Theoretical Lecture: Helical CT & multislice CT

Sixth generation: Helical and spiral CT

Helical computed axial tomography scan (CAT scan or CT scan) also called a spiral CT scan (figure1):

- Helical (or spiral) CT scanners use slip-ring technology. Slip-ring scanners can perform a scan in which the patient moves slowly through the gantry which is referred to as the table speed, while the X-ray tube and detector rotate in a plane perpendicular to the major axis of the patient's body.
- In this technique the data are continuously acquired or collected without pausing while the patient is simultaneously transported at a constant speed through the gantry.
- Scans with CT technique required 15 to 30 minutes. But helical CT scanner is faster.
- One breath-hold and obtain a volume of X-rayed tissue.
- The x-ray beam from the CT traces a helical path (x-ray tube rotates in helical path) as in figure1 and figure 3.
- The helical path results in a three-dimensional data set which can then be reconstructed into sequential images for a stack.

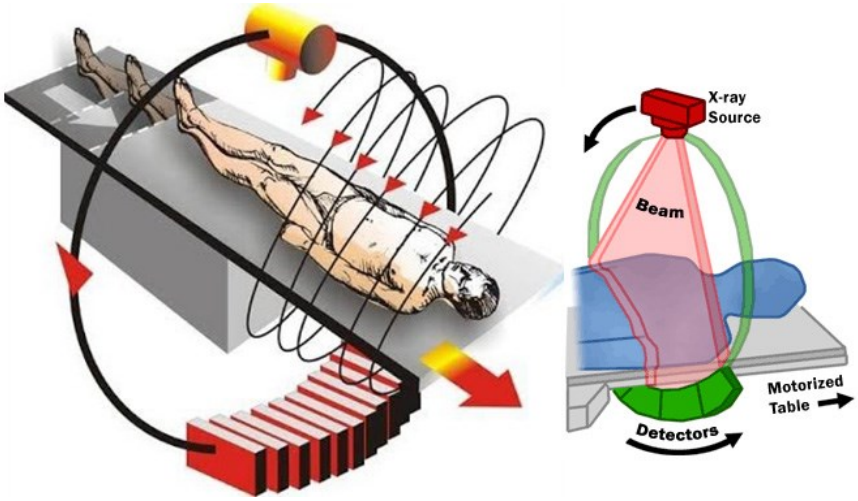


Figure 1: Helical or spiral CT scanner.

- **In helical scanning, using a slip ring technology.**
  - ✓ The tube is energized continuously, and data are collected continuously. Allows the gantry to rotate continuously.
  - ✓ The slip ring has three rings. Each ring makes connectivity to the X-ray generator, detector, and control signals. With slip rings arrangement, the X-ray tube can rotate faster (5 s/rot) and move more than 360 degrees. (Figure2).

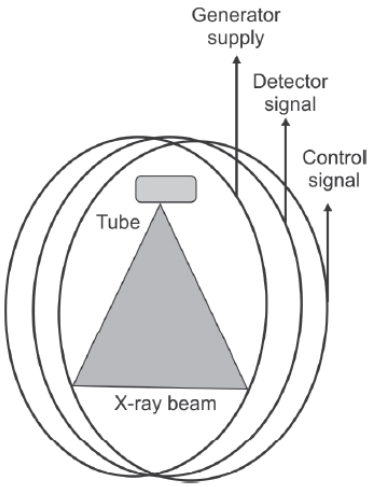


Figure 2: slip ring technology.

  - ✓ Slip ring is used in spiral CT or multislice CT
  - ✓ It eliminates the need of electrical cables, which restrict continuous rotation.
- **Requires higher X-ray power**
  - ✓ X-ray tubes are used for longer exposure > 90 s.
  - ✓ The anode cooling rate must be high and liquid metal bearings are used to withstand heat.
  - ✓ There is a pre- and post-patient collimator of 100 μm thick, made up of tantalum.

Figure 3 shows the difference between the Sequential CT and helical CT.
The specification for a typical helical CT is given in Table1.

