Single Positron Emission Computed Tomography

Friday, 3 March 2017
1:16 pm

Describe the basics of SPECT imaging.

SPECT is a type of tomographic imaging used in nuclear medicine. Tomography is the process of collecting data about an object from multipole views and using these to construct an image of a slice through the object. In nuclear medicine the process of detecting photons emitted from a radiopharmaceutical distributed within the body.

Describe different camera configuration and orbits of rotation.

Single headed cameras must rotate 360' to obtain all necessary views, **double headed** rotate 180' and **triple headed** only need to rotate 120'. **Two headed** camera heads can have a fixed configuration of being parallel for simultaneous anterior and posterior acquisition. The can also have an adjustable configuration that allows for different angular positioning.
Circular orbit is when the head is rotated at a fixed distance from the centre of the body.
Elliptical orbit is when the head is rotated elliptically around the patient.
Contour orbit is when the camera determines the body contour to move in and out getting as close to the patient as possible.

Discuss the limiting role of the collimatior.

Gamma cameras use **collimators** that permit photos following certain trajectories to reach the detector. Thus, collimation, severely limits the performance of gamma cameras.

Describe the terms: line of response, projection and cine view.

Line of response is the radiation accepted bob each collimator hole ignoring absorption and scattering.
Projection or **projection profile** is a full set of response lines acquired during acquisition.
Cine view is the rapid sequential presentation of projection profiles.

Discuss data acquisition.

Step and shoot data acquisition is when a projection is acquired at each angular position with the camera head being rotated 5.6' for 64 views.
Continuous acquisition is when the data is collected continuously as head rotates.

Describe the role of the sinogram.

The **sinogram** is a stack of slices of the acquired view from 0' to the maximum angle of rotation. Each row consists of data acquired at a different angle of rotation with there being a separate sonogram for each slice through the patient. The sinogram is used to detect patient motion.

Compare the two methods of attenuation correction.

The Chang method, presumes a constant attenuation coefficient throughout the patient. This does however, either overcompensate or undercompensate for attenuation. A linear coefficient of 0.12 to 0.13 cm-1 is typical of values used in the reconstruction.

Describe the main data regions in an image.

The image data contains, background, image data and noise data regions.

Briefly describe the back-projection model of reconstruction.

Back projection involves a thin section of homogenous radioactive material has a cross cut in it. Section is divided into 5 columns and rows, where each square contains 1 unit of radioactivity. The back projection is then obtained by summing each row and column.

Basic Waves and Pulsed Ultrasound

Wednesday, 8 March 2017
12:28 pm

Describe the advantages and disadvantages of using ultrasound as an imaging device.

Advantages: non-ionising, can perform both diagnostic and therapeutic procedures, focussed into small beams, can image muscles and soft tissue extremely well, gives live images, rarely causes discomfort to patients and equipment is widely available and flexible.
Disadvantages: Trouble penetrating bone, performs poorly when there is gas in between transducer and organ of interest, depth penetration may be limited, overlying subcutaneous fat attenuates the sound beam, and ultrasound is operator dependant.

Describe the main features of a soundwave.

Sound is the transfer of energy from one point to another. There must be material for the particles to pass through, and vibrate. If there is no material, then no vibration can occur and sound cannot exist, henceforth, sound cannot pass through a vacuum. The direction of motion and that of the vibration of the particles are the same, with particles experiencing only very small back and forth displacement.

Discuss the terms, which describe an ultrasound wave.

A **cycles** is a compression followed by a rarefaction. Pulsed ultrasound has 2-5 cycles in a pulse.
Frequency (f) is the number of cycles per second, represented by hertz for one cycle.
Period (t**)** is the time to complete one cycle.
Wavelength (λ) is the length of a cycle.
The change in magnitude of the material that the ultrasound interacts with is the **amplitude**.
Velocity of propagation is the speed of sound and is 1540 ms^{-1} for ultrasound in soft tissue (it is a constant = **c**). $\boldsymbol{C = f\lambda}$
Acoustic impedance (Z) is a measure of the resistance of a medium to the transmission of sound. The product of velocity (**C**) of the medium and the density of (**p**) of the medium. **Z = pC**

Give the range of ultrasound frequencies used for diagnostic procedures.

