Introduction: المقدمة:

Computed tomography (CT): is an imaging procedure that uses special x- ray equipment to create detailed pictures, or scans, of areas inside the body. It is also called computerized tomography, or computerized axial tomography (CAT). The term *tomography* comes from the Greek words *tomos* (a cut, a slice, or a section) and *graphein* (to write or record). Computed tomography (CT) is noninvasive and produces cross-sectional images of the body. Each cross-sectional image represents a "slice" of the person being imaged, like the slices in a loaf of bread. These cross-sectional images are used for a variety of diagnostic and therapeutic purposes.

Limitations of Film-Based Radiography

 The major shortcoming of radiography is the super- imposition of all structures on the film, which makes it difficult and sometimes impossible to distinguish a particular detail (Fig.1). This is especially true when structures differ only slightly in density, as is often the case with some tumors and their surrounding tissues

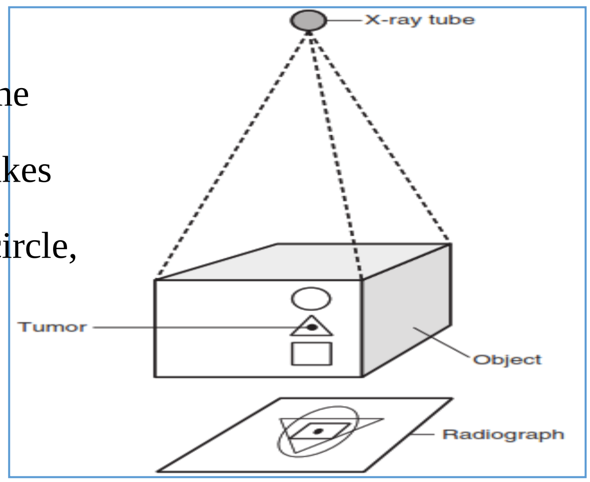


Fig. 1: The major shortcoming of radiography is that the superimposition of all structures on the radiograph makes it difficult to discriminate whether the tumor is in the circle, triangle, or squa

A second limitation is that radiography is a qualitative rather than quantitative process (Fig. 2). It is difficult to distinguish between a homogeneous object of nonuniform thickness and a heterogeneous object (Fig. 2) (includes bone, soft tissue, and air) of uniform thickness.

