

## Medical Physics

### Radioisotopes

- Named because they are radioactive isotopes, they will decay to form other elements.
- The half-life is the amount of time taken for half of the atoms to undergo decay. This is the same amount of time regardless of the initial amount of atoms present.
- Common element used in medical imaging is Tc-99m; this has a half-life of 6 hours.
- advantages of a relative short half-life are:
  - The patient can have an overall smaller dose of radiation as the substance is more active at the start when you are receiving the image.
- Disadvantage is the radiation will still linger in the body for quite some time and the storage of the relatively short half-life is problematic.

### Bone scans

- Bone scans are good at showing the areas of high metabolic rates as these areas are more radioactive.
- Lacks the detail of the X-ray or CAT scan.

### X-rays

- X-Ray images are formed by passing X-rays through the body. Areas of high density (bones, etc.) will absorb the X-rays. The X-rays that are not absorbed pass through the body and hit photo sensitive paper that turns black in the presence of the X-rays. So the areas of high density remain clear. Thus the X-ray image is formed.
- Soft tissue images with an X-ray are made by using a contrasting material like a barium meal. The barium has a higher density and this allows the details in an organ like the small intestine to be seen.

### Endoscopes

- Endoscopes are thousands of coherent bundles of optical fibres that allow the doctor to see inside a patient with as invasive a technique as possible. Making the orientation of the fibres is the same throughout the length of the endoscope.
- The advantage of the endoscope is it allows the doctor to see clear colour images of inside the patient with only a small incision. This greatly decreases the recovery time.

### PET scans

- Positron Emission Tomography is when a radioactive glucose is given to a patient and this glucose will travel all over the body and end up in areas of high metabolism. Cancer is regularly dividing and this means that the cancer has a high metabolism. Giving the radioactive glucose to the patient means that the cancer will show up as an area of high metabolism.

### MRI

- The most significant advantage of MRI over CAT is its ability to distinguish between soft tissues. The MRI is capable of discerning function as opposed to mere structure that the CAT scan can do.
- The MRI aligns the hydrogen nuclei and then supplies a specific radio frequency. When the magnetic field from the MRI is removed the hydrogen nuclei emit the same radio frequency and this is detected, the increased amount of water in the cancerous tissue means that it will appear different to the surrounding tissue. This allows for easier detection of the cancerous tissue.
- Superconducting magnet assemblies are used in MRIs to create the very strong magnetic fields - that cause the hydrogen nuclei to align.
- Introducing gadolinium to the body increases the relaxation time between tissues. This difference allows for greater detail to be formed in the image.

### Ultrasound

- Just like an echo, the ultrasound uses a sound source and waits for the returning waves to calculate how far the reflection occurred.
- Ultrasound images are formed using high frequency sound that reflects from the surface of higher acoustic impedance. The acoustic impedance is calculate using:
  - $Z = \rho v$
  - $Z$  is the acoustic impedance,  $\rho$  is the density of the material,  $v$  is the speed of sound in the material.
- Calculating the amount of sound reflected from a surface. Use the ratio of the Intensities:

$$\frac{I_r}{I_o} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$

- The amount of reflection from an air / skin surface would be very large, so an ultrasound gel is used that has an acoustic Impedance that is around the same as the skin.
- The Doppler Effect is the apparent change in frequency of sound due to the relative velocities of the medium it is travelling in. An example is the Doppler shift in the blood, as the blood is pumped around the body the speed changes, the faster the blood is pumping the greater the change in frequency. This can be used to notice any abnormalities in the circulatory system.
- A piezoelectric crystal is used as the source of the high frequency and also used as the detector. When a high frequency voltage is applied to the crystal it will vibrate at the same frequency. This is how the high frequency sound is made. When the crystal receives a vibration from the returning sound it will produce a small voltage, this is how it is used as a detector.
- Selector scans rock the piezoelectric crystal back and forth recording the reflecting waves and putting this together to form a 2D image.
- Phase scans use multiple crystals fired at different times to gather information at different angles. A computer is then used to determine the 3D image.
- Unfortunately the high acoustic impedance of the bones means that most of the sound is reflected from the surface.