Generations of CT Scanners

Introduction

CT scanners were first introduced ***in 1971 with a single detector for brain study*** under the leadership of ***Godfrey Hounsfield***, an electrical engineer at EMI (Electric and Musical Industries Ltd).

Thereafter, it has undergone several changes with an ***increase in the number of detectors and decrease in the scan time.*** The changes were majorly on the ***X-ray tube and detector arrangements***.

A major adjustment in the technology of CT scanners was manifested in:

- Tube orientation and shape of beam (pencil beam through narrow beam to fan beam)
- Number of detectors (from single detectors to multiple detectors)
- Detector arrangement

First Generation: (Parallel-Beam Geometry)

First-generation CT systems are characterized by a ***single X-ray source*** (***pencil beam or parallel-beam geometry***). ***Multiple measurements*** of X-ray transmission are obtained using a single highly ***single collimated X-ray pencil beam and detector directing across the patient isocenter***. Both, the source and the detector, ***translate simultaneously in a scan plane***, where the beam is translated in a ***linear motion across the patient*** to obtain a ***projection profile***.

This process (***translate – rotate scanning motion***) is repeated for a given number of ***angular rotations***, by approximately ***1 degree***, and another projection profile is obtained, until the source and detector have been ***rotated by 180 degrees***.

The ***advantages*** of this design are ***simplicity, good view-to-view detector matching, flexibility in the choice of scan parameters*** (such as resolution and contrast), and the highly collimated beam provides ***excellent rejection of radiation scattered in the patient.***

The disadvantages (limitations) of first generation CT scanners:

1) Only head scans could be performed.
2) Generates a lot of heat, therefore, require an elaborate cooling system.
3) Scan time was very slow. About 1 minute per slice therefore the duration of scan (average): 25-30 mins.

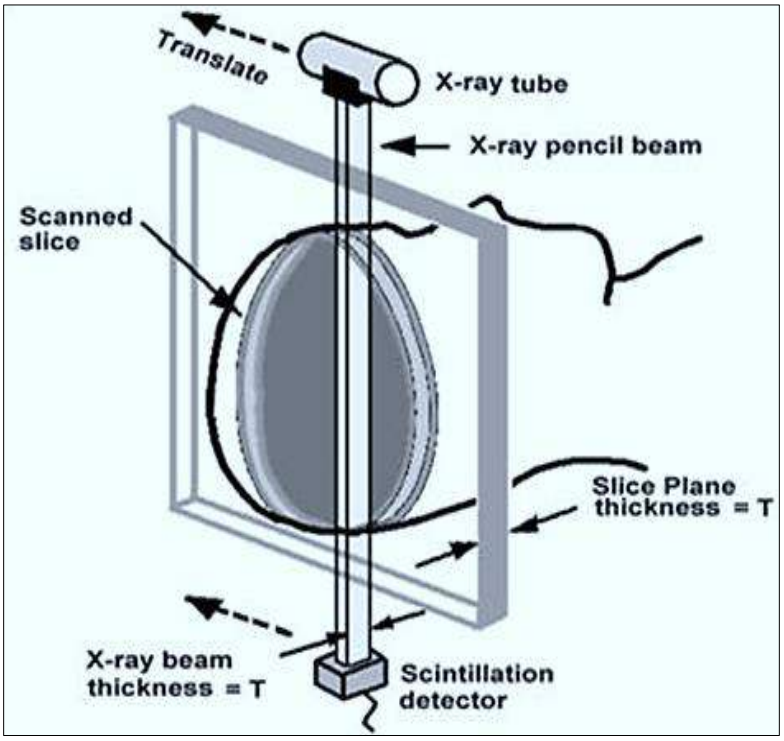


Figure (1): First Generation: Parallel-Beam Geometry

<u>Second Generation: (Fan Beam, Multiple Detectors)</u>

Second-generation CT systems use the same ***translate/rotate scan geometry*** as the first generation. The difference here is that a ***pencil beam is replaced by a fan beam*** and a ***single detector by multiple detectors (5-30)*** so that, a ***series of views*** can be acquired during each translation, which leads to correspondingly ***shorter scanning times***, about ***20 seconds per slice*** therefore duration of scan (average): ***less than 90 sec***. So, objects of ***wide range sizes can be easily scanned with the second-generation scanners***. The ***reconstruction algorithms are slightly more complicated*** than those for first-generation algorithms because they must ***handle fan-beam projection data.***