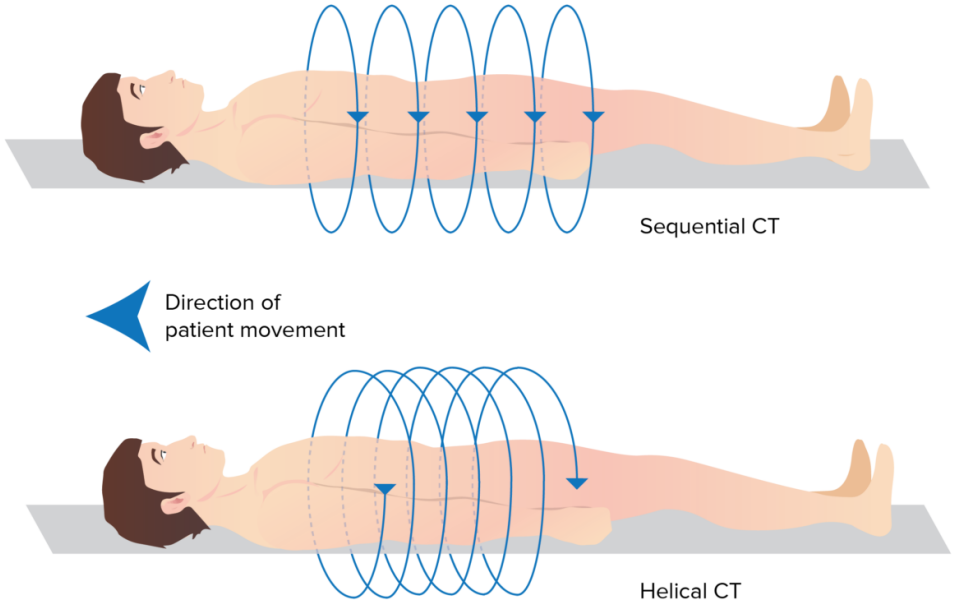


Figure 3: Difference between the Sequential CT and helical CT.

Table1: specification for helical CT.

X-ray tube	Heat storage	6.3 MHU
Generator	Focal spot (mm)	0.7,0.9,1.2
	Anode angle	7°
	Power	60 kW
	kV ranges	80,100,120,140
	mA (max)	440
	Acquisition time (max)	120 s

Interpolation

CT reconstruction Interpolation algorithm assumes that the X-ray source path is circular, not helical around the patient. But, in a helical scan, the X-ray beam path is helical in nature and gives only helical data set. Hence, before the actual CT reconstruction, the helical data set has to be interpolated into a series of planar image sets. Then, with interpolated data set, CT images can be reconstructed at any position along the length of the scan (Figure 4).

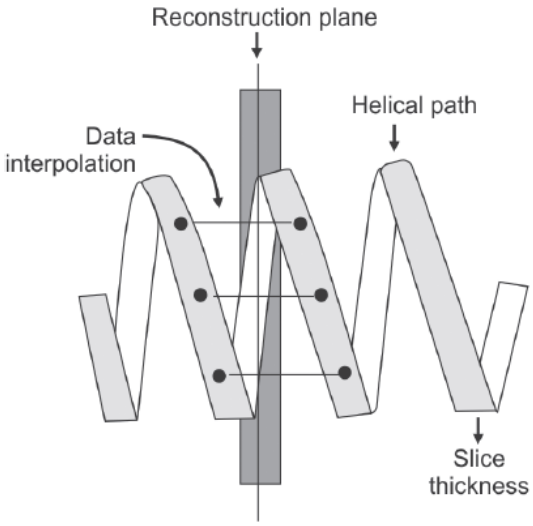


Figure 4: Helical data set and interpolation for reconstruction.

The advantages of a helical CT scan are:

1- The scan speed and patient throughput: e.g. a chest scan with 10 mm slice, can be done in single breath hold in 15–20 s (couch motion 10 mm/s, pitch 1.5)
2- Avoids slice misregistration.
3- Use of higher pitch reduces patient dose and exposure time.

The disadvantages of a helical CT scan are:

1- It is relatively expensive.
2- Precise identification of small distal stones is occasionally difficult.

Uses of helical CT scan:

1- Used to help diagnose disease.
2- Plan treatment.
3- Find out how well treatment is working.

Seventh generation: Multislice Computed Tomography (MSCT)

The multislice CT (MSCT) was started in 1992 with 2 parallel bank of detectors that gives 2 slices. In 1998, solid state multi row detector was introduced to make 4 slices in each rotation.

Multislice CT (figure 5) generally uses third generation CT with helical scanning and low voltage slip rings.