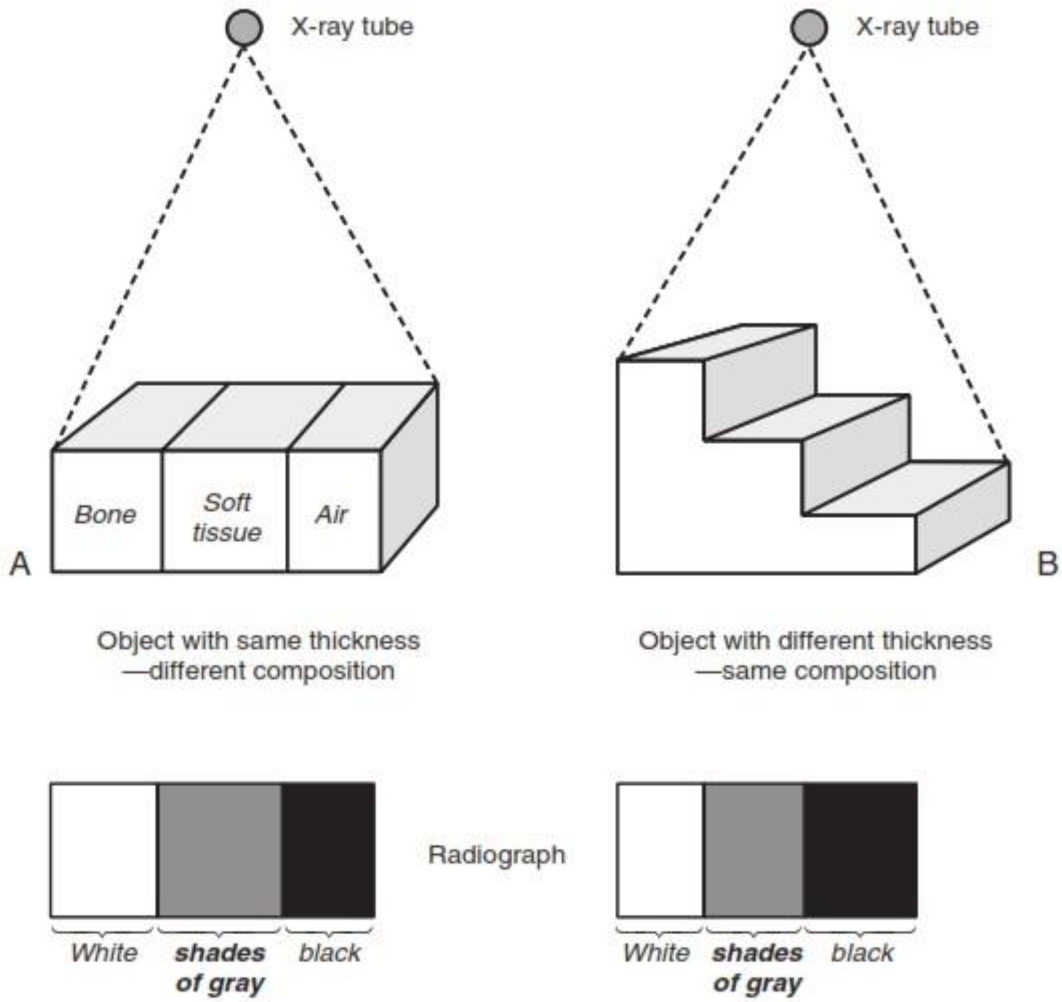


Figure (2): Radiography is a qualitative rather than quantitative procedure. Two radiographs can appear the same although the two objects, **A** and **B**, are entirely different.

Limitations of Conventional Tomography

The problem of superimposition in radiography can be somewhat overcome by **conventional tomography** . The most common method of conventional tomography is sometimes referred to as *geometric tomography* to distinguish it from CT (Fig. 3)

When the **x-ray tube** and film are moved simultaneously in opposite directions, unwanted sections can be blurred while the desired layer or section is kept in focus.

The immediate goal of tomography is to **eliminate structures above and below the focused section, or the focal plane**. However, this is difficult to achieve, and under no circumstances can all unwanted planes be removed. The limitations of tomography include persistent image blurring that cannot be completely removed, degradation of image contrast because of the presence of scattered radiation created by the open geometry of the x-ray beam, and other problems resulting from film-screen combinations.

In addition, both radiography and tomography fail to adequately demonstrate slight differences in subject contrast, which are characteristic of soft tissue.

Radiographic film is not sensitive enough to resolve these small differences because typical film- screen combinations used today can only discriminate x-ray intensity differences **of 5% to 10%.**

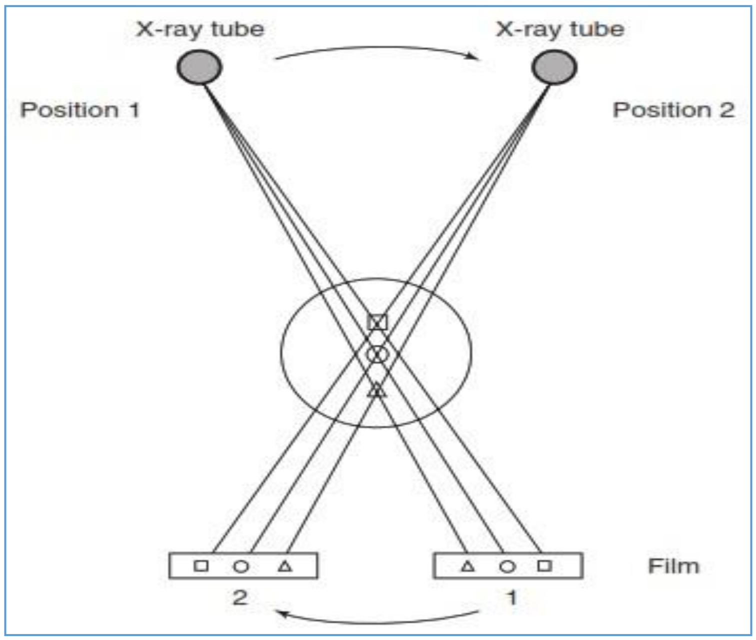


Figure 3: Basic principles of conventional tomography.The x-ray tube and film move simultaneously and in opposite directions to ensure that the desired section(○) of the patient is imaged by blurring out structures above (■) and below(Δ) the plane of interest (○).

