Medical Imaging

Ultrasonic Imaging

An elaborate version of bat vision is used to non-intrusively view the insides of a patient. The frequency, direction, and intensity of the ultrasound can be optimized to allow amazingly clear images of a fetus, heart, or other organs. The higher the sound frequency, the shorter will be the wavelength and the more detailed the image.

MRI – Magnetic Resonance Imaging

Microwave energy absorption of nuclei in a magnetic field. Each isotope precesses in a magnetic field in a manner similar to how a tilted spinning top precesses in a gravitational field. The rate of precession depends on the type of nucleus and the energy absorption depends on the local chemistry around the atom. The microwave frequency must match the precession speed and is different for each type of nucleus. Extremely strong superconducting magnets which must be cooled to within a few kelvin of absolute zero are necessary since the quality of the image increases with magnetic field.

This phenomenon is called nuclear magnetic resonance, but the name magnetic resonance imaging is used to prevent people from thinking incorrectly that it has to do with nuclear radioactivity. MRI imaging is harmless as long as the patient does not have metal in their body and is not wearing a pacemaker. The microwave energy is, of course, much less than is used in a microwave oven.

X-Ray Imaging

Normal medical x-rays have have a small chance of disrupting DNA in tissues so a minimal dosage is used. Generally, the benefits of x-rays, such as for mammography and dental examinations, outweigh the dangers. When I was about 8 years old, I remember using an x-ray machine in my father's shoe store that let you see your bones inside of a shoe. That turned out to be an unnecessary use of x-rays and was soon stopped.

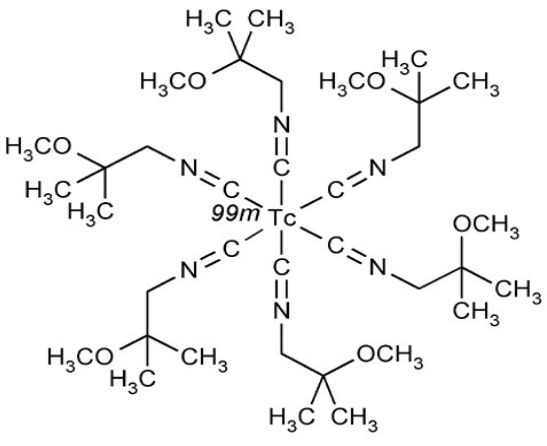
CAT – Computerized Axial Tomography

CAT scans are actually multiple x-ray images taken from many angles to determine a 3-dimensional x-ray image. The term CAT scan makes it sound safer than it is. Still, it is very useful for certain diagnostic purposes where the benefits of the imaging outweigh the risks.

CAT scans were used to diagnose my recent breathing difficulties and later an intestinal pain. Once those images were available, it was immediately clear to the doctors what must be done - dissolve the blood clot in my lungs (too much sitting at my computer during the summer, followed by vigorous wood gathering for winter) and remove an infected gall bladder.

Scintimammography (Miraluma test or $^{99m}_{43}Tc_{56}$ (Tc-99m) sestamibi breast imaging)

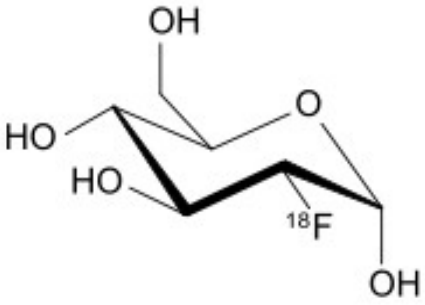
A sestamibi molecule with the radioactive isotope Technetium-99m at its center (see diagram at right) is injected and spreads through the lymph system. After it has spread, a photograph-like image can be taken using a scintillation camera sensitive to its emitted gamma rays. This can be use to locate sentinel lymph notes near a breast cancer nodule.

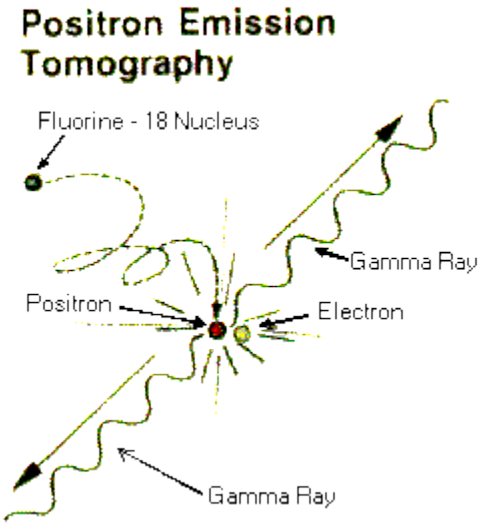


Different carrier molecules are used for imaging other organs.

PET – Positron Emission Tomography

A radioactive substance attached to a glucose-like molecule is injected into the patient. The molecule flows to where glucose is used and its radioactive nucleus, typically $^{18}_{9}F_{9}$, decays emitting a positron (the anti-particles of electrons) which very quickly meets an electron and annihilates producing two gamma rays in precisely opposite directions. The gamma rays escape from the patient and are detected by an array of encompassing detectors to produce an image of where glucose is being used.





On the left is glucose tagged with $^{18}_{9}F_{9}$ in place of an OH group. On the right is shown the positron emission process. Because the gamma rays are emitted in opposite directions to conserve momentum, the source of the emission is located along a specific line. Precise timing can tell where it was along the line to within about 10 cm, but multiple detectors observing multiple emission events can gain a 3-D picture of where the glucose is concentrated.

Again, different carrier molecules are used for each type of pathology being studied.

Endoscope

A combination of light, microscope and surgical tools that fit in a slender flexible tube that can perform surgeries through a relatively small incision. The key technology that makes this possible is the fiber-optic light pipe, a bundle of tiny glass tubes that allow light to travel a curved path with nearly 100% efficiency.

The removal of my gall bladder was done through 4 small incisions using endoscopic surgery.