MRI: Magnetic resonance imaging:

Like CT, MRI produces detailed cross sectional images of body regions. However the physical principles of image acquisition are different and very complicated.

The following is a simplified overview of how MRI works:

- Protons are present in all the atoms of the body.
- They are positively charged and are spinning.
- Any moving charged object produces a magnetic field around itself.
- Thus these protons are surrounded by a small magnetic field.
- If the number of protons in an atom is even, the magnetic fields cancel each other.
- If the number of protons is odd, then the atom will act like a small bar magnet.
- Commonest element in the body is Hydrogen with only one proton.
- The direction of the spin axis is random and thus the magnetic fields cancel each other.
- If the tissue is subjected to strong magnetic field the spin axes become aligned and either spin up or spin down. Slightly more choose to spin up.
- As they spin they also precess (the motion of the rotation axis of a rigid body, such as a spinning top, when a disturbing torque is applied while the body is rotating such that the rotation axis describes a cone, with the vertical through the vertex of the body as axis of the cone, and the motion of the rotating body is perpendicular to the direction of the torque). and the stronger the magnetic field the faster this precession.
- Thus when the patient is placed inside the magnetic field generated by the MRI machine, millions of protons align themselves to produce a single magnetic vector force and all precessing at a frequency similar to that of radio waves (approx. 42MHz).
- A radio signal of precisely the right frequency is then transmitted which upsets the alignment of a proportion of the spinning protons.
- As the electric field thus induced decays they return to the original state and reradiate radio signals which can be detected and recorded.
- Each tissue has characteristics related to the rate of decay of the electric field known as T1 and T2.
- T1 & T2 are used to vary the contrast between different tissues.
- The images produced may be thus either T1 weighted or T2 weighted.

The MRI image:

MRI images are also cross sectional. In this respect interpretation requires similar anatomical knowledge to that from diagnostic ultrasound or computed tomography images. The appearance of each tissue or fluid depends on the image weighting. Image interpretation relies in obtaining multiple sequences (examination series) with different tissue weighting and specific criteria .

For example, fluid appears generally black in T1 weighted images and bright on T2. Fat is bright on T1 and T2 and air and bone are dark on both T1 & T2. Also, other sequences
allow for the elimination of the signal that arises from a particular tissue. This allows for example obtaining T2 weighted images where the signal of CSF no longer appears. This would allow differentiation of CSF from other fluids such as oedema.

MRI allows for acquisition of slices in any plane along the body. This contrasts with CT in which the imaging plane is limited to a transverse plane.
As in CT, contrast agents are also used in MRI. The most common molecule used is Gadolininium, which due to its magnetic properties appears as a bright signal in T1 images. This is used to see the distribution of the contrast in areas of the body or lesions.

**Advantages of MRI**

Has superior soft tissue resolution than CT.
Does NOT utilize ionizing radiations.

**Disadvantages of MRI.**

Not so useful for the evaluation of bone.
Strong magnetic field used may affect pacemakers and metallic objects and create a safety hazard.
Longer scanning times.
Expensive equipment.

**Indications for MRI**

**Brain**

- Epilepsy
- Inflammatory brain disease-GME etc
- Neoplastic brain disease
- Syringohydromyelia
- Nasal disease
- Oral masses
- Local lymph nodes

**Spine**

- CNS disease-GME
- Syringohydromyelia
- Cord compression-intradural
- Lumbosacral cord compression

**Soft tissues**

- Neoplasia-extension margins
- Muscles and joints
COMPUTED TOMOGRAPHY (CT)

Computed Tomography (Also known as CT, computed axial tomography or CAT) is a diagnostic imaging modality which produces cross sectional images of any body region, using X-rays. Since its discovery, CT technology has improved dramatically. Modern multi-detector CT machines can scan an entire patient within seconds, producing slices of less than one millimetre in thickness.

Physical principles:

Computed tomography uses similar principles to conventional radiography. An X-ray tube mounted in a gantry rotates around the patient, generating a narrow high kV x-ray beam. The fan shaped X-ray beam passes through the patient, and is attenuated to varying extents depending on the characteristics of each tissue. A detector assembly in the opposite side of the gantry measures the intensity of the beam after passing through the patient. The data is recorded from multiple projections obtained at different angles. A computer then uses all the different projections to generate a two-dimensional cross sectional image or slice. The same process is repeated at different levels of the patient to produce consecutive CT slices.
Newer CT machines use helical technology. In this case, the X-ray tube rotates continuously while the patient is transferred through the gantry at a continuous speed generating data acquisition in a helical path. This has many advantages, particularly a decrease in scanning time and improved three dimensional image rendering.

The CT image:

Due to the high kV used, the attenuation of the X-rays is proportional to the density of the tissue. In conventional radiography, the opacities of the organs in the image depend in many other factors and we can only differentiate five opacities: air, fat, soft tissue, mineral and metal. In computed tomography, the attenuation values (Hounsfield units) of each part of the image can be accurately measured. For example, water measures 0 HU, air -1000 HU, soft tissues 50-200 HU,… As a result CT images have a high contrast resolution. This allows us to differentiate for example fluid from soft tissue, which is not possible with conventional radiography. In fact, the measurements are so accurate that it is possible to distinguish between different types of fluids such as urine, pus or blood or between different soft tissues such as liver or spleen.

The final image is made out of a grid of pixels, and each pixel has an attenuation value ranging approximately between -1000 and 2000. However, the human eye is not able to differentiate between 3000 shades of grey and the scale of attenuation values is adjusted to a grey scale during review of the images, this process is called a window level or windowing. Different window level settings will be used for evaluating different tissues such as lung, bone, brain.

The figure below shows the same image displayed with two different window levels. The image on the left is displayed using a brain window and the one on the right a bone window.
Note how in the left image you can appreciate the difference between brain parenchyma and CSF in the lateral ventricles (Star). In the right image, we can not appreciate this difference but the bone detail is superior.

**Multi-planar reconstruction and 3D rendering:**

Another advantage of CT is the ability to produce three-dimensional images, or images in virtually any plane across the patient. To achieve this, the computer integrates all the information from the consecutive axial (transverse) slices to generate a 3D volume. This feature is particularly useful for surgical planning, as the body area can be evaluated from all the different angles. The image is a 3D image of the skull of a cat. The image below is sagittal reconstruction of the cervical spine of a dog with a disc herniation C2-C3.
Advantages of CT:

- High detail cross sectional images - thus avoid superimposition seen in conventional radiography.
- Can process the image to give greater resolution of narrow contrast bands.
- The ability to reformat the information.
- Post-processing can enhance an area of special interest.

Disadvantages of CT:

- Uses long X ray exposure times.
- Contributes a radiation dose.
- Lower spatial resolution of low contrast objects.
- Expensive equipment.

Indications for Computed Tomography

Head
- Nasal disease
- CNS disease
- Oral masses
  - Local lymph nodes
- Otitis externa and media
- Neoplasia
- Fractures

Spine
- Intervertebral disc disease
- Neoplasia
- Fractures
- Infection

Fractures
- Non union of humeral condyle
- Fragmented coronoid process
- Neoplasia

Soft Tissues
- Angiography-PSS

Grateful acknowledgement to Manuel Pinilla for his invaluable contribution to the presentation and notes