Radioactivity in medicine

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Left: *Doctors examining the results of a patient's PET scan*

GCSE key words
Isotope
Half-life
Meiosis
Mitosis
Mutation

Radiation has many uses in medicine, both in finding out what is wrong with a patient (diagnosis) and in the treatment of cancer (therapy). In the last issue of C*ATALYST, we looked at the medical uses of electromagnetic radiation. In this issue, we focus on the uses of radiation from radioactive materials.*

Radioactivity has been used in medicine since soon after it was discovered in 1896. For a while it became the latest health fad: people drank water with radium in it, put it in their baths and even made toothpaste out of it. Many people claimed that radiation cured all kinds of diseases, and an article in the reputable publication the *American Journal of Clinical Medicine* stated that: 'Radioactivity prevents insanity, rouses noble emotions, retards old age, and creates a splendid youthful joyous life.'

However, it soon became apparent that the people who used these products regularly or worked with radiation, such as the girls who painted radium on the faces of watches to make them glow, were suffering from a number of symptoms. These included burns, hair loss, bone diseases and various types of cancer.

Although the manufacturers of these products made false claims about their benefits, and radiation in large doses can be dangerous, radiation has many uses in modern medicine.

What radiation does to cells

There are three types of ionising radiation: alpha (α), beta (β) and gamma (γ). When a cell absorbs radiation, it may damage the DNA inside the nucleus:

- Sometimes the cell can repair itself with no lasting damage.
- Sometimes the cell repairs itself but with a change in its DNA code (a **mutation**).
- Sometimes the cell is unable to repair itself and dies.

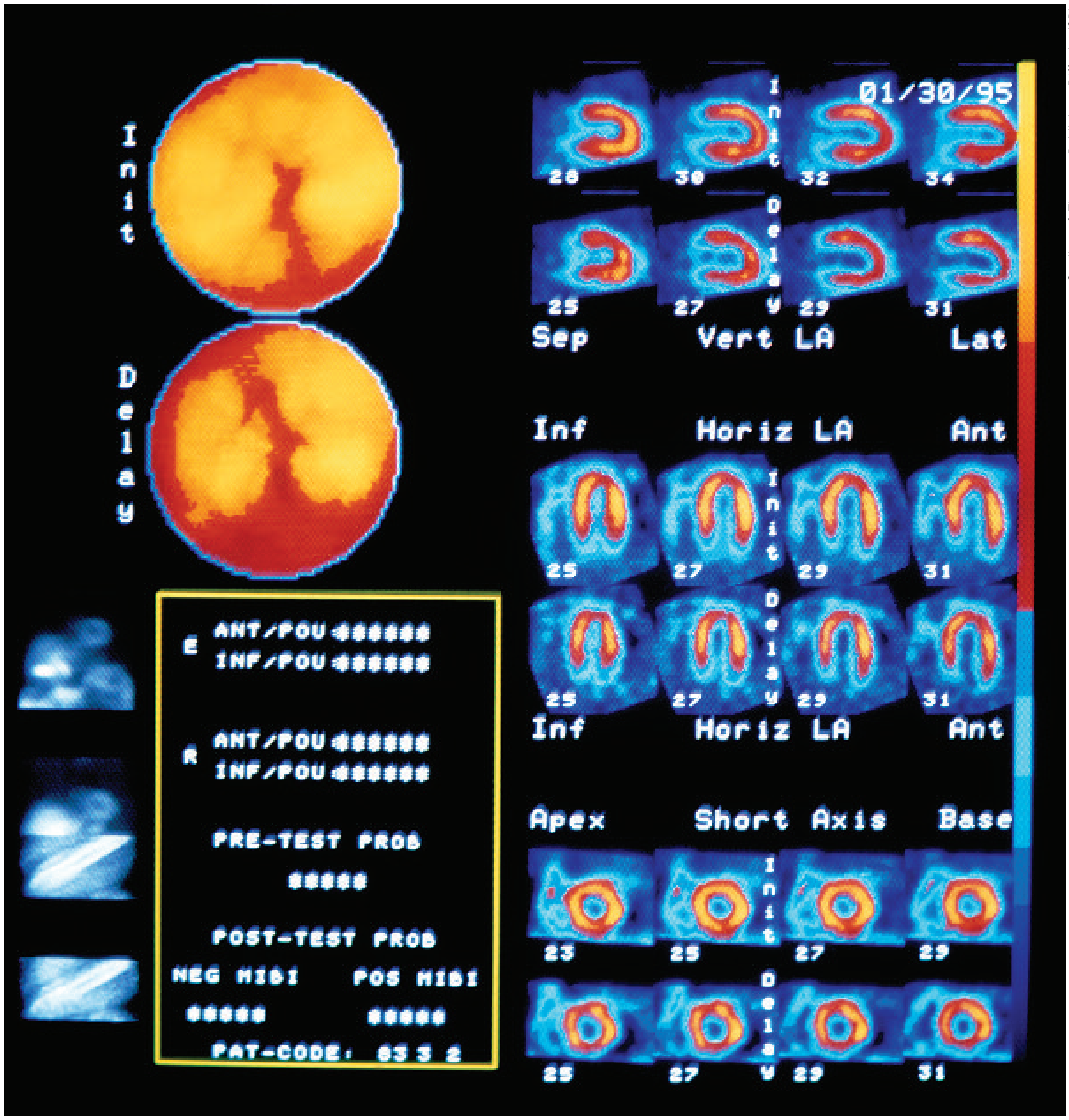
Not all mutations are harmful, though some can kill the cell or cause it to become cancerous and start dividing more rapidly. Cells that are dividing (by **mitosis** or **meiosis**) are more susceptible to radiation damage, so are more likely to be killed.