Diagnostic ultrasound uses 2 MHz to 20 MHz.

Discuss the factors that affect speed of propagation and acoustic impedance.

The **speed of propagation** is influenced by the density of tissues, with more dense tissues having a higher speed of sound. **Acoustic impedance** is determined by the product of the velocity and the density of the medium.

State the value of the velocity of sound in soft tissue.

1540 ms^{-1}

Discuss why the velocity of sound is an important concept in ultrasound imaging.

If the velocity of ultrasound differs in two tissues, refraction can occur.

Describe the difference between continuous and pulsed ultrasound.

Pulsed ultrasound has 2-5 cycles in a pulse, as the ultrasound beam is intermittently transmitted.

Discuss why pulsed ultrasound is used for imaging.

The basis of ultrasound imaging lies in echo ranging. The transceiver probe sends out a pulse of ultrasound and then remains still for a period of time, the pulse travels at the velocity of propagation of sound in that medium. As the transducer cannot emit and receive pulses simultaneously, the majority of the time is spent listening for echoes.

Introduction and Basics of MRI

Wednesday, 5 April 2017
1:10 pm

Provide a basic overview of MRI imaging.

The signal measured by an MRI system is the combined signal of billions of atoms, as one single atom does not generate a large enough nuclear magnetic moment to be observed. There a billions upon billions of **hydrogen protons** in the human body, a proportion of these will align with the strong magnetic field produced by an MRI when a patient is place in the scanner. This magnetic field is deemed the **external** or **main magnetic field** and is denoted by $\mathbf{B_0}$. Protons are aligned within this magnetic field and are then moved out of alignment by RF pulses. The frequency of these pulses is selected to resonate with a particular group of protons in the body. As the protons then move back into alignment, a RF signal is generated which is what is used to construct the MR image. The strength of magnetisation is dependant on the presence of magnetic nuclei, hence why hydrogen is used, being the most dominant nuclei in the human body. The level of this magnetisation at a certain time determines image brightness.

Discuss the advantages and disadvantages of MRI.

Advantages:

- High contrast sensitivity to soft tissue differences
- Inherent safety due to use of non-ionising radiation

Disadvantages:

- High equipment costs
- Scan acquisition complexity
- Relatively long imaging times
- Significant image artefacts
- Patient claustrophobia
- Certain implants

Describe how a proton in the body acts within a magnetic field.

The protons in the body act as small magnets, and are defined as nuclei with a net charge. These nuclei are spinning and can acquire a magnetic moment resulting in alignment of their axis of rotation to an applied magnetic field (B_0).

Discuss the effect of an external magnetic field on the proton nuclei.

In the absence of a magnetic field, the hydrogen nuclei will experience randomly orientated magnetic moments. When placed within a strong static external magnetic field, these magnetic moments will align with (**parallel**) or against (**anti-parallel**) the magnetic field.

Describe the TWO energy levels of a magnetic nuclei and discuss the Net Magnetisation Vector (NMV).

Low energy nuclei align magnetic moments parallel to the external field and are known as **spin up** nuclei. High energy nuclei align anti-parallel to the external field and are known as **spin down** nuclei. The larger the B_0 field, the greater the difference in energy levels and the larger the excess number aligned with the field.

Describe the precession and be familiar with the Larmor Equation.

Each hydrogen nucleus is spinning on its axis, when B_0 influences on the hydrogen nucleus, an additional spin will be produced of the NMV around B_0. This secondary spin is called **precession** and causes the magnetic moments to follow a circular path around B_0. **Precessional frequency** is the frequency at which NMV wobbles around B_0. This can be calculated using the **Larmor equation** (MHz); 1MHz = 1million cycles per second.