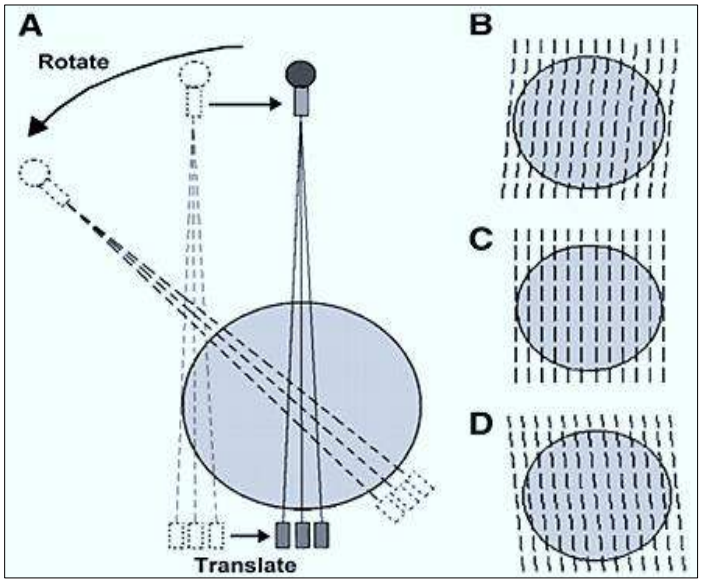


Figure (2): Second Generation: Fan Beam, Multiple Detectors

Third Generation: (Fan Beam, Rotating Detectors)

A ***fan beam*** of X-rays is rotated ***360 degrees*** around the isocenter. ***No translation motion*** is used; however, the ***fan beam must be wide enough to completely contain the patient***. A ***curved detector array*** consisting of ***several hundred independent detectors (500-1000)*** is mechanically coupled to the X-ray source, and both rotate together. As a result, these ***rotate-only motions*** acquire projection data for a single image in ***as little as 1 s***. Typically, third generation systems are ***faster than second-generation systems***. The detectors here have incorporated ***bigger amount of sensors in the detector array.***

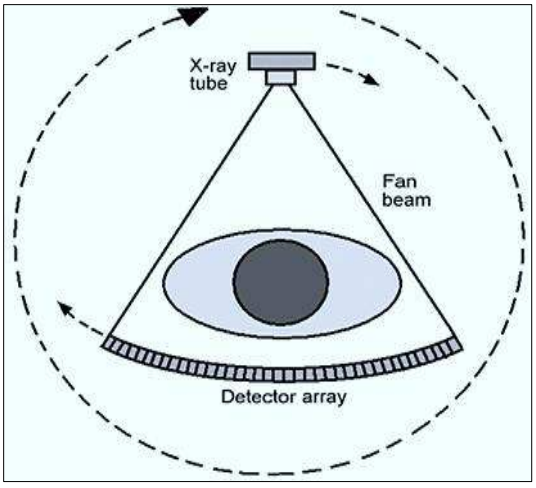


Figure (3): Third Generation: Fan Beam, Rotating Detectors

Fourth Generation: (Fan Beam, Fixed Detectors)

In a fourth-generation scanner, ***X-ray source and fan beam rotate about the isocenter***, while the ***detector array remains stationary***. The detector ***array consists of 600 to 4800*** (depending on the manufacturer) independent detectors in ***a circle that completely surrounds the patient***. Scan times are less than third-generation scanners ***(~ 2sec.)***. The ***number of views is equal to the number of detectors***.

Two detector geometries are currently used for fourth-generation systems:

1. a rotating X-ray source inside a fixed detector array and
2. a rotating X-ray source outside a nutating detector array

Both third and fourth generation systems are commercially ***available with advanced configurations***.

