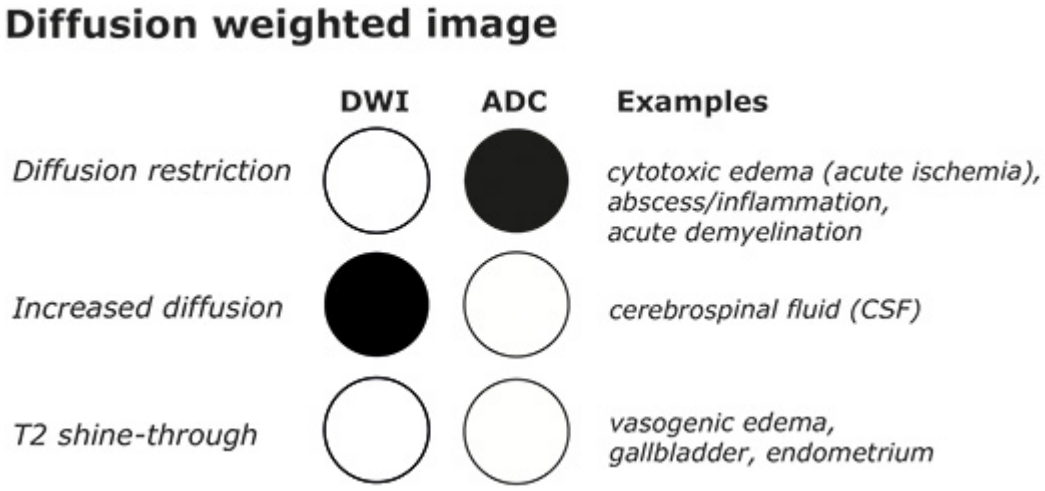



Figure 23. Signal intensity of DWI and ADC in diffusion restriction, increased diffusion and T2 shine-through.

Remember: when evaluating diffusion, also look at the ADC. We do not use the term diffusion restriction until the tissue has high signal intensity on DWI and low signal intensity on ADC.