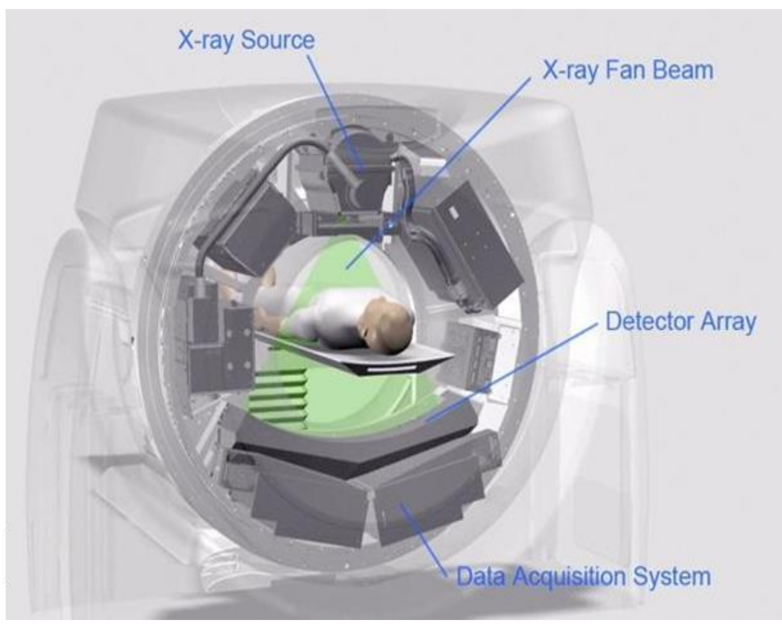
The limitations of radiography and tomography result in the inability of film to image very small differences in tissue contrast. In addition, contrast cannot be adjusted after it has been recorded on the film. Digital imaging modalities such as CT, for example, can alter the contrast to suit the needs of the human observer (radiologists and technologists) by use of various digital **image postprocessing** techniques

CT scans can be performed on every region of the body for a variety of reasons (e.g., diagnostic, treatment planning, interventional, or screening). The cross- sectional images generated during a CT scan can be reformatted in multiple planes, and can even generate three-dimensional images which can be viewed on a computer monitor, printed on film or transferred to electronic media. Although most common in medicine, CT is also used in other fields, such as nondestructive materials testing, to study biological and paleontological specimens.

CT differs from the conventional radiography in two significant ways:

- First, CT forms across-sectional image, eliminating the superimposition of structures that occurs in plane film imaging because of compression of 3D body structures onto the two-dimensional recording system.
- Second, the sensitivity of CT to subtle differences in x-ray attenuation is at least a factor of 10 higher than normally achieved by screen-film recording systems because of the virtual elimination of scatter.

Figure (5) : Schematic of a CT system



Purpose of CT scan

CT-scans provide detailed cross-sectional images of various internal structures, for example, internal organs, blood vessels, bones, soft tissue etc., and can be used for:

- Diagnostic purposes-
- Guidance for specific treatment or further tests- surgeries, biopsies and radiation therapy
- Detection and monitoring of conditions- Cancer, heart disease, lung nodules, liver masses.

Technique

Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation.

 In the circular opening a flat “patient couch (table)” is mounted, the diameter measures between 24-28 inches. The patient lies flat onto the table and can be adjusted upwards, downward, frontwards or backwards to position for imaging.

 The table moves the patient into the gantry and the x-ray tube rotates around the patient. The scanner gantry contains the rotating portion that holds the X-ray tube generator and the detector array. As x-rays pass through the patient to the detectors, A computer system acquires and performing the necessary calculations to go from measurements to a viewable image.

 One cross sectional slice of the body is obtained for each complete rotation. Multiple shots are taken as the scanner rotates and these are called “profiles”. Within one rotation about 1,000 profiles are acquired. A two dimensional image (slice) is formed when a full set of profiles from each rotation that are analyzed by a computer are compiled

Introduction: المقدمة:

Generations of CT scanners

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.

Scientific Content: المحتوى العلمي:

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

- Tube orientation and shape of beam (from 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 acrossthe 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.

This scanner was limited because;

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.

