KREP

2025

KARNATAKA RADIOLOGY EDUCATION PROGRAM

CT SCAN

A CT scan is a diagnostic imaging exam that uses X-ray technology to produce images of the inside of the body.
A CT scan can show detailed images of any part of the body, including the bones, muscles, organs and blood vessels.
CT scans can also be used for fluid or tissue biopsies, or as part of preparation for surgery or treatment.
CT scans are frequently done with and without contrast agent to improve the radiologist's ability to find any abnormalities.

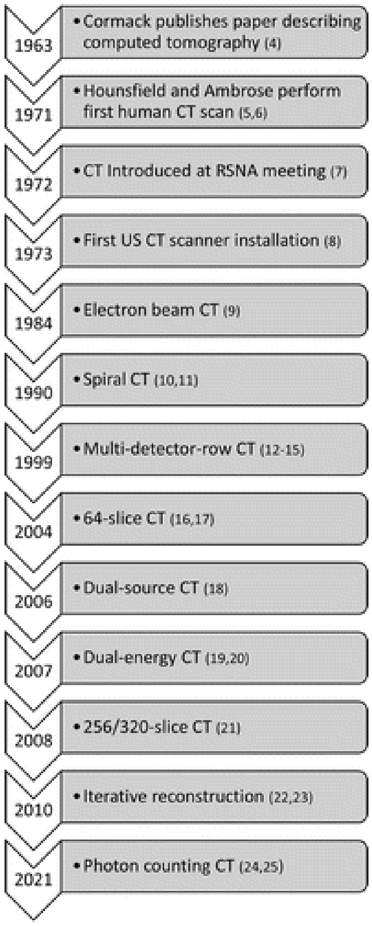


Diagram shows major milestones in the history of CT. Numbers in parentheses are reference numbers.

Essentials

■ Multiple CT scanner geometries, or generations, have existed since the introduction of CT in 1971.

■ Each new generation of technology increases the speed and spatial resolution of CT, enables new clinical applications, and decreases the required doses of radiation and iodinated contrast media.

■ Shorter gantry rotation times, multidetector row, multisector reconstructions, and dual-source CT technologies have increased the quality and robustness of cardiac CT.

■ Radiation doses in CT are reduced using tube current modulation, lower tube potential, beam-shaping filters, beam collimation, and iterative reconstruction algorithms.

■ Photon-counting CT uses semiconductor detectors for ultrahigh-spatial-resolution imaging and multienergy binning from a single acquisition.

Pages from History.....

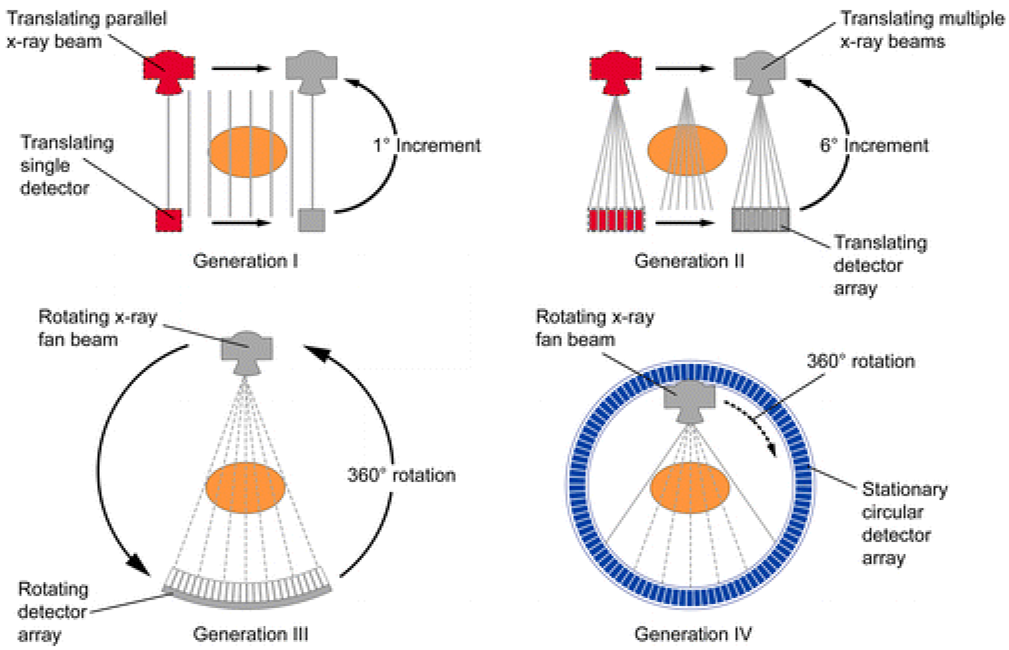
Designed by ***Godfrey N. Hounsfield*** to overcome the visual representation challenges in radiography and conventional tomography by collimating the X-ray beam and transmitting it only through small cross-sections of the body.

