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Radio tracers' supply chain

The short shelf life of nuclear medicine materials calls for special measures, says S.Ananthanarayanan.

The availability of short-lived radioactive materials has found application in medical diagnostics. Radioactive material is introduced into the body, usually injected, and allowed to course through the blood stream. The materials are in minute quantities and are selected so that their radiation does not pose significant danger. As the materials are selected to be of short-lived radioactivity, their danger decays very fast, anyway.

Radiation tracking

While the radioactive material courses through the body, it keeps emitting radiation, which can be detected through special detectors that are placed around or moved around the body. The radiation detected at different places, angles and planes can then add up to provide a scan of where atoms of the material has reached and hence of the internals of the body.

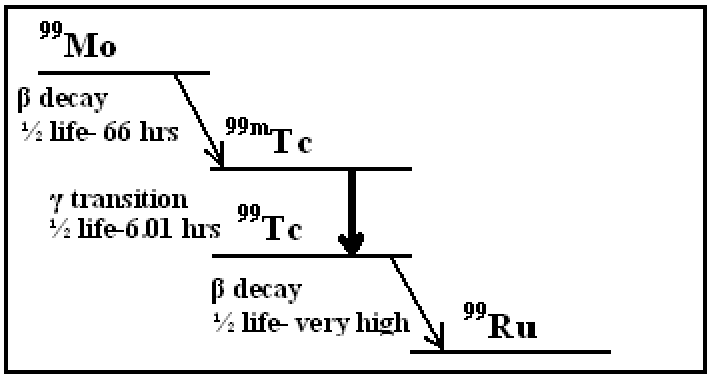
A common use of this kind of scan is in bone and brain scans, or scans of the muscles of the heart, using ***Technetium-99m***, a radioactive substance whose radioactivity keeps falling by half every 6.1 hours. The material hence provides a reasonable level of emission for a short while and the products of radioactivity, which would remain active for longer, but not greatly longer, are also rapidly biologically thrown out by the body. The use of this material hence leaves little radioactive traces in the body very soon after it has been administered.

Technetium-99m, or **^{99m}Tc**, as it is known, emits gamma rays (a form of light of very short wavelength) and decays into ^{99}Tc, another form of the same element. The letter 'm' in the superscript indicates that the mother atom is a ***metastable***, or short lived form of the daughter itself. The energy of the gamma rays emitted is also low and do not pose a danger. But even very small quantities of a material contain such huge numbers of atoms that reasonably strong signals are emitted. Gamma rays are readily detected by a variety of detectors and ^{99m}Tc scans are a very common component of many diagnostic or pre-operative investigations.

Another kind of scan, which is useful to detect cancers or infections, is where the tracer material is allowed to be fully excreted from the body, except where the cancerous or infected cells have chemically captured and retained radioactive atoms. Thus, a week after the material has been administered, traces that remain could disclose the presence of cancer or infection.

Technetium-99m production

^{99m}Tc is itself produced from a nuclear reaction, when **^{99}Mo**, or a radioactive form of ***molybdenum***, decays, with a half life of 66 hours. Thus, to deliver the short-lived ^{99m}Tc to a hospital, what is done is that the longer lived ^{99}Mo is delivered, usually by express air package. The ^{99}Mo then keeps decaying into ^{99m}Tc, which can be easily separated from the ^{99}Mo using water. Even a few micrograms of ^{99}Mo, delivered in a piece of resin, can keep producing ^{99m}Tc for a week and this can be used for thousands of patients.



The ^{99}Mo is itself produced in nuclear reactors, when enriched ^{235}U, or a radioactive form of uranium, in a concentrated form, is bombarded with neutrons. The decay of the ^{235}U, gives off two neutrons of its own, which can induce more decays, and so on and this is the principle of the nuclear chain reaction of nuclear power plants and atom bombs. ^{99}Mo is thus extracted from nuclear reactors which use enriched uranium and then needs to be shipped to hospitals around the world within 66 hours of its creation.

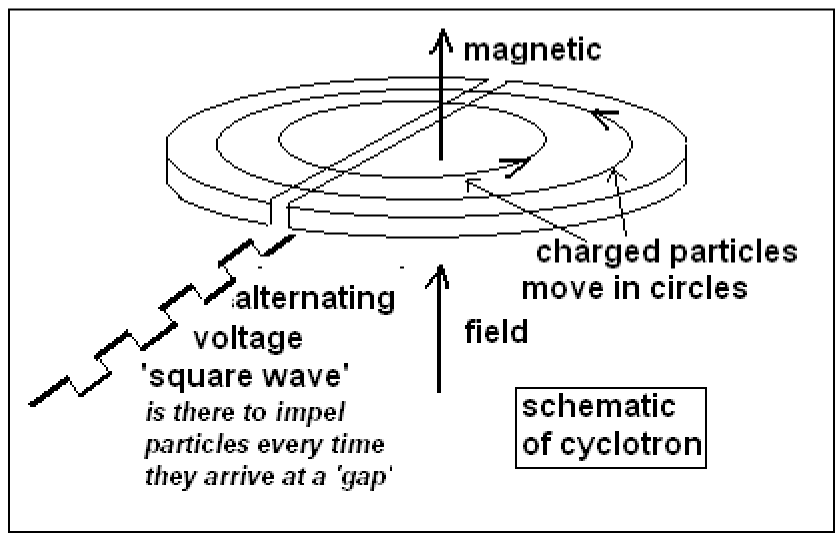
The sources dedicated to such extraction and delivery are naturally scarce and in fact a very small number of nuclear reactors supply all the ^{99}Mo that is used in the world. When the Chalk River reactor in Canada, one of the main suppliers, was closed down for a month in Nov 2007, the supply of ^{99}Mo to North America was hit and thousands of investigations had to be cancelled or surgeries carried out without nuclear scans. Again, in Aug 2008, the other major facility, at Petten, Netherlands, was shut down just when most other sources were off line for different reasons. The incidents have drawn attention to the fragile supply assurance of ^{99}Mo. Any major obstacle could easily precipitate a medical crisis.

Alternate sources

And yet, having more ^{235}U based sources of ^{99}Mo cannot become a solution, because the facility needs to be planned and then controlled in many ways. There is also the inherent risk of ^{235}U systems, that ^{235}U, a raw material for atom bombs, could fall into the wrong hands. A mini reactor attached to hospitals, as some have suggested, is simply ruled out.

An alternate means of producing ^{99}Mo has been suggested in an article in last week's issue of the journal, ***Nature***. The material, ^{99}Mo does not have to be produced from ^{235}U alone. Even the stable, ie, non-radioactive, ^{238}U can become ^{99}Mo when bombarded with high energy photons, or pure light. If high light beams of sufficiently energy could be produced, then ^{238}U could be used and there would be a safe method for hospitals to produce ^{99}Mo and remove their dependence on nuclear reactors.

The writers in ***Nature*** suggest that if electrons, which are very light, negatively elementary particles, could be accelerated to high speeds using particle accelerators, like the cyclotron, then hospitals could have in-house facilities for production of ^{99}Mo.



The cyclotron is a device that uses rapidly alternating voltage and a magnetic field to speed charged particles round in circles and is routinely used for creating high energy particle beams for research into collisions of nuclear particles.

But when charged particles move in circles, they also give of an intense beam of light, whose frequency depends on the how quickly the path of the particle is turning round. As electrons would move very fast, the radiation they emit would be more energetic and could be used to induce fission in ^{238}U.