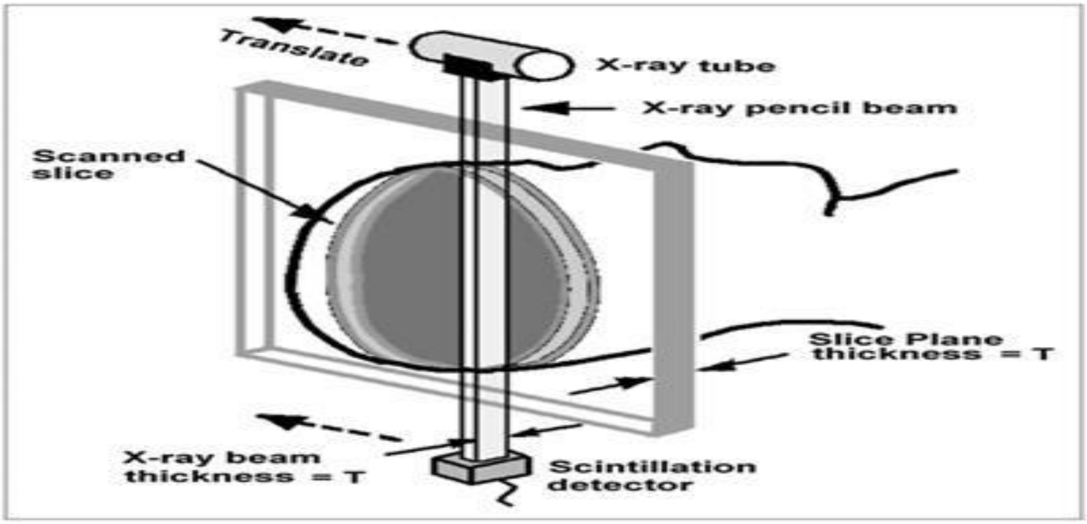


Figure (1) : First Generation: Parallel-Beam Geometry.

► ***<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 <u>pencil beam</u> is replaced by <u>a fan beam</u> and a <u>single detector</u> by <u>multiple detectors (5-30)</u> 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.

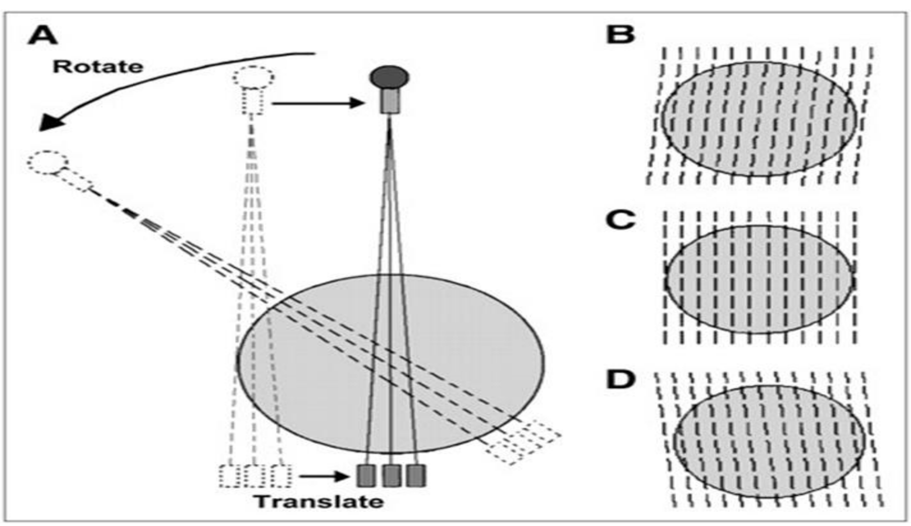


Figure (2) : Second Generation: Fan Beam, Multiple Detectors.

▶ ***Third Generation: (Fan Beam, Rotating Detectors)***

A fan beam of x-rays is rotated 360 degrees around the isocenter. No translation motionis 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