In 1979, **G.N. Hounsfield** shared the Nobel Prize in Physiology & Medicine with **Allan MacLeod Cormack**, Physics Professor who developed solutions to mathematical problems involved in CT.

Godfrey N. Hounsfield

Allan MacLeod Cormack

1917	Austrian mathematician Johann Radon proved that a 2D/3D object could be reproduced from an infinite set of all its projections
1956	Bracewell, working in radioastronomy, constructed a solar map from ray projections.
1961 and 1963	Oldendorf and Cormack understood the concept of computed tomography and built laboratory models.
1968	Kuhl and Edwards built a successful mechanical scanner for nuclear imaging, but did not extend their work into diagnostic radiology
1969	G.N. Hounsfield developed first clinically useful CT head scanner
1971	First clinically useful CT head scanner was installed at Atkinson-Morley Hospital (England)
1972	First paper on CT presented to British Institute of Radiology by Hounsfield and Dr. Ambrose



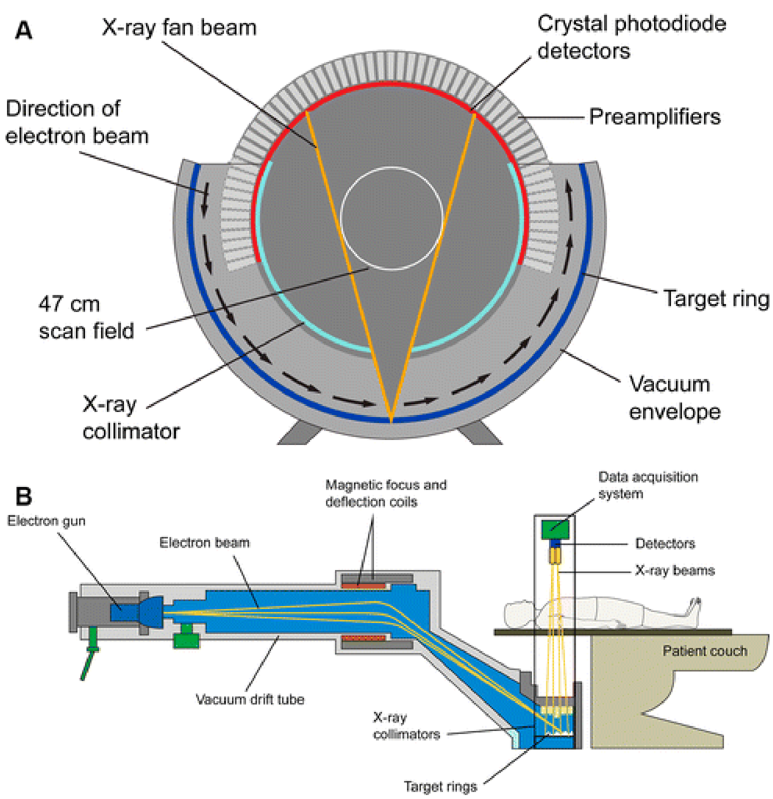


Diagram of fifth-generation geometry, also known as electron-beam CT, which uses a stationary/stationary geometry. (B) Side view of the system shows the electron accelerator behind the scanner.

First generation

detectors: one
type of beam: pencil-like x-ray beam tube-detector
movements: translate-rotate. duration of scan (average): 25-30 mins

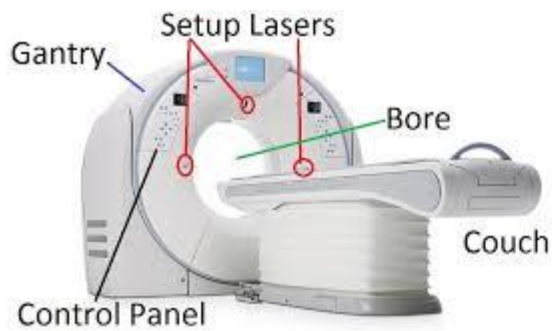
Second generation
detectors: multiple (up to 30), type of beam: fan-shaped x-ray beam, tube-detector
movements: translate-rotate,Duration of scan (average): less than 90 sec

