^{99m}Technetium: A radioactive diagnosis

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Introduction

We are studying the ^{99m}Tc radioisotope. This radioisotope, as well as a variety of its complexes, are used in medical imaging techniques.

- Imaging with ^{99m}Tc is most commonly used in bone, liver, respiratory, renal and thyroid scans. [3]
- ^{99m}Tc complexes have been successfully used to detect serious illnesses including:
  - Heart disease [3], Bone disease [3], Breast Cancer [6]

Chemical Properties of ^{99m}Tc

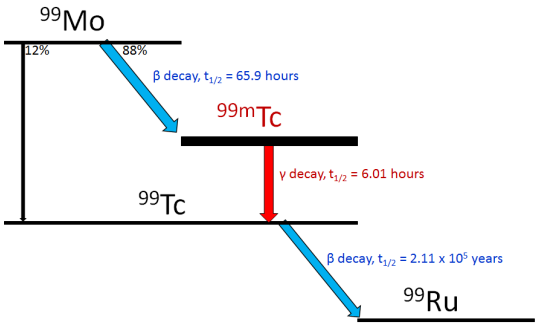


Figure 1. Decay scheme for Tc^{99m} (adapted from Strominger et. al)[1]

- Tc^{99m} is a radioactive product of ^{99}Mo decay.[1,2,3]
- Because it is a decay product the nucleus is in an excited state.[1,2]
- The m in Tc^{99m} indicates that it is a metastable decay product.[1]
- The nucleus relaxes to the ground state by emitting γ radiation.[1,2,3]
- The emitted γ radiation is approximately 140 eV in energy.[1,2]
- The half-life of ^{99m}Tc is 6 hours.[1,2]

Radiation

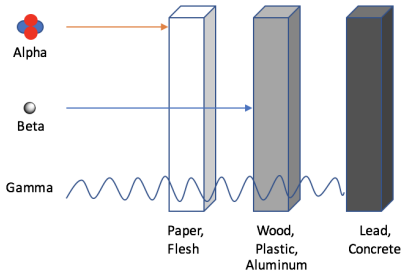


Figure 2. Strength of various forms of radiation.

- Alpha radiation is the least harmful, but it can't penetrate skin or be imaged.
- Beta radiation can penetrate flesh, but it is high energy and potentially very harmful.
- Gamma radiation is the highest energy and can penetrate the most materials.

Advantages of Using ^{99m}Tc as a Medical Imaging Agent

^{99m}Tc is an ideal radioisotope for medical imaging because:

1. Gamma radiation is energetic enough to penetrate the body without being excessively harmful.[2,3]
2. The gamma rays produced by ^{99m}Tc are easily detected by medical imaging machinery.[2,3]
3. A 6 hour half-life provides enough time for medical imaging to be carried out, without too much radiation exposure.[2,3]
4. ^{99m}Tc does not decay via harmful beta radiation.[2,3]
5. ^{99m}Tc is able to form complexes with a variety of organic molecules which allow for localization within the body. [3]

First Uses of ^{99m}Tc for Medical imaging

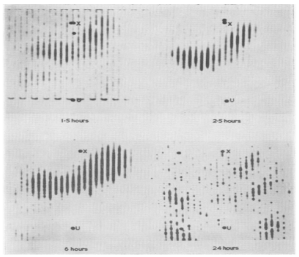
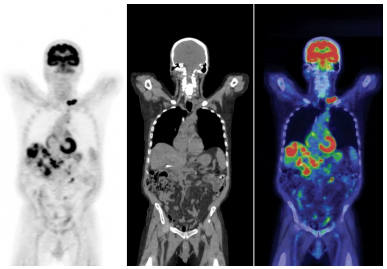


Figure 3. Scans of stomach after intravenous injection of ^{99m}Tc.[2]

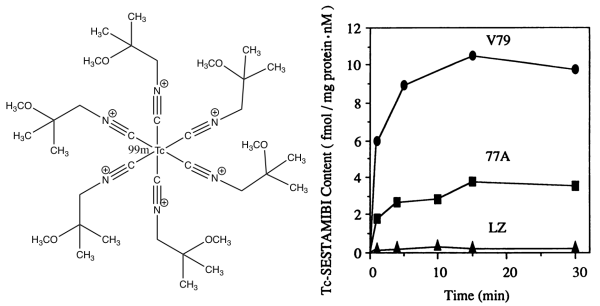
- First shown to be useful for imaging the stomach and thyroid.[2]
- Injected intravenously into human subjects as saline pertechnetate (TcO_4), or ingested orally.[2]
- The thyroid and stomach demonstrated sufficient ^{99m}Tc uptake to allow for medical imaging.[2]
- Metabolism and clearance of ^{99m}Tc in vivo showed the biological half-life of ^{99m}Tc to be approximately 60 hours.[2]

Modern Uses of ^{99m}Tc for Medical Imaging



- Nuclear imaging techniques are often used over x-ray techniques because they allow for imaging of soft tissue in addition to bone. [3]
- Nuclear imaging with injected ^{99m}Tc is sometimes more useful than imaging via PET scans because there is a larger time window for imaging. [3]
- ^{99m}Tc is more commonly used than other radioisotopes such as ^{131}I because lower radiation doses can be delivered. [2]
- ^{99}Mo, used to make ^{99m}Tc is the medical fission isotope in the greatest demand. The ^{99}Mo world market is currently valued at $550 million per year.[3]
- Due to shortages of ^{99}Mo in recent years, lots of funding has been directed at improving ^{99}Mo production capability.[3]

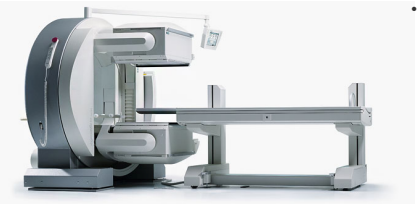
^{99m}Tc Sestamibi Complex



Figures 4 & 5. Molecular structure of ^{99m}Tc sestamibi complex (left). Net accumulation of tracer in Chinese hamster V79 lung fibroblasts, and the Adriamycin selected 77A and LZ cell lines expressing modestly low, intermediate, and high levels of Pgp (right).[5]

- Used for cardiac imaging, parathyroid imaging, and breast imaging.[4,6]
- Methoxyisobutylisonitrile (MIBI) group allows for interaction with proteins and other cellular organelles.
- The molecule is a transport substrate that's recognized by P-glycoproteins (Pgp) in cells.[4,5]
- Radioactivity in tumor cells is enhanced after exposure to multidrug resistant modulators or chemosensitizers, which inhibit Pgp functionality.[6]
- Expulsion of Tc-99m sestamibi by Pgp from the cell helps identify multidrug resistant tumors.[6]

Imaging apparatus



- Similar to a MRI or PET scan, the radioisotope is injected, the patient is positioned on the bed, and the scan of emitting gamma rays is taken. The procedure takes around 20 minutes.[3]

Figure 6. Gamma camera used for medical radioactive imaging.

References

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