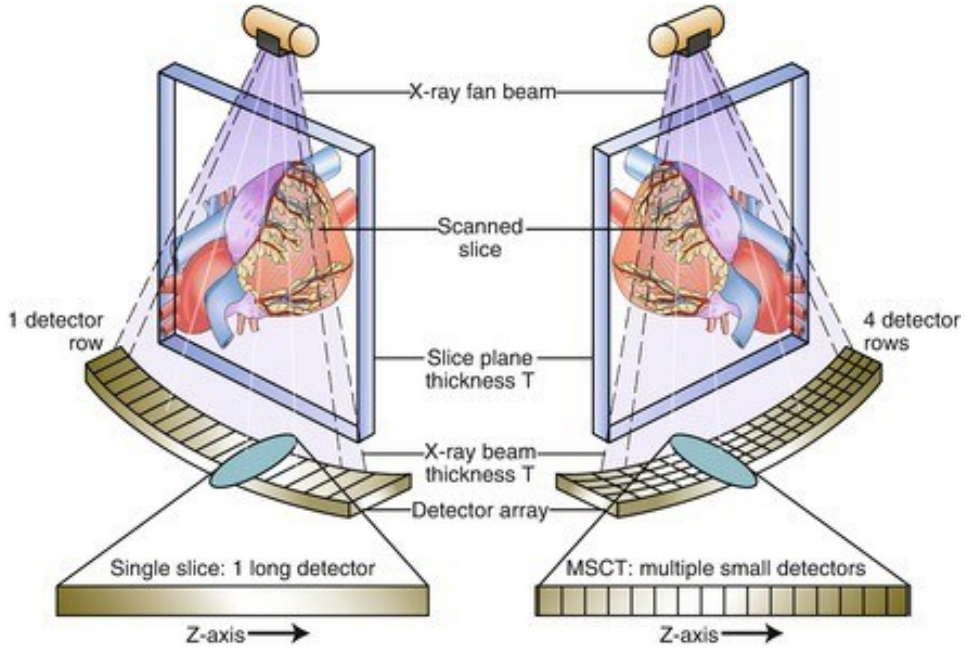


Figure 5: Multi slice computed tomography.

The special features of MSCT are:

- Faster rotation subsecond times (0.5–0.8 s), that reduces the examination time.
- The image quality is similar to that of single slice scanners.
- It is different in dose, pitch, image artifacts, and method of image reconstruction.
- To scan longer anatomic area, more than 4 slices are required and hence gantry speed has to be increased.

Multidetector array

Multidetector array is a combination of several linear arrays (multiple solid state detector array). In this, the X-ray tube is directed at multiple rows of detectors along the longitudinal (Z) axis. Each row has hundreds of separate detector elements (Figure3).

It has separate data acquisition channels for each detector element and can generate multiple channels (4, 8, 16, and 64) of spatial data.

Difference between single slice and multislice scanner:

1. MSCT perform 0.5 s rotation with simultaneous acquisition of 4 slices.
2. It gives 8 times higher performance than single section CT, for same scanning time.
3. Recent advances has brought scanners with 4, 8, 16, and 64 slices in practice.

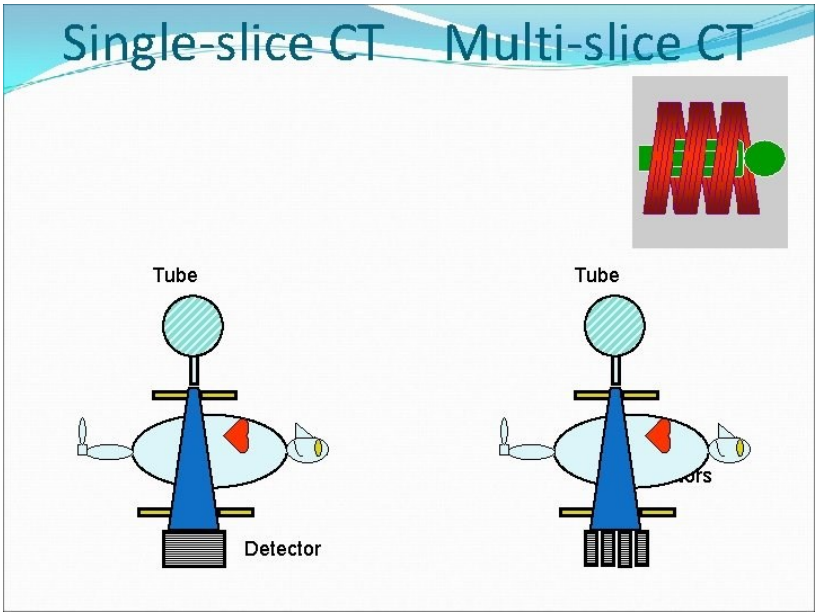


Figure 6: single and multislice computed tomography.