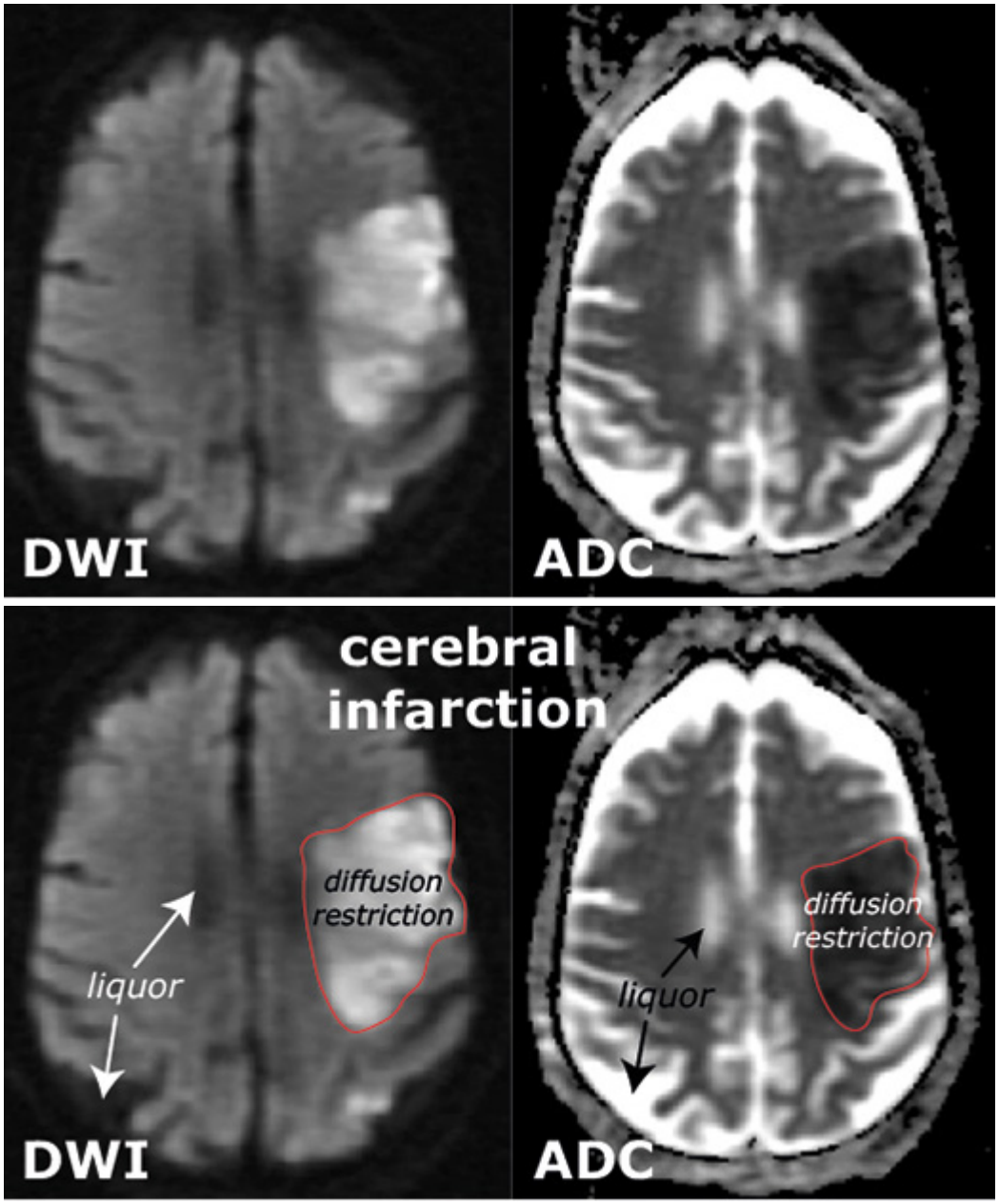



Figure 24. Diffusion restriction secondary to cytotoxic edema in an infarction in the left hemisphere (middle cerebral artery territory). The DWI has high signal intensity and ADC low signal intensity. Note also the (physiologically) increased diffusion of the CSF.

In addition to the above pathology, diffusion restriction may also occur in cell-rich tumors (including epidermoid and lymphoma).
It is a good tool to distinguish acute ischemia (= abnormal diffusion) vs chronic ischemia and pus in an abscess (= abnormal diffusion) vs necrosis in a tumor.
Diffusion restriction does not mean that we are always dealing with pathology. For instance, the myelum, testicles/stroma of the ovaries, spleen/lymphatic nodes and red bone marrow will all show diffusion restriction. The reason for reduced movement in these tissues is not entirely clear and may be associated with high cellularity.
In recent years there has been extensive research of new applications to detect/characterize pathology using diffusion weighted imaging (e.g. in prostate carcinoma). It may also be an additional tool to evaluate the effect of therapy on tumors; reduced tumor cellularity after treatment may lead to reduced diffusion restriction.