Third generation
detectors: multiple, initially 288; newer ones use over 700 arranged in an arc type of beam:
fan-shaped x-ray beam tube-detector
movements: rotate-rotate duration of scan (average): approximately 5 sec

Fourth generation
detectors: multiple (more than 2000) arranged in an outer ring which is fixed
type of beam: fan-shaped x-ray beam
tube-detector movements: rotate-fixed , duration of scan (average): a few seconds

Other technologies
Other CT technologies have been adapted to third and fourth-generation scanners, including:
helical ("spiral") image acquisition used in all modern CT machines
slip-ring technology made the helical acquisition possible
dual-energy CT scanning
electron beam CT considered a fifth-generation technology, electron beam CT has been around since 1984 involved an electron beam that is deflected via a magnet around the gantry (no moving parts, great temporal resolution)
initially designed for cardiac imaging, electron beam CT was made obsolete once multi-detector CT demonstrated better spatial resolution along (with the final blow being ECG-gated scanning)

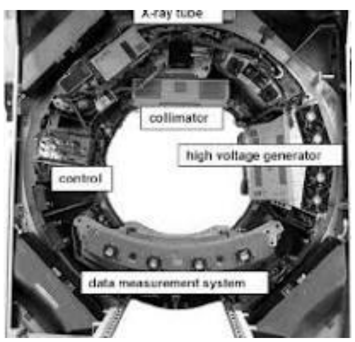
COMPONENTS OF CT SCAN
CONSOLE
IMAGE PROCESSING
GANTRY
PATIENT COUCH

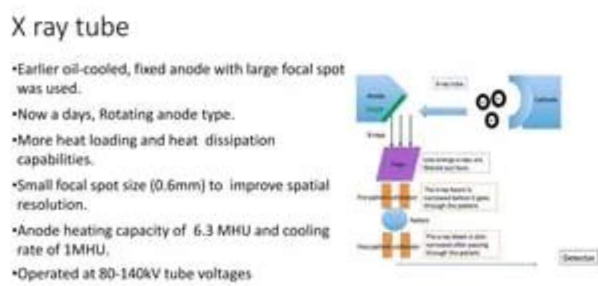


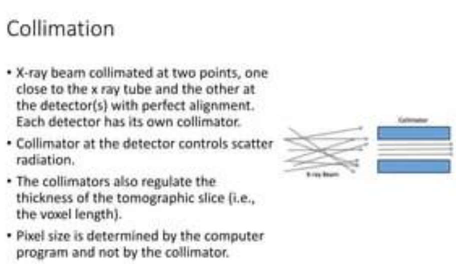
CONSOLE **COUCH**

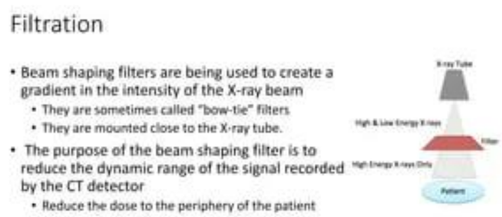
GANTRY

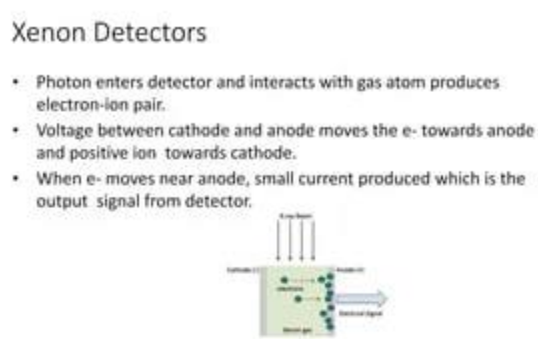
CT gantry has the following gadgets: (i) X-ray tube, (ii) collimation and filtration (iii) detector (iv) high voltage generator.

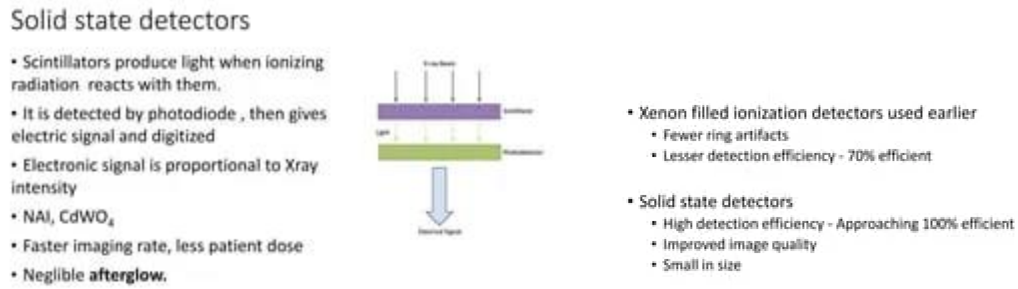












The detectors of the CT scanner do not produce an image. They measure the transmission of a thin beam (1-10 mm) of x-rays through a full CT of the body. The image of that section is taken from different angles, and this allows to retrieve the information on the depth (in the third dimension).