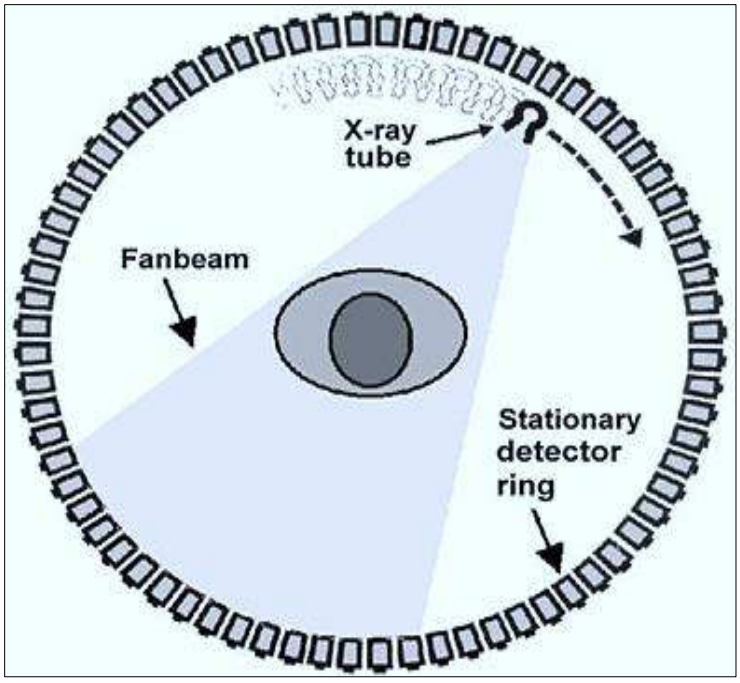


Figure (4): Fourth Generation: Fan Beam, Fixed Detectors

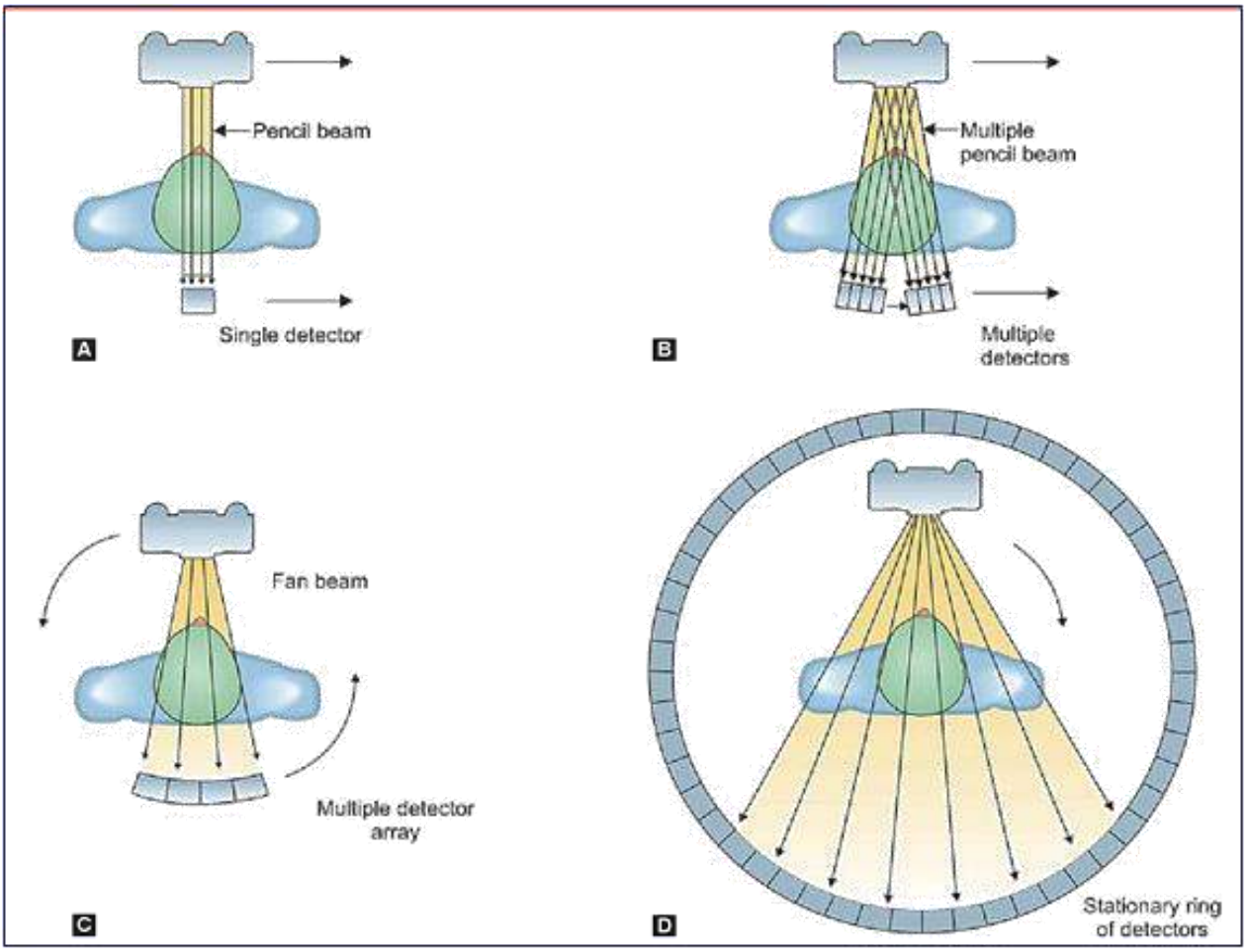


Figure (5): The Four Generations of CT scan

Fifth Generation: (Electron beam scanning EBSCT)

Fifth-generation scanners are unique in that the ***X-ray source becomes an integral part of the system design***. The detector ***array remains stationary***, while a high – energy ***electron beams is electronically swept along a semicircular tungsten strip anode***. X-rays are produced at the point ***where the electron beam hits the anode***, resulting in a ***collimated fan beam X-rays that rotates*** about the patient with no moving parts.

