Medical Imaging Techniques

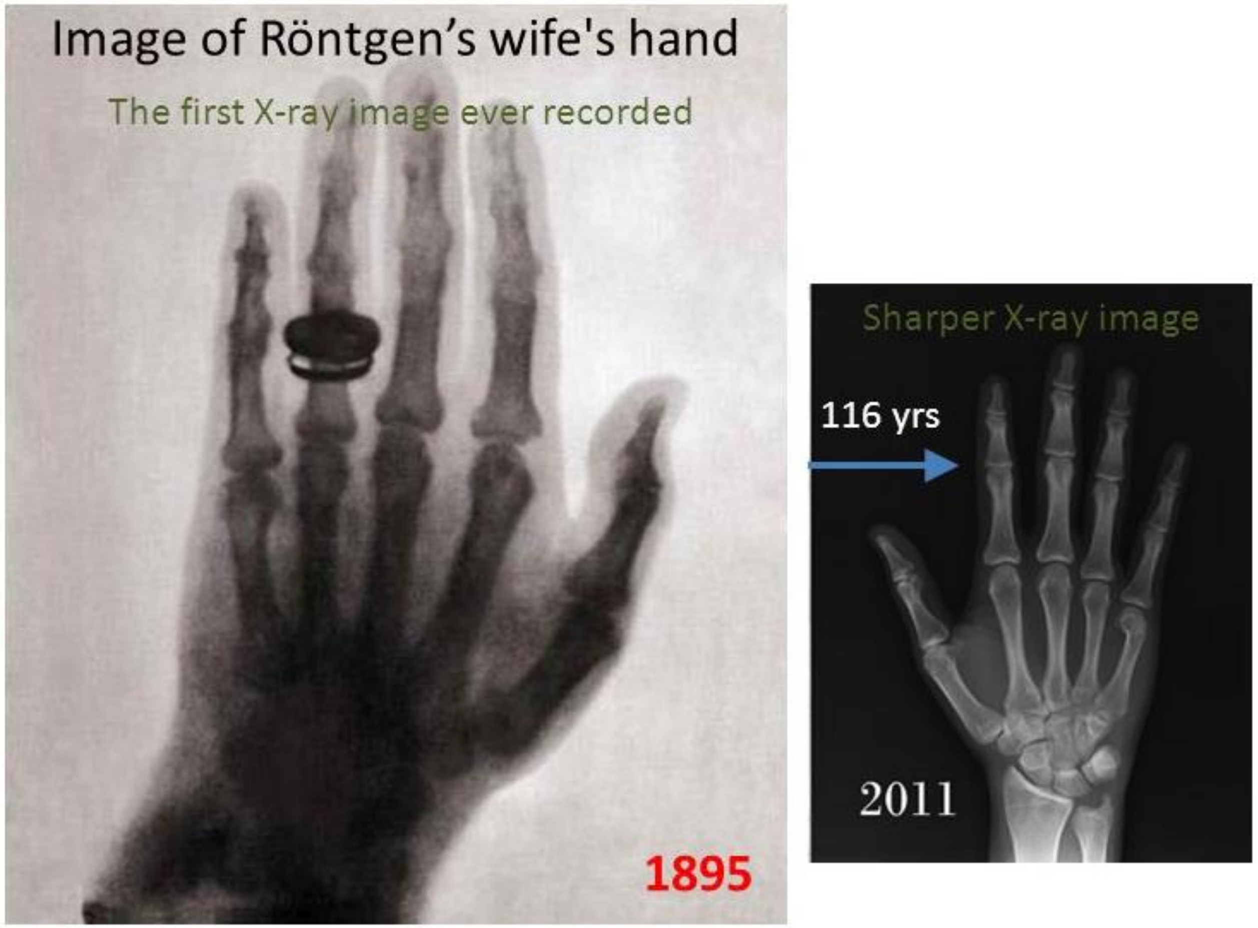
Jani Saunavaara

Medical physicist, PhD

VARSINAIS-SUOMEN
SAIRAANHOITOPIIRI

History of Medical Imaging

Medical imaging began in November 1895 with Wilhelm Conrad Röntgen’s discovery of X-ray.



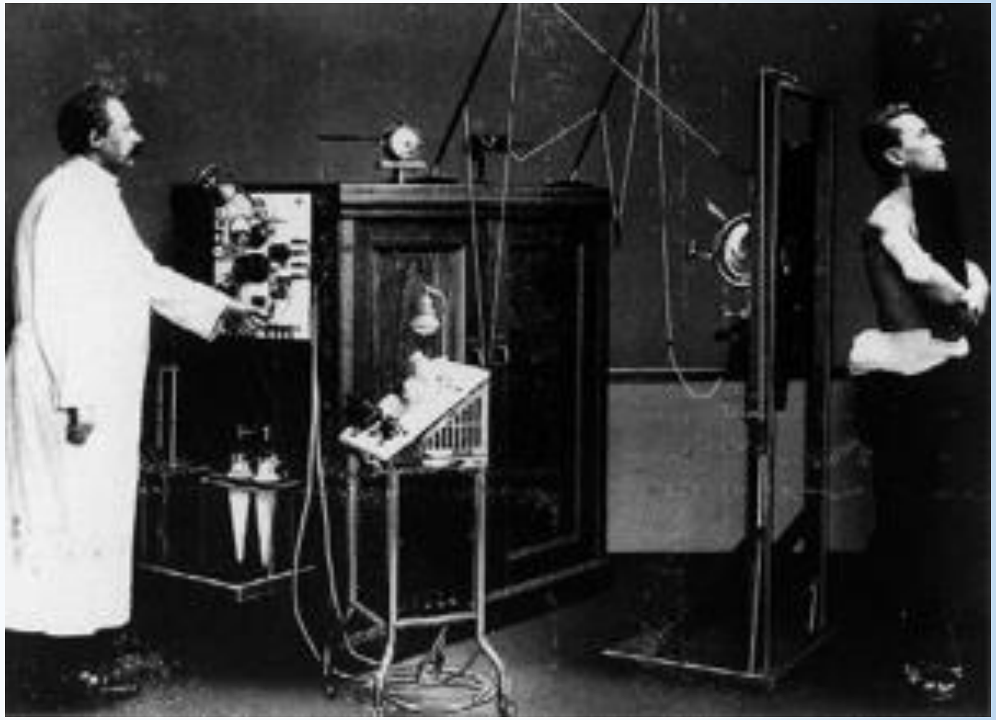
The first x-ray of the human body, taken by Conrad Röntgen on November 8, 1895. He called the new form of radiation he had discovered x-rays, with the X standing for unknown.