Fifty years ago, one of CATALYST's editors had a verucca dealt with by having a tiny pellet of radium plastered onto the sole of his foot. He lived to tell the tale!

Beta particles are usually negative (–), but they can be positive (+).

- **Which gives greater cause for concern — radiation causing mutation as mitosis is occurring or as meiosis is occurring? (Clue: Think of the type of cells produced by meiosis. Answer is on page 13.)**

Right: *Coloured SPECT scans of blood flow through a human heart*



Ouellette & Theroux, Publiphoto Diffusion/SPL

- **To see more images, search for 'nuclear medicine' in Google Images (www.google.co.uk/imghp).**

Most gamma-emitting isotopes also emit either alpha or beta radiation. Technetium-99 is useful in nuclear medicine because it emits only gamma radiation.

Beta+ particles are also known as positrons or positively-charged electrons; they are particles of antimatter.

When any particle of matter meets its antiparticle, they annihilate, leaving only energy in the form of gamma rays.

Nuclear medicine

Nuclear medicine uses radioactive **isotopes** (radioisotopes) to find out what is going on *inside* the body. X-ray images show the structure of the body, so can only be used to diagnose things like broken bones and some tumours. Unlike X-ray images, nuclear medicine follows what happens to certain chemicals as they pass through the body and so can see if an organ is doing its job properly. The chemicals, called tracers, are labelled with a radioactive isotope and their path through the body can be followed by detecting the radiation they emit.

The radioisotopes are produced in generators in which isotopes with long half-lives (e.g. molybdenum-99, half-life 67 hours) decay to isotopes with shorter lives (e.g. technetium-99m, half-life 6 hours). The shorter half-lives are necessary so the patient does not stay radioactive for much longer than the time it takes to get the images. In fact everyone is slightly radioactive as we have isotopes in our bodies that were taken in as part of food or drink.

The isotope with the shorter half-life is drawn out of the generator in a solution and can be made into a range of drugs (radiopharmaceuticals) that are absorbed by different parts of the body. The radiopharmaceutical is drawn up into a syringe shielded with lead and its dose checked before it is injected into the patient.

The gamma rays given off by the radioisotope are detected by a gamma-camera (a detector that is sensitive to gamma rays). This is connected to a computer and gives an image of the distribution of the isotope in the patient. The image shows where the drug is absorbed, and if several pictures are taken over a period of time it can also show how quickly the isotope is absorbed.

Boxes 1 and 2 describe how two different types of gamma-cameras work.

Box 1 SPECT

SPECT (single photon emission computed tomography) uses a gamma-camera on a ring, which moves around the patient in a circle, taking pictures from many different positions. These pictures go to a computer which produces an image that is a 'slice' through the patient.

The images can either be viewed as a series of slices, or can be made into a three-dimensional image. The process of getting slices is called **tomography** and can also be done using X-rays. This is called CT (computed tomography).

The doctor can see even more information if the X-ray image and SPECT image are combined.

Box 2 PET

PET (positron emission tomography) scanning uses isotopes emitting beta radiation. A beta+ particle travels only about 1 mm before losing its energy and slowing down. When it slows down enough, it will meet a negative electron from a nearby atom and they will annihilate, leaving no particles. Their energy is converted into two gamma rays which travel in opposite directions so that momentum is conserved.

A PET scanner has a ring of detectors so that both gamma rays are seen, and is connected to a computer which can work out where the gamma rays came from and produce an image.

Not all hospitals have PET scanners as they need machines called cyclotrons nearby to produce the beta+ emitting isotopes. The isotopes have a shorter half-life than the gamma emitters used in traditional nuclear medicine (e.g. carbon-11, half-life 20.5 minutes).

Above: A patient being treated in a linear accelerator

A combined PET/CT scan

Radiotherapy

Radiation is not just used for diagnosis, but can be used for treating cancer. This is called **radiotherapy**. Radiotherapy uses the fact that ionising radiation damages cells, and high enough doses can kill them. The cells in cancerous tissue are dividing rapidly. This makes them more susceptible to damage by radiation than healthy cells, so there is a higher chance that they will be killed and the healthy cells will recover.

Even so, care must be taken to ensure that only the malignant cancer cells, and not the surrounding healthy tissue, receive a high dose of radiation. This is done by mounting the system on a ring so that it can rotate around the patient, with the tumour at the centre of the rotation. In this way the tumour gets a higher dose of radiation than the surrounding healthy tissue.

Some radiotherapy machines use the radioactive element cobalt-60, which emits gamma rays and has a half-life of 5.2 years. It does not need a short half-life as it is not inside the patient, and the machine keeps the cobalt-60 in a 'head' with lead shielding around it that the gamma rays cannot pass through. More recent radiotherapy machines have linear accelerators instead of a radioactive source. Linear accelerators (linacs) produce high energy X-ray beams, which are electromagnetic like gamma rays.

Conclusion

Although radiation needs to be handled with care, it can be used in many different ways to diagnose and treat illnesses, and new ways to use radiation to care for people are still being found.

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- **Patients who have undergone diagnosis or treatment in which a radioactive substance has been introduced into their bodies may be warned to flush the toilet several times after use, and to avoid kissing anyone. Can you think why?**

By developing more *sensitive* detectors of radiation, the dose of radioactivity given to a patient can be reduced. This means there is less risk to the patient's health — the balance of *benefit* to *risk* is improved.

Meiosis. Sex cells would be affected, so the mutation might be passed on to all cells in any child developing if the sex cell is involved in fertilisation.