**In/out-of-phase**

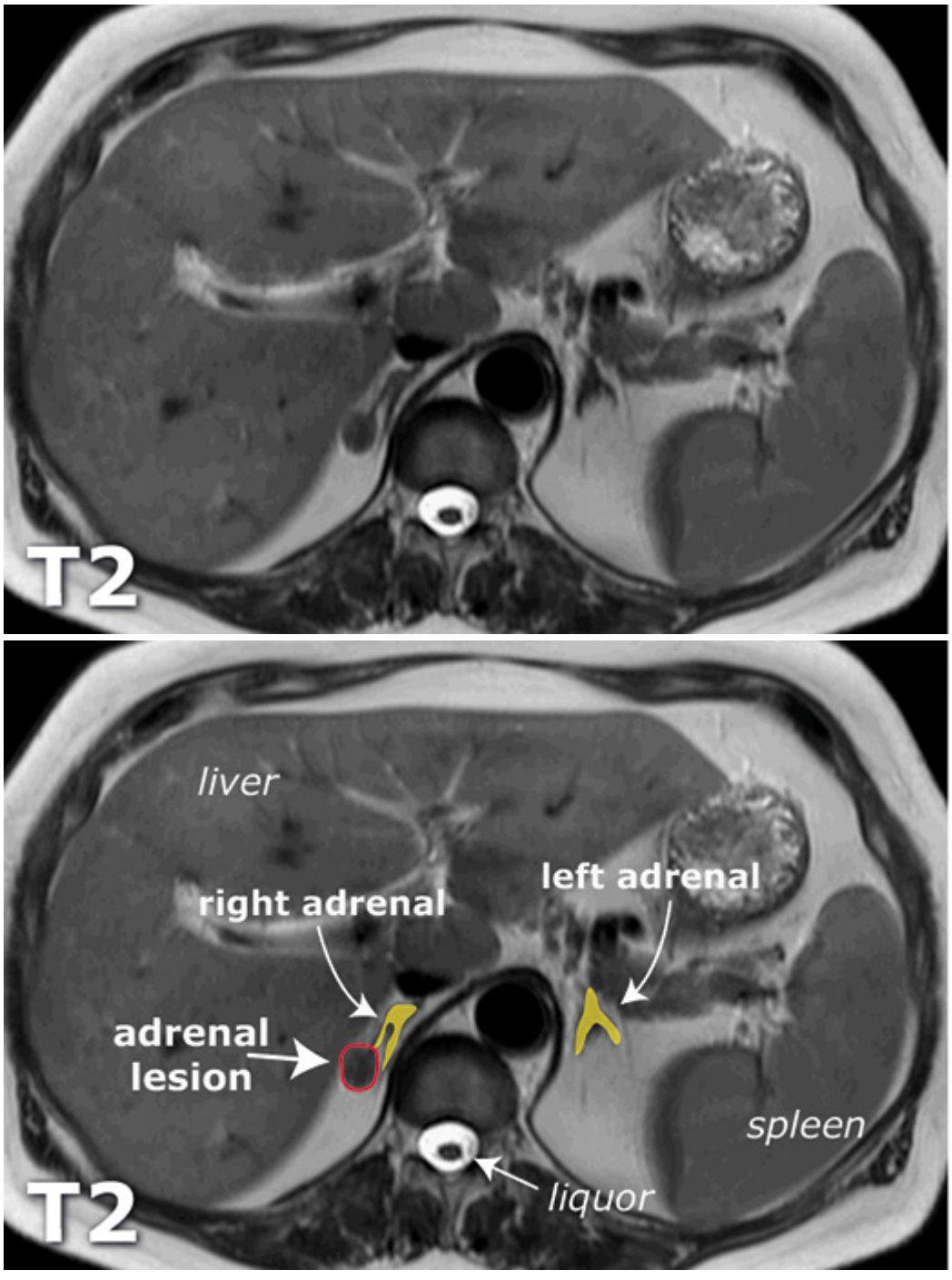
An in/out-of-phase is a gradient sequence used as a tool to detect microscopic fat in a lesion/organ. It is used in particular to evaluate adrenal masses (fat-containing adenoma vs adrenal carcinoma) and fatty infiltration of the liver.