Radiography

For the first fifty years of radiology, the primary examination involved creating an image by focusing x-rays through the body part of interest and directly onto a single piece of film inside a special cassette.

In the earliest days, a head x-ray could require up to 11 minutes of exposure time. Now, modern x-rays images are made in milliseconds and the x-ray dose currently used is as little as 2% of what was used for that 11 minute head exam 100 years ago.

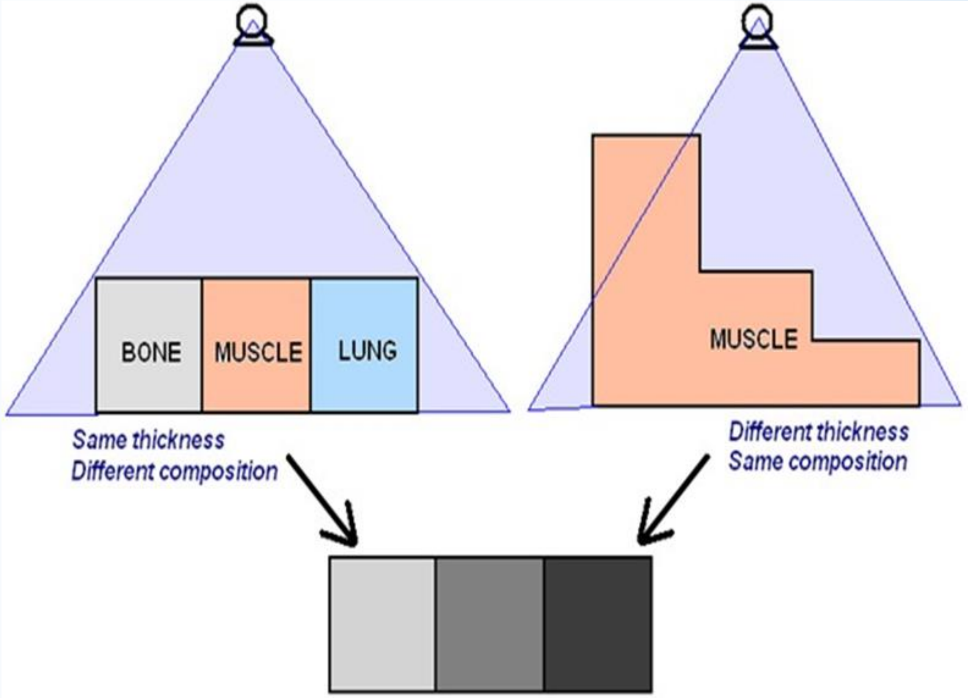
Further, modern x-ray techniques have significantly more spatial resolution and contrast detail. This improved image quality allows the diagnosis of smaller pathology that could not be detected with older technology.



An x-ray system from the pioneering days. Patients still had to hold the cassettes themselves

Modern X-ray based imaging modalities
Radiography

Physical principle is still the same:
A radiographic image is composed of a 'map' of X-rays that have either passed freely through the body or have been variably attenuated (absorbed or scattered) by anatomical structures.



Modern X-ray based imaging modalities

Mammography, Dental x-ray,…

Different modalities, but same physical principles.

Fluorescent screens

The next development (around 1920s) involved the use fluorescent screens and special glasses so the doctor could see x-ray images in real time. This caused the doctor to stare directly into the x-ray beam, creating unwanted exposure to radiation.

In 1946, George Schoenander developed the film cassette changer which allowed a series of cassettes to be exposed at a movie frame rate of 1.5 cassettes per second. By 1953, this technique had been improved to allow frame rates up to 6 frames per second by using a special "cut film changer."

A major development along the way was the application of pharmaceutical contrast medium to help visualize organs and blood vessels with more clarity and image contrast. These contrast media agents (liquids also referred to as "dye") were first administered orally or via vascular injection between 1906 and 1912 and allowed doctors to see the blood vessels, digestive and gastro-intestinal systems, bile ducts and gall bladder for the first time.

In 1955, the x-ray image intensifier (also called I.I.) was developed and allowed the pick up and display of the x-ray movie using a TV (television) camera and monitor. By the 1960's, the fluorescent system (which had become quite complex with mirror optic systems to minimize patient and radiologist dose) was largely replaced by the image intensifier/TV combination. Together with the cut-film changer, the image Intensifier opened the way for a new radiologic sub-specialty know as angiography to blossom and allowed the routine imaging of blood vessels and the heart.

