

## 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.

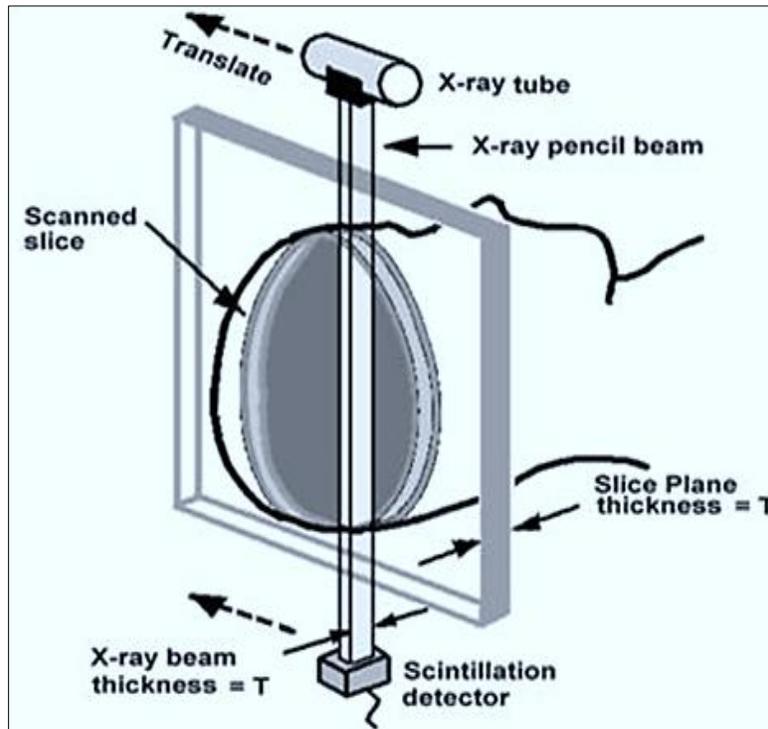


Figure (1): First Generation: Parallel-Beam Geometry

**Second Generation: (Fan Beam, Multiple Detectors)**

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*.

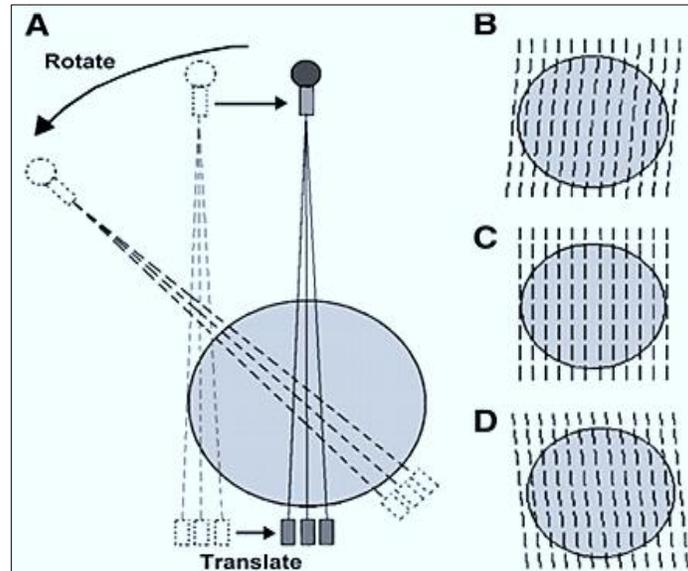


Figure (2): Second Generation: Fan Beam, Multiple Detectors

**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*.

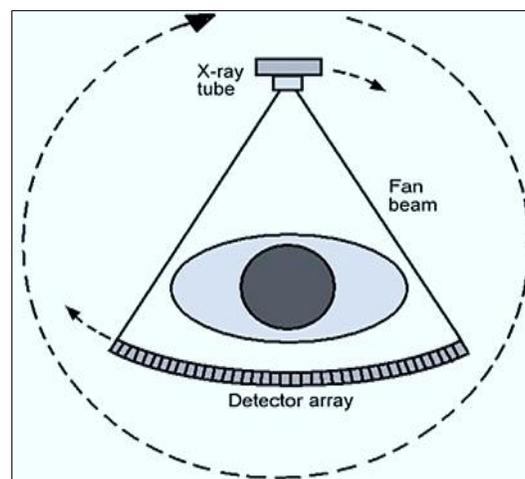


Figure (3): Third Generation: Fan Beam, Rotating Detectors

### **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 ( $\sim 2\text{sec.}$ ). 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 rotating detector array