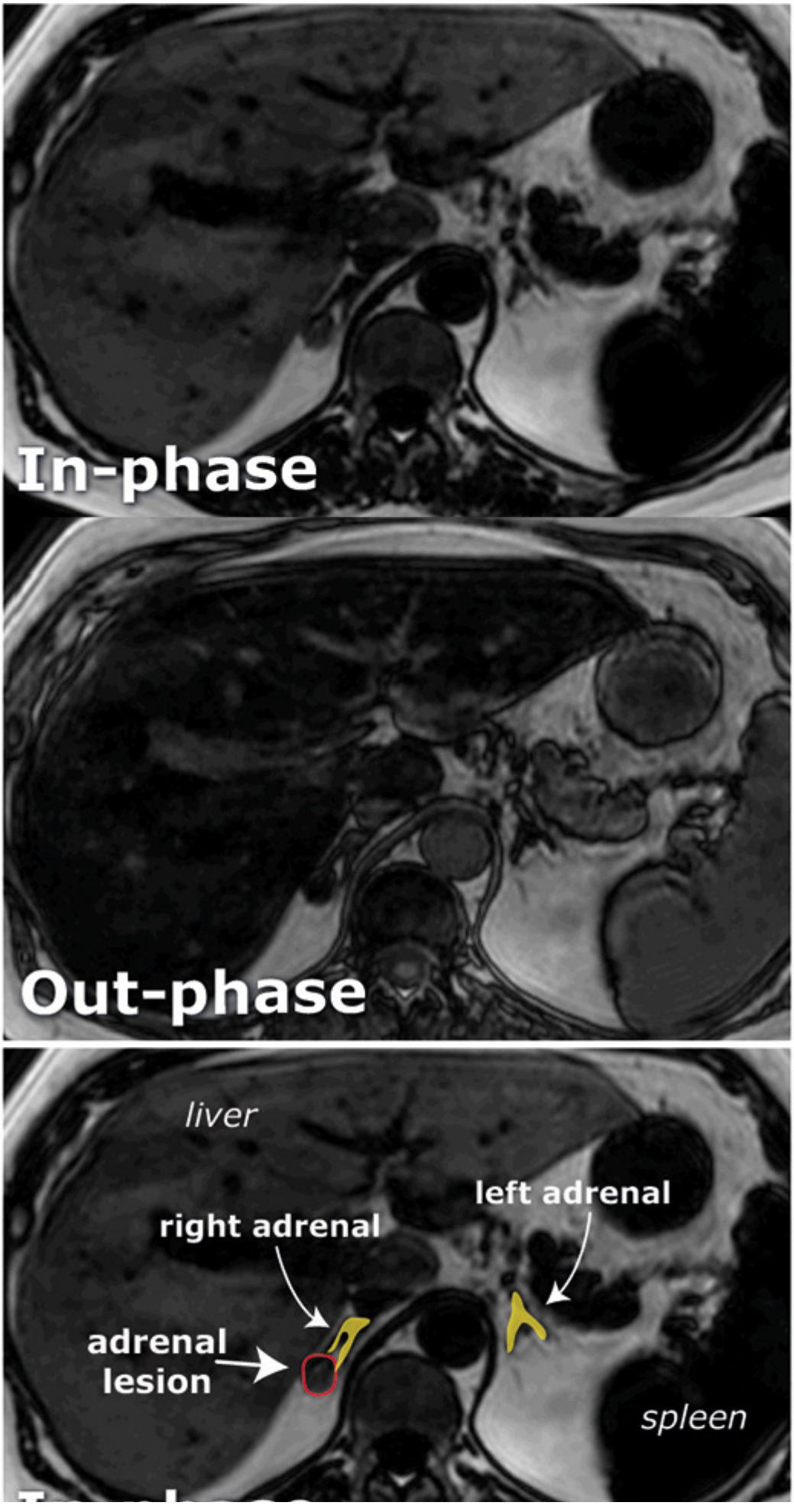
*Background*: the protons in fat and water have a slight difference in Larmor frequency, which may cause a so-called chemical shift artifact (details on chemical shift artifact will not be discussed in this course).

The series has two components: the in-phase sequence and the out-of-phase sequence. When reading the signal on the in-phase sequence, the protons of the fat and water are in exactly the same phase (despite the slight difference in Larmor frequency). The protons are in-phase and therefore give off signal.

The signal in the out-of-phase sequence is read at a specific different moment, the moment that the protons of the fat and water are not exactly in the same phase. This eventually leads to signal loss (Note: the protons are out-of-phase).