Modern X-ray based imaging modalities

Angiography / Fluoroscopy

Digital Imaging Techniques

Digital imaging techniques were implemented in the 1970's with the first clinical use and acceptance of the Computed Tomography or CT scanner, invented by Godfrey Hounsfield. Analog to digital converters and computers were also adapted to conventional fluoroscopic image intensifier/TV systems in the 70's as well.

Angiographic procedures for looking at the blood vessels in the brain, kidneys, arms and legs, and the blood vessels of the heart all have benefited tremendously from the adaptation of digital technology.

Over the next ten to fifteen years a large majority of conventional x-ray systems will also be upgraded to all digital technology. Nowadays, all of the film cassette/film screen systems are being replaced by digital x-ray detectors.

Benefits of Digital Technology to all X-Ray systems

- less x-ray dose can often be used to achieve the same high quality picture as with film

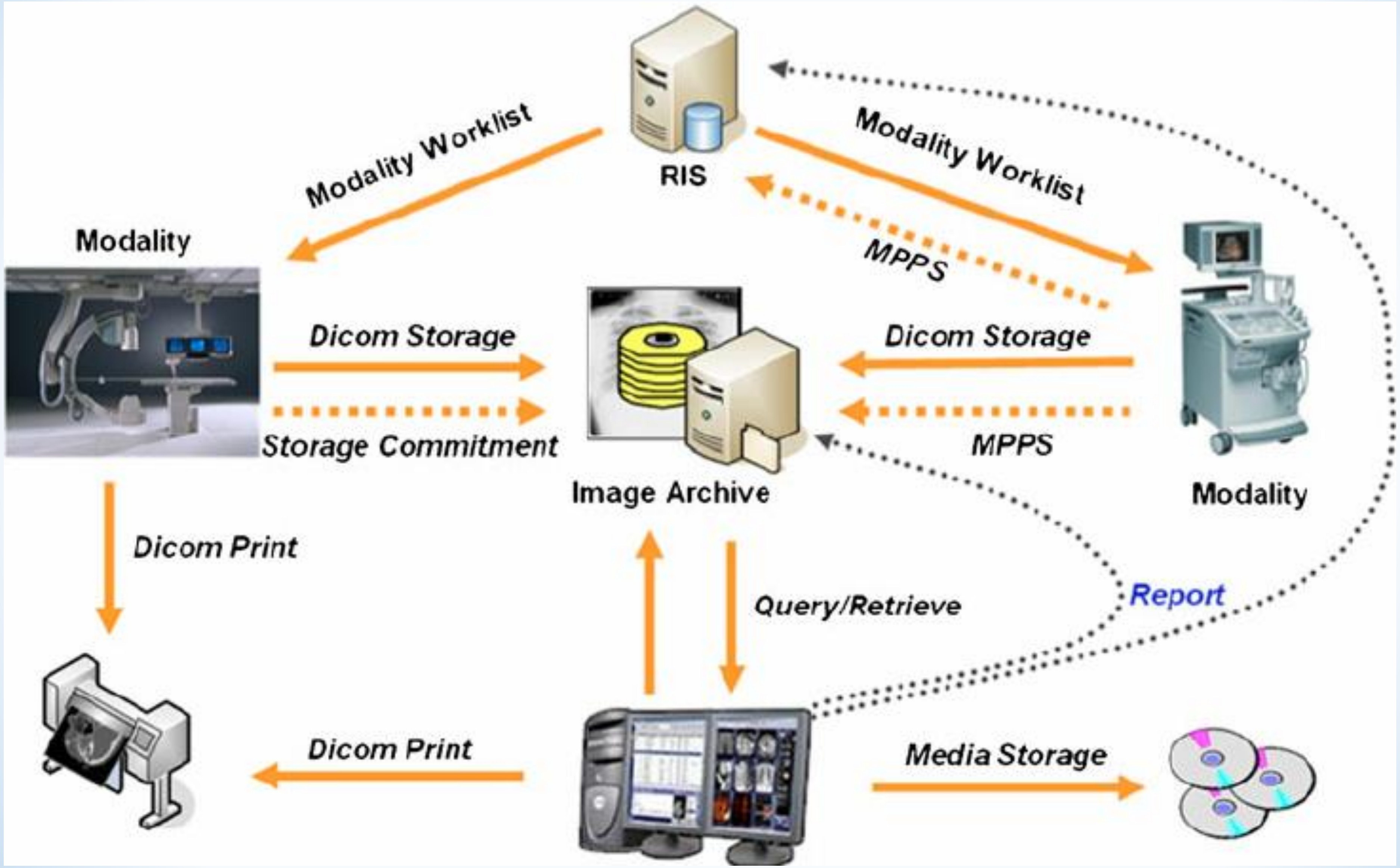
- digital x-ray images can be enhanced and manipulated with computers

- digital images can be sent via network to other workstations and computer monitors so that many people can share the information and assist in the diagnosis

- digital images can be archived onto compact optical disk or digital tape drives saving tremendously on storage space and manpower needed for a traditional x-ray film library

- digital images can be retrieved from an archive at any point in the future for reference.