Projections data can be acquired in approximately ***(<50ms)*** and performing ***complete scans in a little as 10-20ms***, which is fast enough to ***image the beating heart without significant motion artifacts***. So, it was designed for ultrafast scans ***to freeze cardiac motion*** in ***Cardiac CT scans***, where was a hurdle with previous existed generation.

The idea behind the ultrafast scanner is the large bell shaped X- ray tube. It ***doesn't use conventional X-ray tube;*** instead, a large ***arc of tungsten encircles the patient and lies directly opposite to the detector ring***. X-rays are produced from a focal track as ***a high energy electron beam strikes the tungsten***. The concept is known as ***EBCT (Electron Beam CT)***.

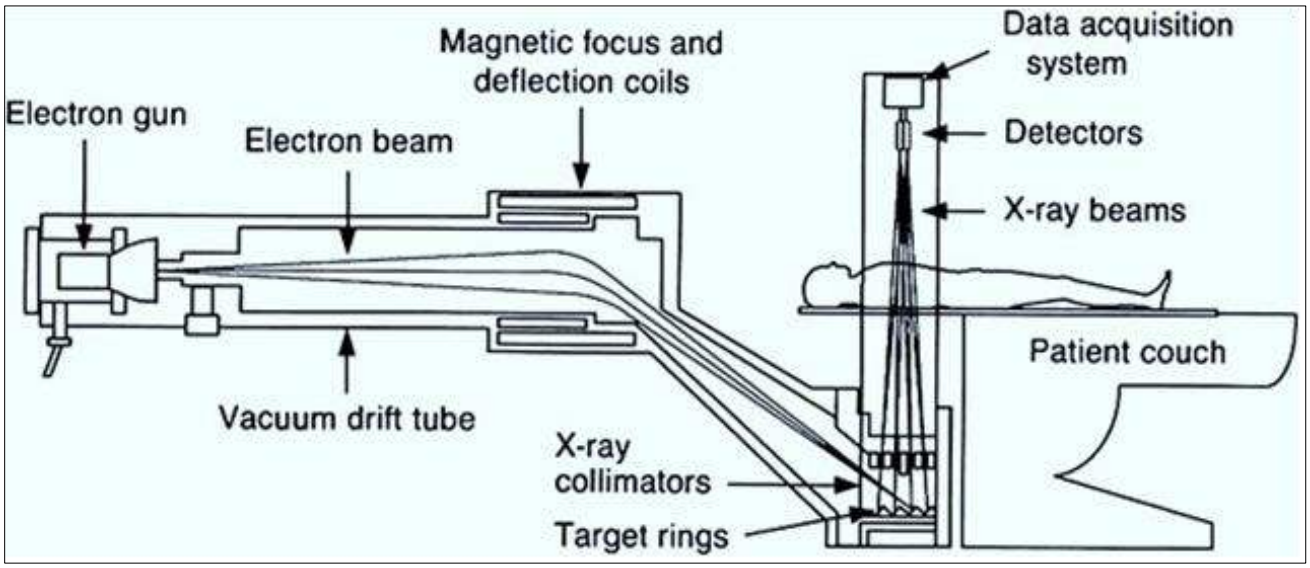


Figure (6): Electron beam scanning EBSCT