*Example*: a fat-containing adrenal lesion has high signal intensity on the in-phase sequence and low signal intensity on out-of-phase (fig. 25).




In-phase
Out-phase
liver
left adrenal
right adrenal
adrenal lesion
spleen

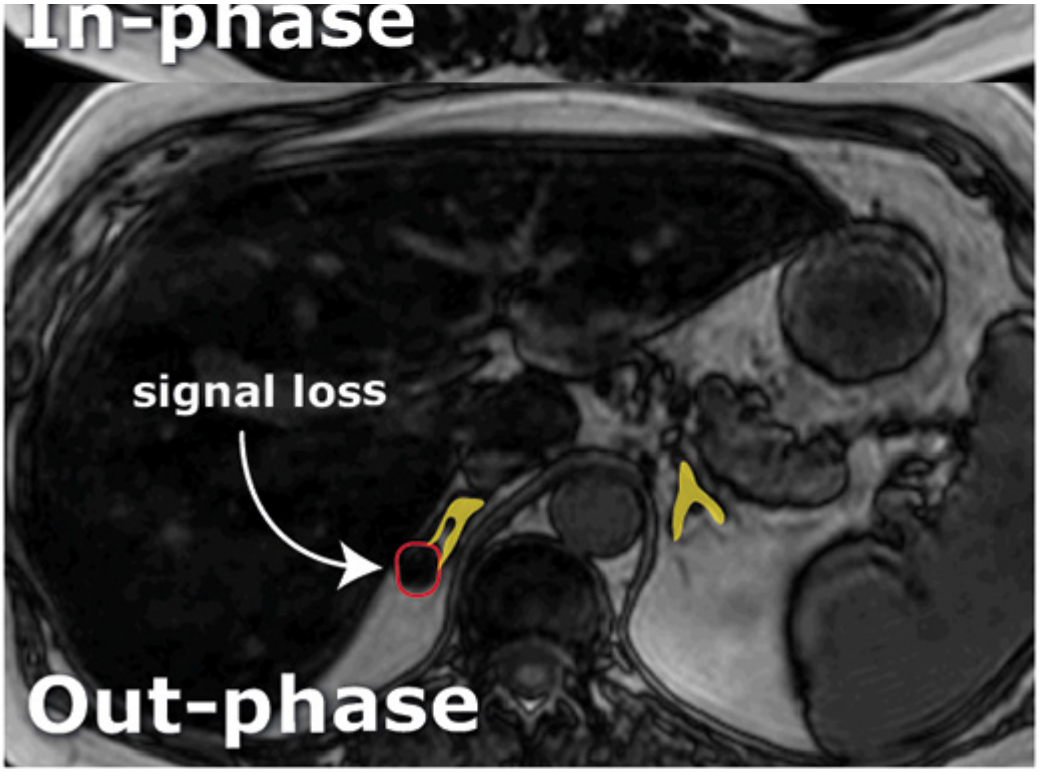
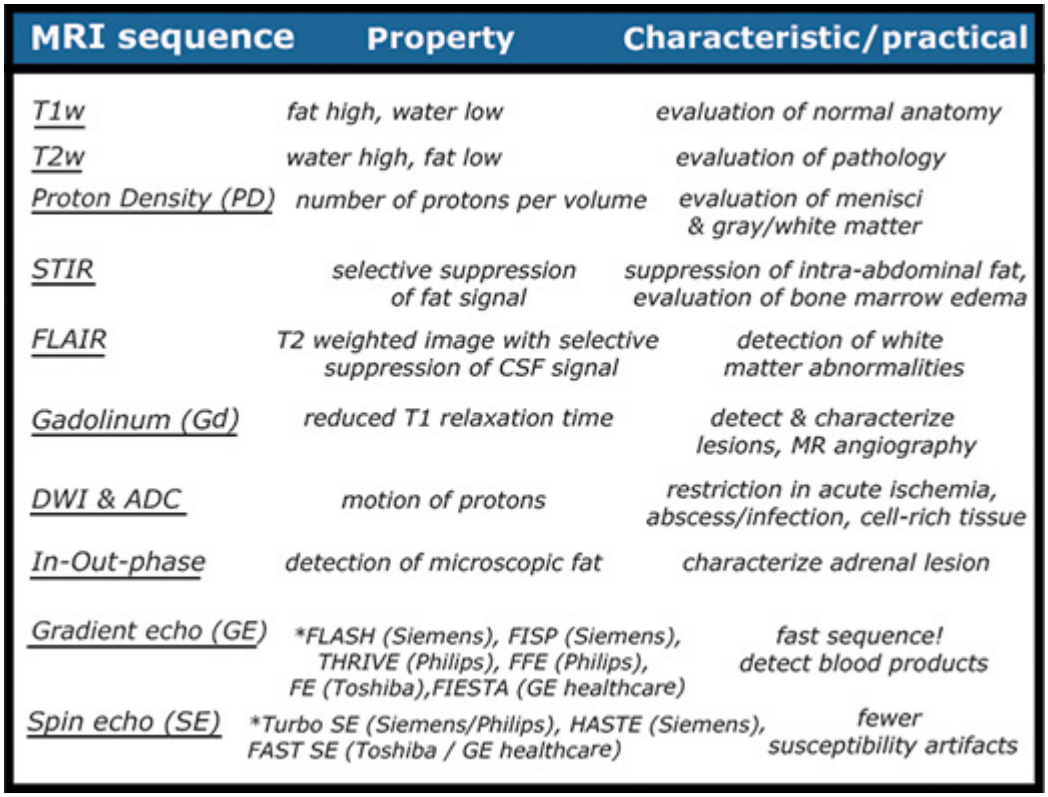