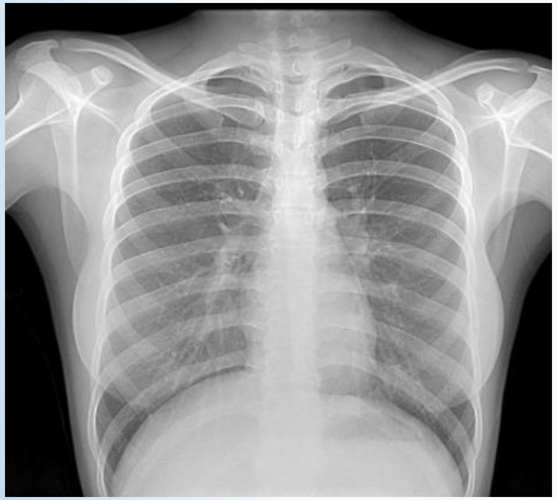
Medical Image archiving and data handling

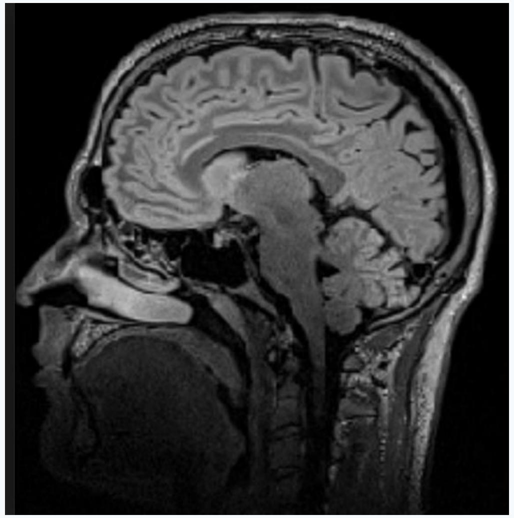
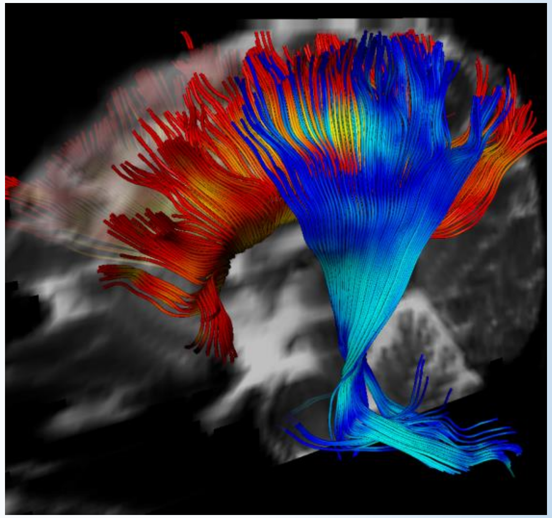


Dicom Images

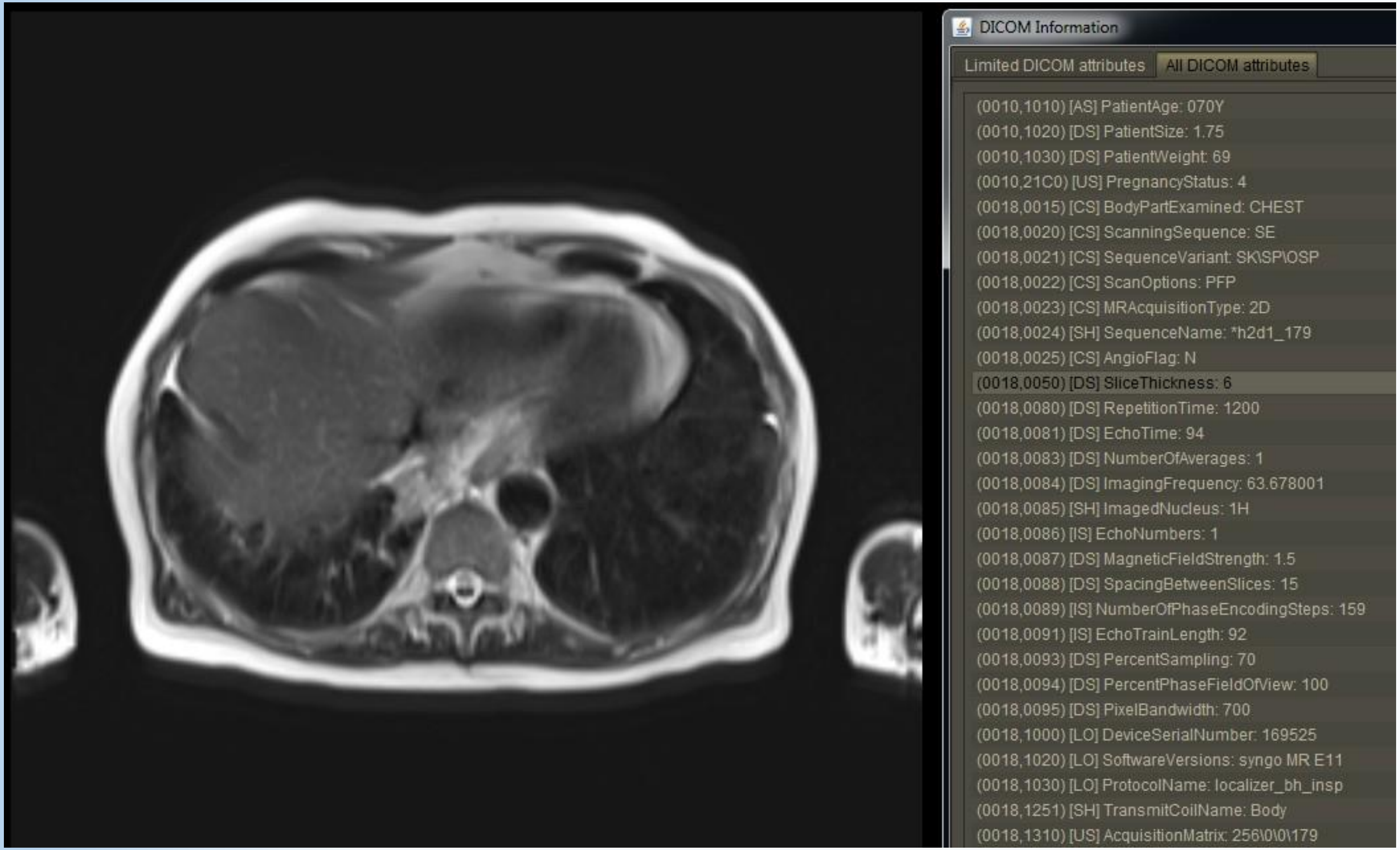
DICOM® — Digital Imaging and Communications in Medicine — is the international standard for medical images and related information. It defines the formats for medical images that can be exchanged with the data and quality necessary for clinical use.