4. In a single slice scanner, the detectors are wide (15 mm) and collimator determines (adjustment) slice thickness of 1–13 mm.
5. In a MSCT, the individual detector elements along the z-axis are summed, to get several slice thickness. Thus, the slice width is determined by the detector not by the collimator (figure7).

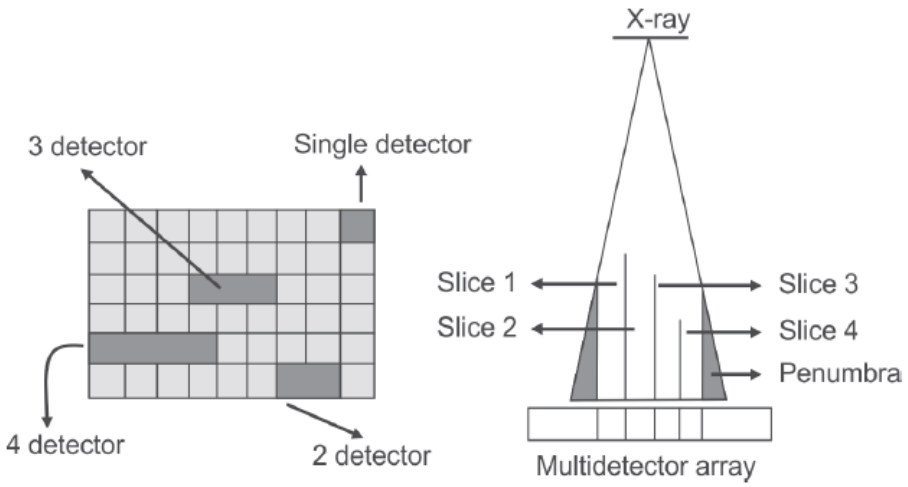
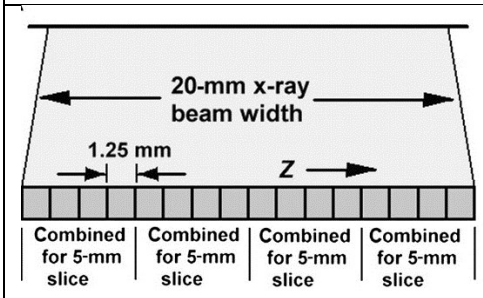
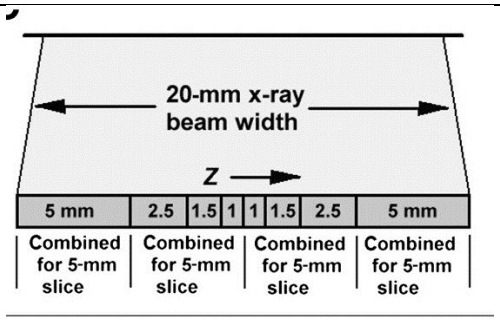


Figure7: Multidetector array and slice selection.

Types of the MSCT detectors:

Two commercial designs of detectors in MSCT:

Linear or matrix detector	Adaptive array detector
In the linear array, the width is equal, e.g. it may have 1.25 mm throughout the dimension with 16 detector module.	The detector width is unequal, e.g. it may have detector width as 1.0, 1.5, 2.5 and 5 mm from the center to edge.
	

Pitch

- In MSCT, the pitch influences radiation dose, image quality and scan time.

- The pitches are **(1)** collimator pitch and **(2)** detector pitch.

  - **The collimator pitch is given by the relation:**

$$\text{Collimator pitch} = \frac{\text{Table movement per 360° gantry rotation}}{\text{Collimator width at isocenter}}$$

- Pitch = 1, refers normal scanning, pitch = 0.75 refers over scanning, and the table motion is slow. This gives increased image quality with increased radiation dose.
- If the pitch = 1.5, it is said to be under scanning and the table motion is faster with lesser patient motion.

  - **The detector pitch is defined as follows:**

$$\text{Detector pitch} = \frac{\text{Table movement per 360° rotation of gantry}}{\text{Detector width}}$$

The collimator pitch and the detector pitch of a given CT is related as follows:

Collimator pitch = Detector pitch ÷ N

Where, N is the number of detector arrays in the multislice CT.

The MSCT scanners with 4 detector arrays uses 3–6 as detector pitch values, e.g. a pitch of 6 corresponds to 1.5 for conventional scanner, since N = 4.

The clinical advantages of MSCT includes:

(i) Increased speed, and shorter acquisition times.

(ii) Accurate anatomical 3D reconstruction especially in angiography and virtual endoscopy with lesser helical artifacts.

(iii) increased volume coverage per unit time

(iv) Reduced partial volume artifacts and noise.