Figure 25. T2 weighted image & in/out-of-phase of the abdomen in transversal direction. A spherical mass originating in the right adrenal can be seen on the T2 weighted image. As compared to the in-phase, signal loss of the lesion occurs on the out-of-phase series, a sign of microscopic fat. Diagnosis: high-fat adrenal adenoma.
Coincidental finding: note also the buildup of fats in the liver (fatty liver).

The in/out-of-phase sequences are therefore useful to detect microscopic fat in a lesion.
Information on whether a tumor does or does not contain fat may help in the differential diagnosis.

## Summary of MRI sequences

It is of course impossible to review all MRI sequences in this course. Below is a summary of some frequently used MRI sequences and their applications (fig. 26).



| MRI sequence | Property | Characteristic/practical |
|---|---|---|
| T1w | fat high, water low | evaluation of normal anatomy |
| T2w | water high, fat low | evaluation of pathology |
| Proton Density (PD) | number of protons per volume | evaluation of menisci & gray/white matter |
| STIR | selective suppression of fat signal | suppression of intra-abdominal fat, evaluation of bone marrow edema |
| FLAIR | T2 weighted image with selective suppression of CSF signal | detection of white matter abnormalities |
| Gadolinum (Gd) | reduced T1 relaxation time | detect & characterize lesions, MR angiography |
| DWI & ADC | motion of protons | restriction in acute ischemia, abscess/infection, cell-rich tissue |
| In-Out-phase | detection of microscopic fat | characterize adrenal lesion |
| Gradient echo (GE) | *FLASH (Siemens), FISP (Siemens), THRIVE (Philips), FFE (Philips), FE (Toshiba),FIESTA (GE healthcare) | fast sequence! detect blood products |
| Spin echo (SE) | *Turbo SE (Siemens/Philips), HASTE (Siemens), FAST SE (Toshiba / GE healthcare) | fewer susceptibility artifacts |

Figure 26. Summary of MRI sequences *The operators of MRI sequences use many different abbreviations, the above abbreviations will probably be the most common. For a full outline of MRI sequence abbreviations, see the website IMAIOS.com – e-MRI – sequences – acronyms.

## Sources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