DICOM® is implemented in almost every radiology, cardiology imaging, and radiotherapy device (X-ray, CT, MRI, ultrasound, etc.), and increasingly in devices in other medical domains such as ophthalmology and dentistry.



Dicom Images (+ Dicom header)



Dicom Header contains a lot of valuable information from the patient and from the study itself.

For example, all the different parameters of MRI acquisition are usually found from Dicom Header, so based on one image, it possible to repeat the sequence, if you have similar scanner.

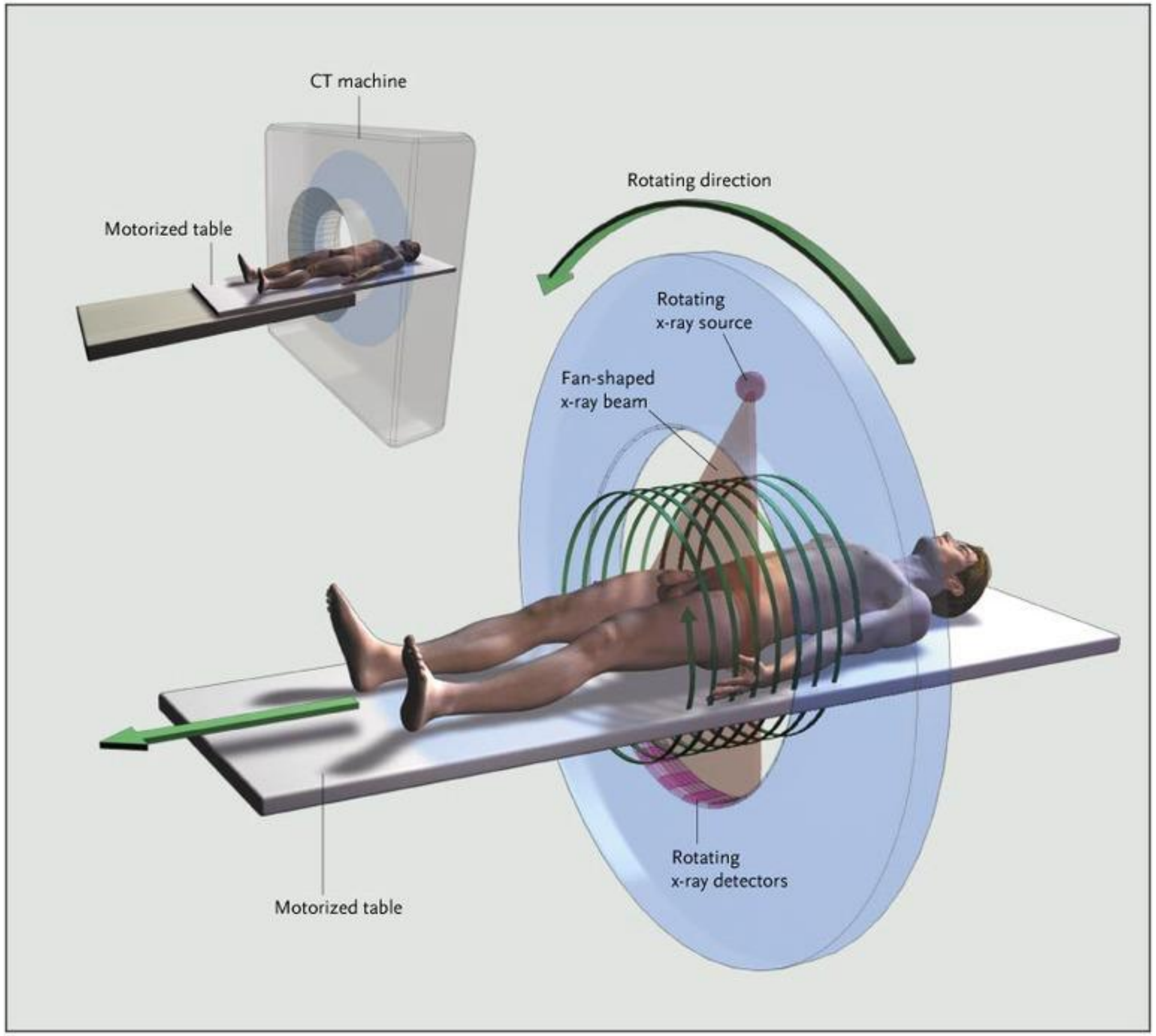
Computed Tomography

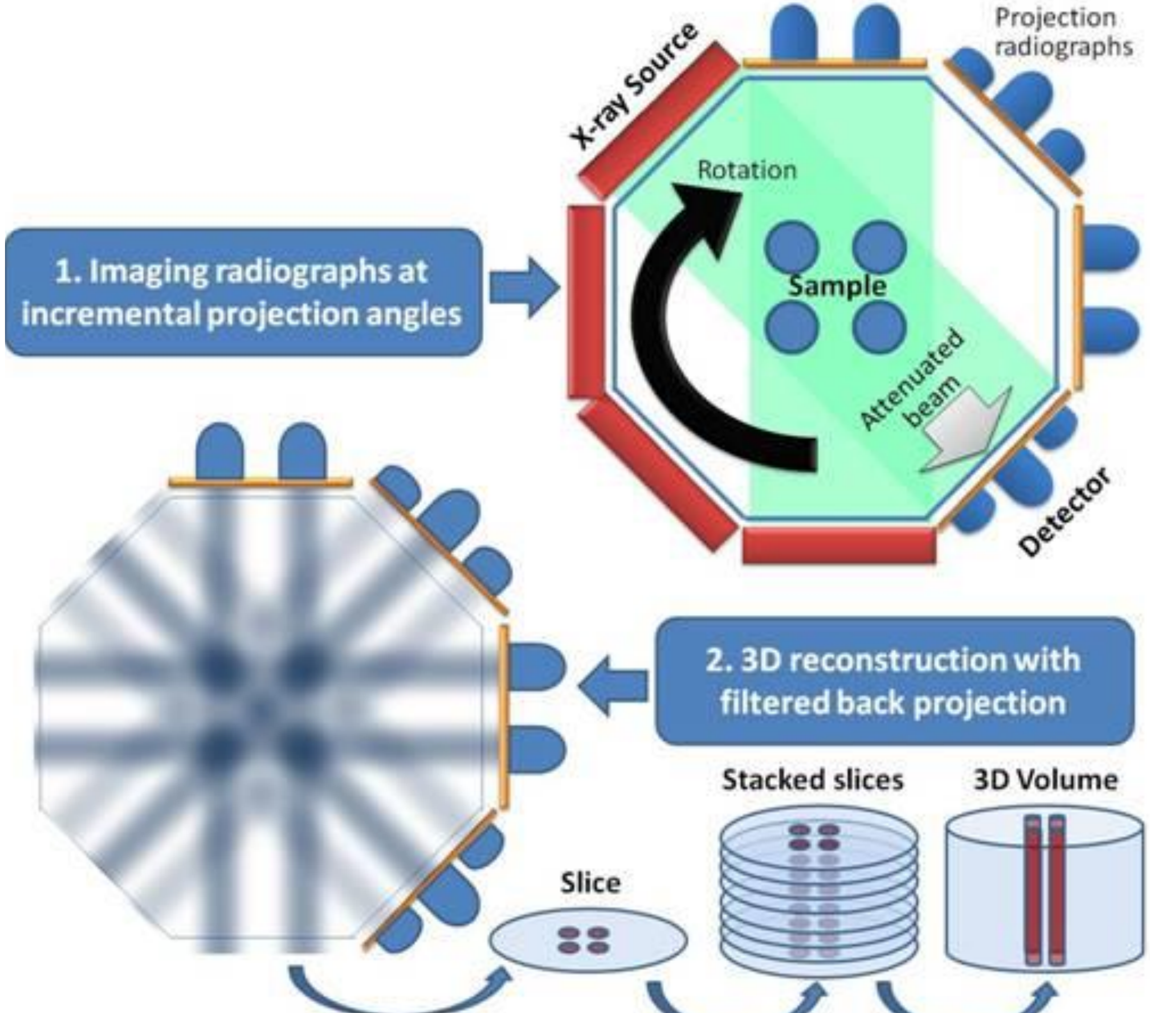