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

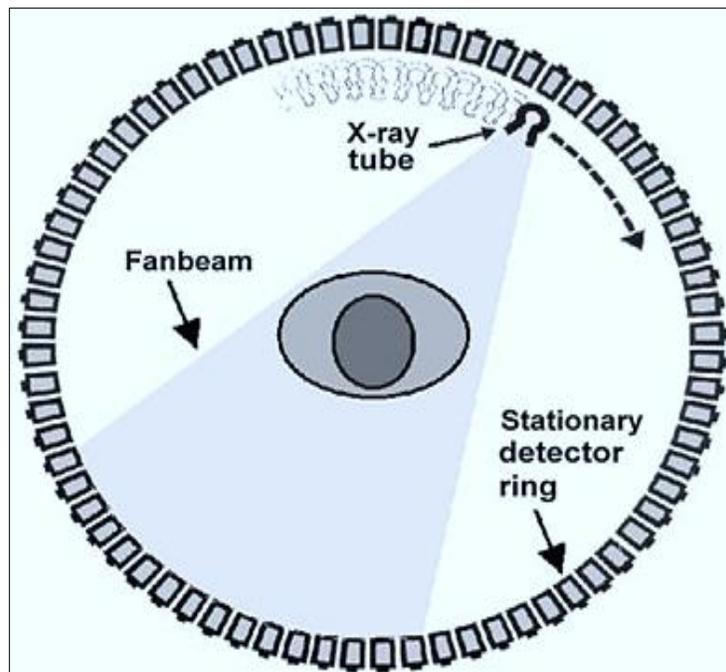


Figure (4): Fourth Generation: Fan Beam, Fixed Detectors

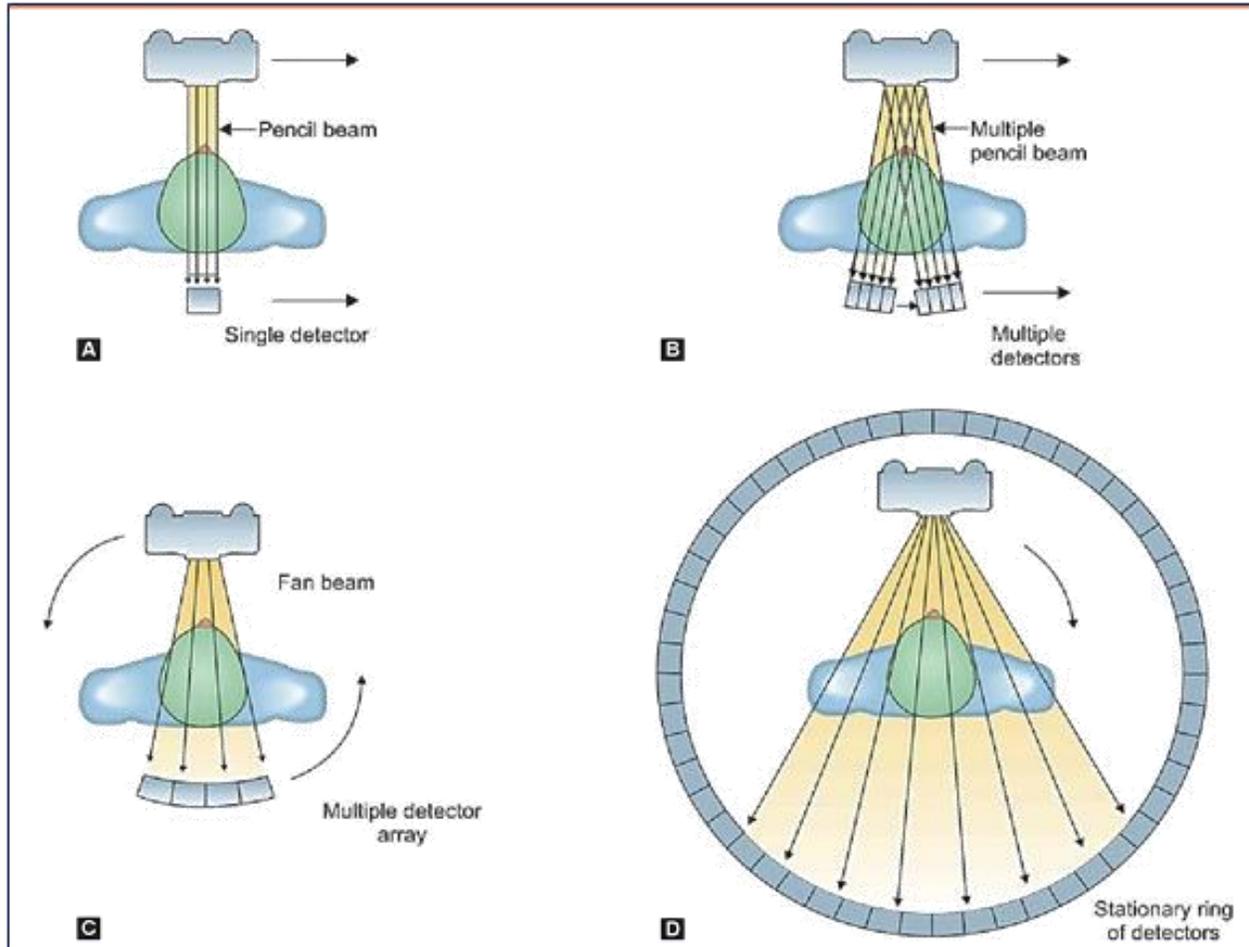


