A2 Level Physics

Chapter 21 – Medical Imaging

21.2.1 Diagnostic Methods in Medicine

Notes

Medical Tracers

Medical tracers are radioactive substances that are used to show the function of tissue or organs.

X-rays, for example, only show the structure of organs, whereas medical tracers display both structure and function.

To diagnose or treat an illness, these radioactive elements or compounds are either ingested or injected into a patient.

Note:

- Gamma-ray sources are commonly used as tracers. The ionising properties of alpha and beta rays are much higher, and therefore they would cause significant damage if they are to be used as tracers.
- The tracer's half-life must be long enough to complete the investigation, but not longer then that. The half-life should be long enough to get it from the manufacturing facility to the patient.
- Tracers must be non-toxic.
- The tracer's activity must be high enough to be monitored from outside the body.

Technetium-99m

Technetium-99m is commonly used as a medical tracer.

It's a gamma-emitter with a 6 hour half-life.

Tc-99m can be used to monitor the function of heart, liver, lungs, kidneys, brain, etc…

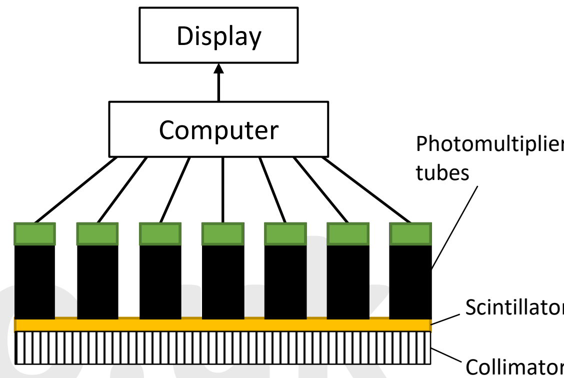
Tc-99m emits gamma-ray photons, which are detected by a gamma-camera, which helps to diagnose the function of the organ, under investigation, by locating the tracer's position.

The Gamma (γ) camera

A gamma camera detects the gamma rays emitted by radiotracers in a patient's body.

The key components of a gamma camera are shown in the diagram opposite.

The patient is given technetium-99m and placed in such a way that the camera is above the organ being examined.



The gamma camera is made up of five basic components:

- **Collimator**

A collimator is a block of lead with thousands of vertical holes in it and only γ-ray photons parallel to the holes travelling along the tube axes will reach the scintillator. Any photons travelling in the other directions are absorbed by the lead. This improves the image's sharpness.

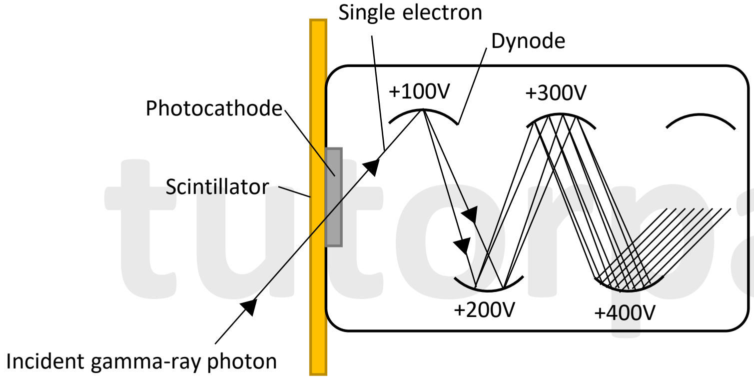
- **Scintillator**

The scintillator is a large crystal of sodium iodide, a fluorescent material that absorbs γ-ray photons and emits visible light photons. An array of photomultiplier tubes then collect these light photons.

The Gamma (γ) camera

Photomultiplier tubes

Each photomultiplier tube contains a photocathode, which uses the photoelectric effect to transform light photons into electrical signals. From the photocathode, one visible photon produces one electron. This electron speeds up and collides with the initial dynode, releasing two or three secondary electrons. These electrons then accelerate to the second dynode releasing more electrons and this process continues causing an exponential increase in the number of electrons in a cascade (as shown on the diagram opposite). The large number of electrons arriving at the last dynode generates an electrical pulse, which is amplified and recorded by the computer.



Computer and display

The computer registers the electrical pulses and uses them to produce an image of the tracer within the patient's organ, which is then displayed on a monitor.

The liver, brain, thyroid, lungs, spleen, heart, kidneys, and circulatory system are all examined with a gamma camera.

Techntium-99m is the most commonly used tracer.

If the tracer is combined with another chemical, the image created will show the concentration of the tracer and indicate the concentration of the specific compound used in order to show the function of the bodily part.

Positron Emission Tomography (PET)

Positron Emission Tomography (PET) scans involve injecting a patient with a substance that the body uses, such as glucose, containing a positron-emitting radiotracer with a short half-life, such as Fluorine-18.

PET is commonly used to monitor and diagnose brain function. PET can also be used to monitor blood flow and detect nervous system problems.

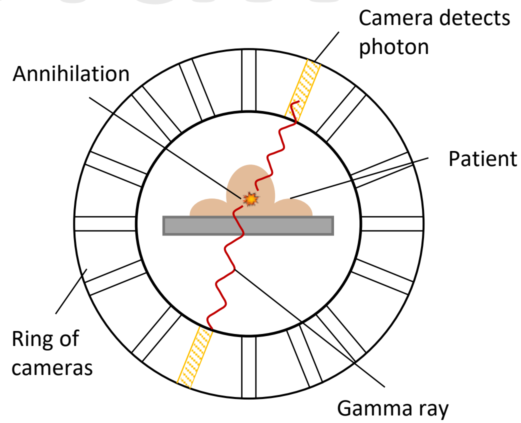
It works in a similar way to CAT in that it produces images of slices through the body, but instead of X-rays, it uses γ- rays.

The patient is given glucose with the positron (β^+) emitting tracer fluorine-18. As the F-18 decays, positrons are emitted..

$$^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{+1}e + \gamma + {}^{0}_{0}\nu_e$$

The emitted positrons annihilate when they collide with electrons on the organs, resulting in two gamma-ray photons released in opposite directions.

The patient is placed in a ring of γ-ray detectors inside the PET scanner, which detects and records these gamma-rays. The data from the detectors is then sent to a computer, which creates a map of the body's radioactivity. The computer compares the arrival times of the two γ-ray photons and uses the difference in arrival times to find the centre of the annihilation.



This creates a 3D image of the tracer, which can then be used to diagnose any abnormalities in brain function.

Positron Emission Tomography (PET)

Advantages of PET

- While certain non-invasive technologies cannot penetrate the skull, PET allows us to examine brain activity.
- Give information on the cancerous nature of tumours and whether they are spreading.

Disadvantages of PET

- Ionising radiation is used, which has the potential to harm the patient's cells.
- Scans can take a long time to complete.
- Requires the patient to remain still for an extended period of time in a small machine, which can be uncomfortable and claustrophobic.
- The machine is both expensive and big.

Positron Emission Tomography (PET)

PET scans vs CAT scans:

- PET scans show the biological function of an area in the body, while CAT scans offer detailed images of bone and tissue structure.
- PET scans can take up to 2 - 4 hours, while CAT scans only take about 30 minutes.
- PET scans are more expensive.
- PET scans only expose a patient to about the same amount of radiation as an X-ray, however CAT scans often expose patients to much higher radiation doses.

Please see '21.2.2 Diagnostic Methods in Medicine worked examples' pack for exam style questions.

For more revision notes, tutorials and worked examples please visit www.tutorpacks.co.uk.

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