CT imaging (also called CAT scanning for Computed Axial Tomography) was invented in 1972 by Godfrey Hounsfield in England. Hounsfield used gamma rays (and later x-rays) and a detector mounted on a special rotating frame together with a digital computer to create detailed cross sectional images of objects.

Hounsfield's original CT scan took hours to acquire a single slice of image data and more than 24 hours to reconstruct this data into a single image. Today's state-of-the-art CT systems can acquire a single image in less than a second and reconstruct the image instantly.

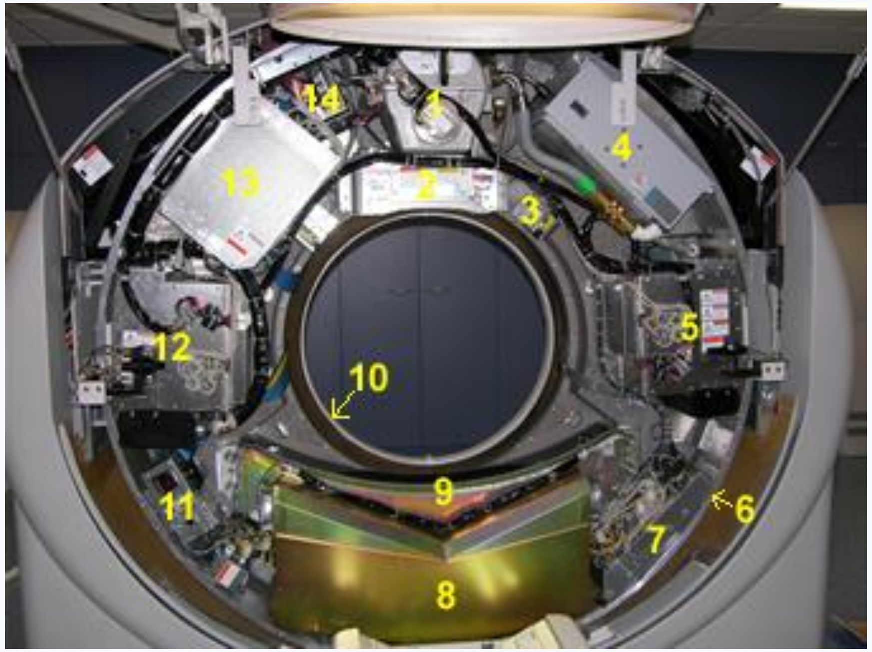
The invention of CT was made possible by the digital computer. The basic algorithms involved in CT image reconstruction are based on theories proposed by the scientist Radon in the late 1700's.