If the x-ray at the exit of the tube is made monochromatic or quasimonochromatic with the proper filter, one can calculate the attenuation coefficient corresponding to the volume of irradiated tissue by the application of the general formula of absorption of the x-rays in the field (see Figure 1).

The outgoing intensity I(x) of the beam of photons measured will depend on the location. I(x) is smaller where the body is more radiopaque.

The CT image is a digital image and consists of a square matrix of elements (pixel), each of which represents a voxel (volume element) of the tissue of the patient.

The typical CT image is composed of 512 rows, each of 512 pixels, i.e., a square matrix of 512 x 512 = 262,144 pixels (one for each voxel). In the processing of the image, the value of the attenuation coefficient for each voxel corresponding to these pixels needs to be calculated.

HOUNSFIELD UNIT

Hounsfield units (HU) are a dimensionless unit universally used in computed tomography (CT) scanning to express CT numbers in a standardized and convenient form. Hounsfield units are obtained from a linear transformation of the measured attenuation coefficients 1. This transformation (figure 1) is based on the arbitrarily-assigned radiodensities of air and pure water:
radiodensity of distilled water at standard temperature and pressure (STP) equals 0 HU
radiodensity of air at STP equals –1000 HU

Hounsfield unit formula

$$HU = \left(\frac{\mu_{\text{material}} - \mu_{\text{water}}}{\mu_{\text{water}}}\right) \times 1000$$

μ = CT linear attenuation coefficient

Typical values

Although values will vary somewhat between healthy individuals and between manufacturers, different tissues have predicable normal values on non-contrast CT 10-12.

air: -1000 HU
bone (cortical): >1000 HU
bone (trabecular): 300 to 800 HU
brain (grey matter): 40 HU 11
brain (white matter): 30 HU 11
subcutaneous fat: -100 to -115 HU 10
liver: 45-50 HU 10
lungs: -950 to -650 HU 12
metal: >3000 HU
muscle: 45 to 50 HU 10
renal cortex: 25 to 30 HU 10
spleen: 40 to 45 HU 10
water: 0 HU (by definition)

WINDOWS

Windowing, also known as grey-level mapping, contrast stretching, histogram modification or contrast enhancement is the process in which the CT image greyscale component of an image is manipulated via the CT numbers; doing this will change the appearance of the picture to highlight particular structures. The brightness of the image is adjusted via the window level. The contrast is adjusted via the window width.

Window width

As the name suggests, the window width (WW) measures the range of CT numbers in an image.
Therefore, a wider window width (2000 HU) will display a wider range of CT numbers.
Consequently, the transition of dark to light structures will occur over a larger transition area to that of a narrow window width (<1000 HU).
Accordingly, it is important to note, that a significantly wide window displaying all the CT numbers will result in different attenuations between soft tissues to become obscured 1.

Wide window

Defined as 400-2000 HU best used in areas of acute differing attenuation values, a good example is lungs or cortical tissue, where air and vessels will sit side by side.

Narrow window
Defined as 50-350 HU are excellent when examining areas of similar attenuation, for example, soft tissue. It is widely used in differentiating subtle soft tissue attenuation differences i.e stroke imaging 5.

Window level/center
The window level (WL), often also referred to as the window center, is the midpoint of the range of the CT numbers displayed.
When the window level is decreased the CT image will be brighter and vice versa.

Typical window width and level values
Although this varies somewhat from institution to institution and vendor to vendor, window width and centers are generally fairly similar. The values below are written as width and level (W:x L:y) in Hounsfield units (HU).
head and neck brain W:80 L:40

subdural W:130-300 L:50-100
stroke W:8 L:32 or W:40 L:40 3
temporal bones W:2800 L:600 or W:4000 L:700
soft tissues: W:350–400 L:20–60 4
chest lungs W:1500 L:-600
mediastinum W:350 L:50
vascular/heart W: 600 L: 200 or e.g. W: 1000 L: 400
abdomen soft tissues W:400 L:50
liver W:150 L:30
spine soft tissues W:250 L:50,
bone W:1800 L:400

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REF : Christensen's Physics of Diagnostic Radiology,Radiopedia.