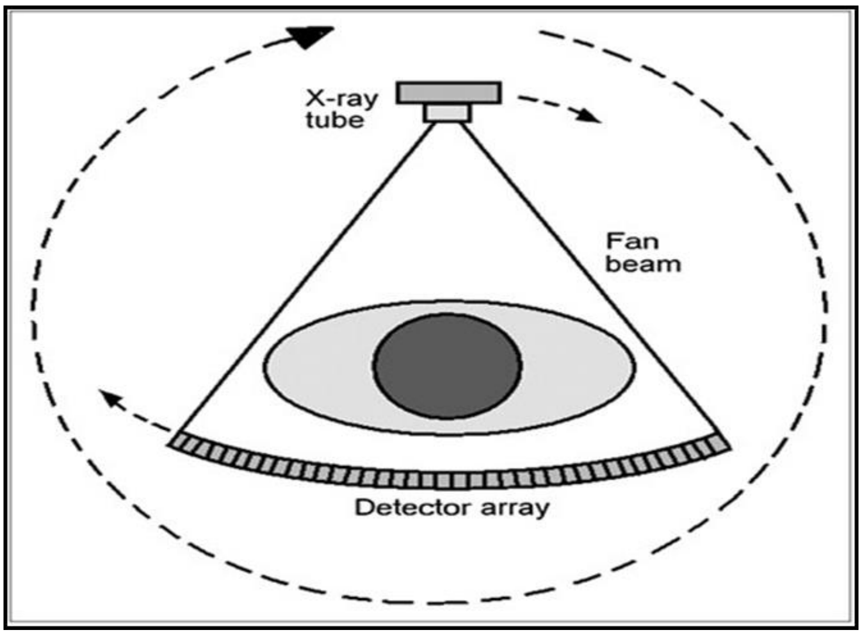


Figure (3) : Third Generation: Fan Beam, Rotating Detectors

▸ ***Fourth Generation: (Fan Beam, Fixed Detectors)***

In a fourth-generation scanner, the 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** to those of 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.

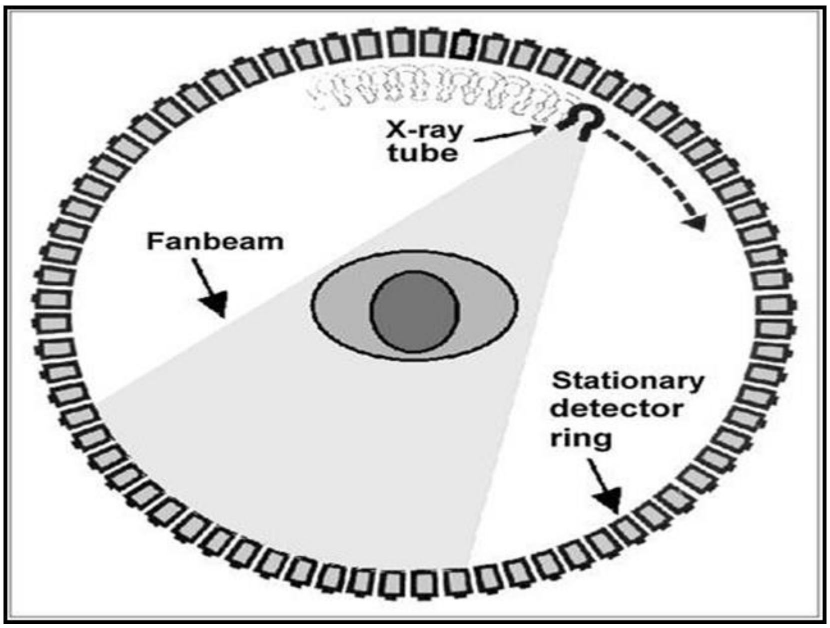


Figure (4): Fourth Generation: Fan Beam, Fixed Detectors.