Computed Tomography





Computed Tomography

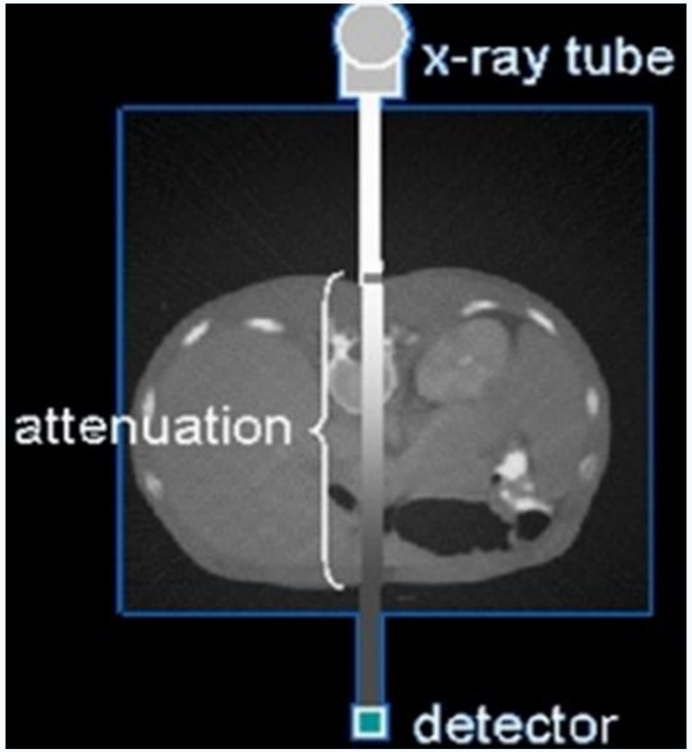


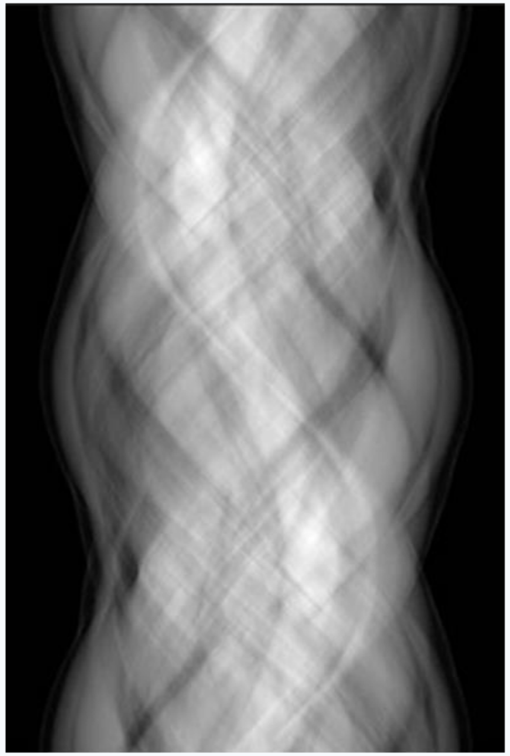
1. X-ray tube
2. Filterts, collimator
3. Internal projector
4. X-ray tube oil cooler
5. Generator
6. Direct drive gantry motor
7. Rotation control unit
8. Data acquisition
9. Detectors
10. Slip rings
11. Detector temperature controller
12. Generator (75-150kV)
13. Power unit (AC to DC)
14. Line noise filter