Figure (5): The Four Generations of CT scan

### **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)*.

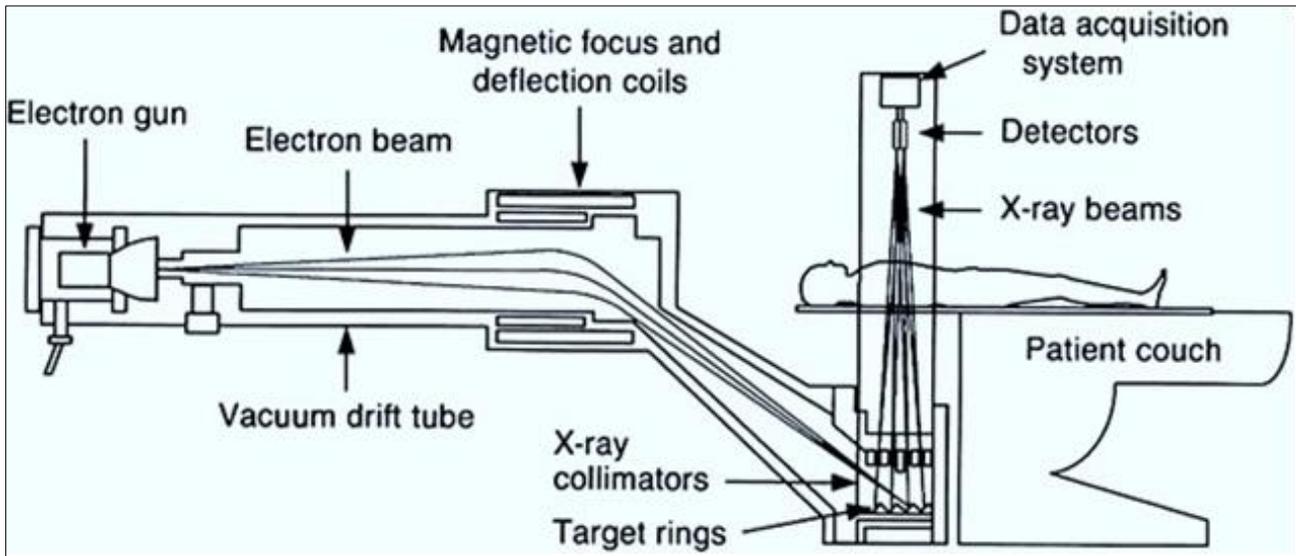


Figure (6): Electron beam scanning EBSCT