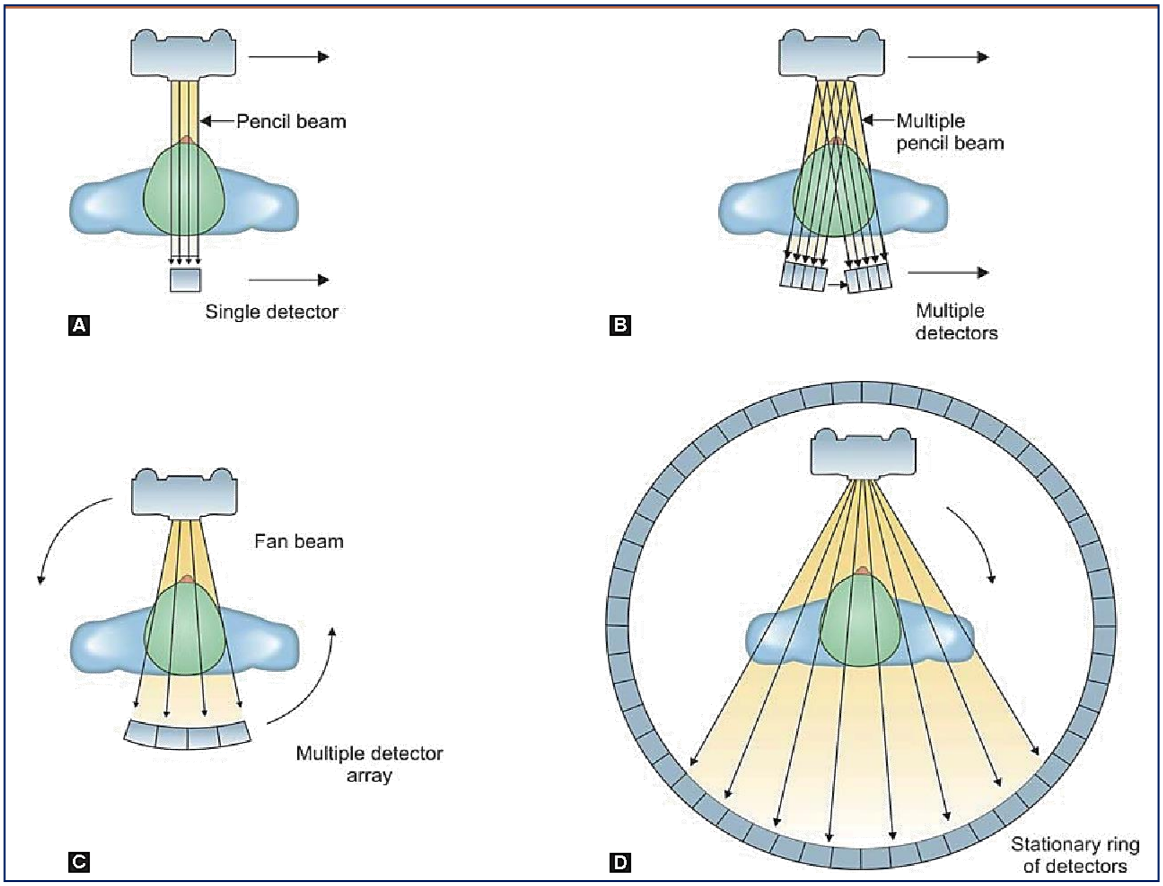
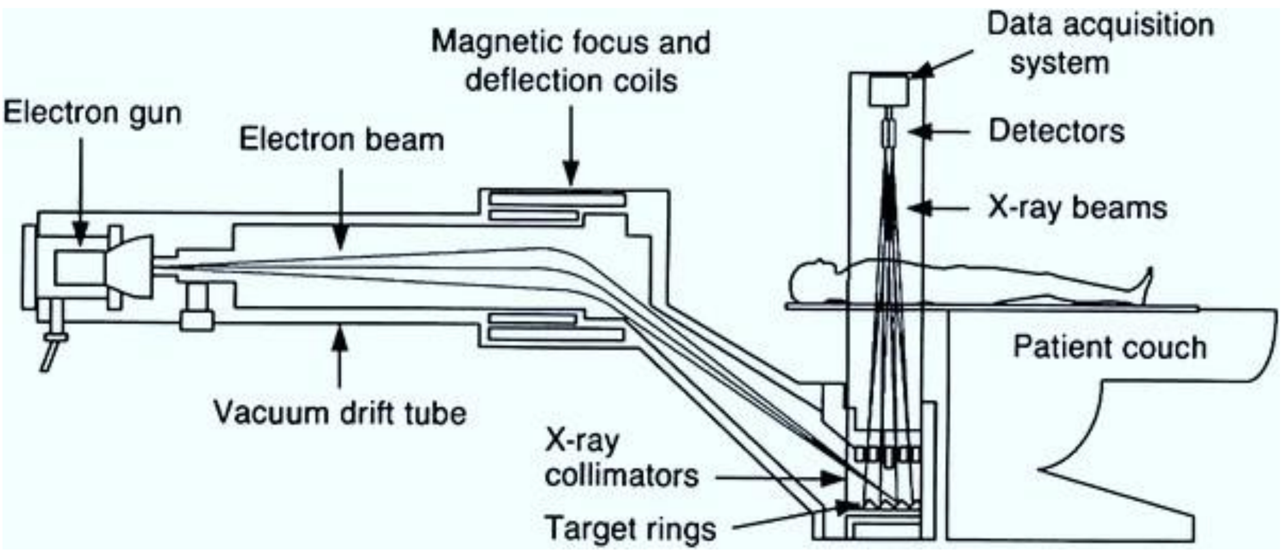


Figure (5): The Four Generations of CT scan

► ***<u>Fifth Generation: (Electron beam scanning EBSCT)</u>***

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 **<u>is the large bell shaped x- ray tube</u>**. 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