Computed Tomography

Measures attenuation of radiation from several different angles

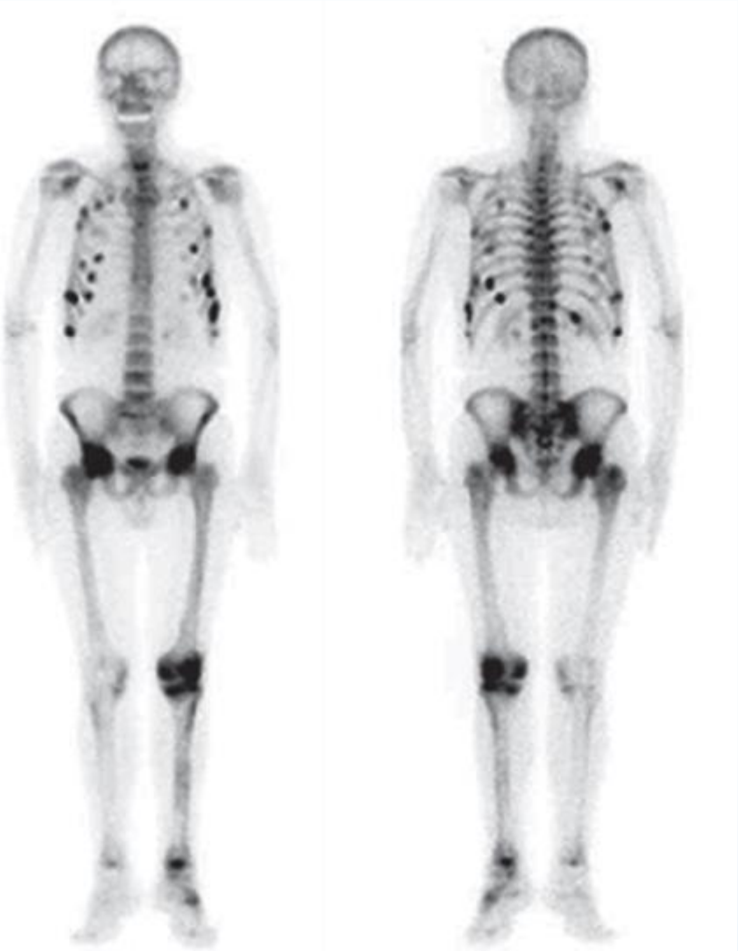
Raw data = sinogram





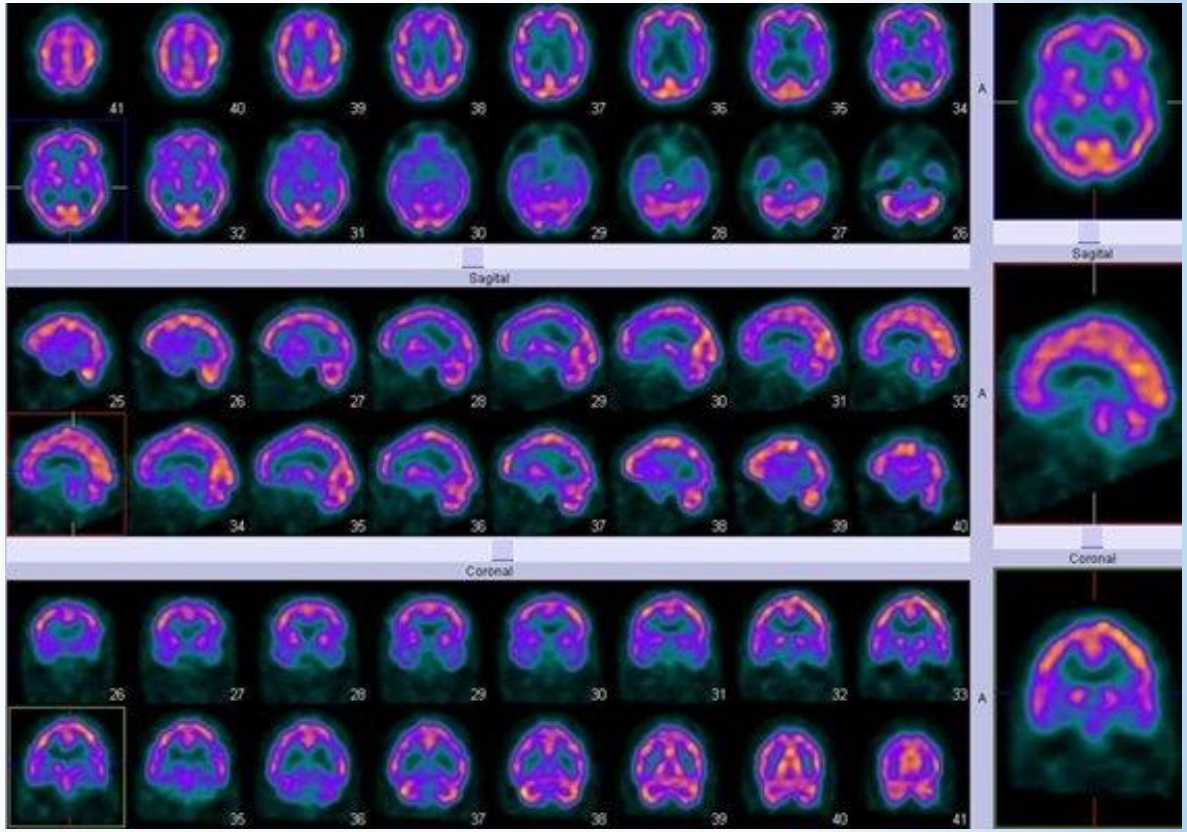
Nuclear Medicine

Nuclear Medicine studies (also called radionuclide scanning) were first done in the 1950s using special gamma cameras. Nuclear medicine studies require the introduction of very low-level radioactive chemicals into the body. These radionuclides are taken up by the organs in the body and then emit faint radiation signals which are measured or detected by the gamma camera.



Nuclear Medicine

SPECT uses a geometry similar to a CT scanner to form an image of the concentration of a radiopharmaceutical compound.



Ultrasound scanning

In the 1960's the principals of sonar (developed extensively during the second world war) were applied to diagnostic imaging.

The process involves placing a small device called a transducer, against the skin of the patient near the region of interest, for example, the kidneys. This transducer produces a stream of inaudible, high frequency sound waves which penetrate into the body and bounce off the organs inside.

The transducer detects sound waves as they bounce off or echo back from the internal structures and contours of the organs. These waves are received by the ultrasound machine and turned into live pictures with the use of computers and reconstruction software.

To be continued…

Next ”episode”:

Magnetic Resonance Imaging