

Physics of Medical Devices

ninth lecture

Computed Tomography

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Fourth Stage

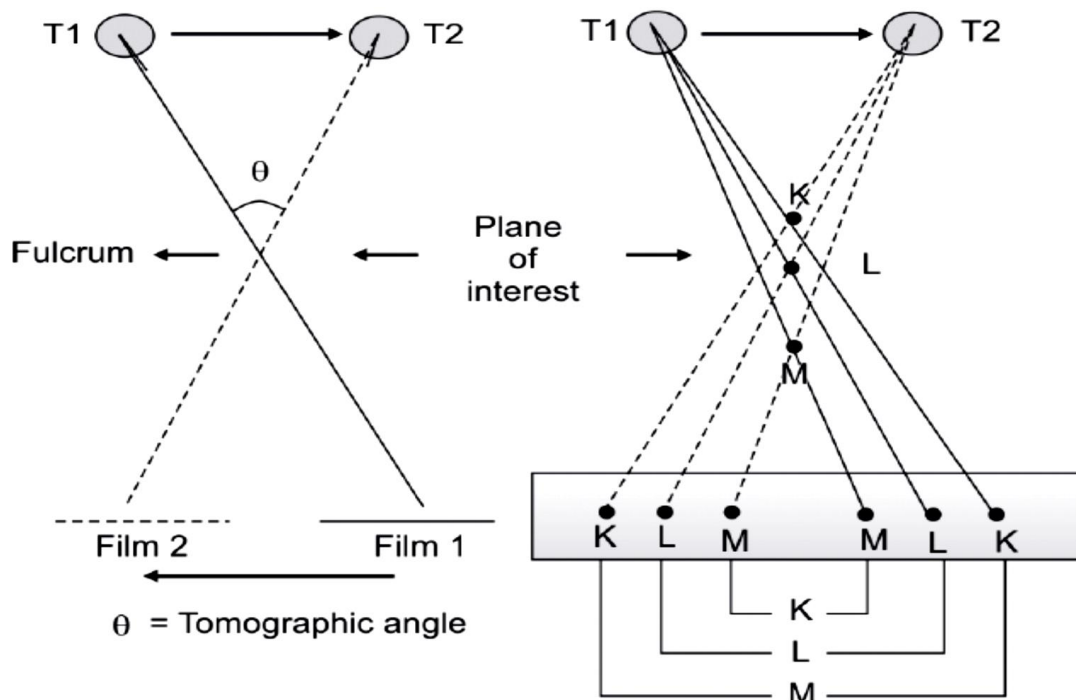
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2021- 2022

1. Introduction

- ❖ It is an imaging technique that produces sectional view of the patient in a plane, parallel to the table top.
- ❖ The essential parts of a linear tomography system are X-ray tube, X-ray film and a rigid connecting rod that rotate about a fixed fulcrum.
- ❖ If the tube moves in one orientation, the film moves in the opposite direction.
- ❖ The film is placed in a tray under the X-ray table, so that it is free to move without disturbing the patient.
- ❖ The fulcrum is the only point in the system that remains stationary.
- ❖ The amplitude of the tube travel is measured in degrees and is called the tomography angle.



Tomography principle

- Computed tomography (CT) is a special form of tomography in which a computer is used to make a mathematical reconstruction of a tomographic plane or slice.
- It generates images in transaxial section, i.e, perpendicular to the axis of rotation of the X-ray tube.
- The special features of CT image includes
 - (i) images are cross sectional.
 - (ii) eliminates the superimposition of structures.
 - (iii) not influenced by the properties of the neighboring region.
 - (iv) subtle differences in X-ray attenuation is 10 times higher than radiographic image, due to scatter elimination. The minimum contrast in radiography is 2%, whereas it is 0.1–0.3% in CT scan.

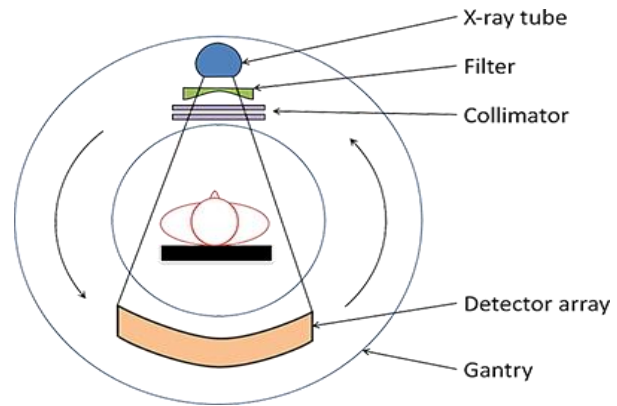
2. Equipment for computed tomography

- CT scanners are available as **single slice scanner**, **helical scanner** and **multi-slice scanner**.
- In general, all the scanners possess a
 - (i) control console,
 - (ii) computer,
 - (iii) gantry
 - (iv) couch.
- Recent developments have brought **slip ring technology** and **multi-detector**
- The Z-axis is the gantry rotation axis, longitudinal, and run along foot to head of the patient.
- The Y axis is perpendicular to the patient in the direction ground to ceiling.
- The X-axis runs side-side of the patient.

3. The gantry contains

➤ CT gantry has the following gadgets:

- (i) X-ray tube,
- (ii) collimation and filtration
- (iii) detector
- (iv) high voltage generator.



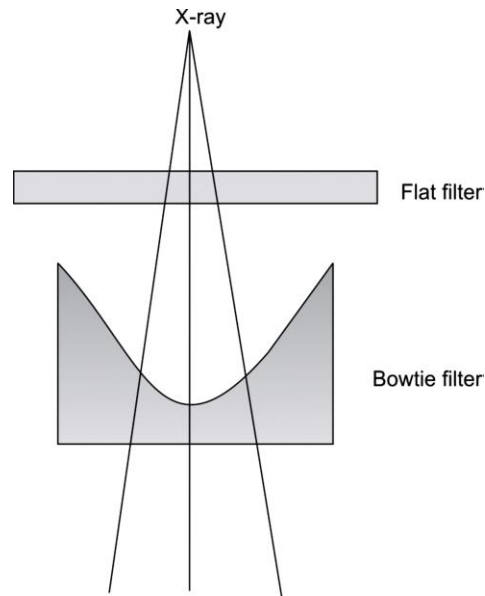
X-ray Tube

- ✚ The X-ray tube uses intense pulse of X-ray and its performance must be stable.
- ✚ Tubes are operated for prolonged exposure time at high mA (e.g. 90 s, 120 kV, 200 mA).
- ✚ The Heat capacity of the tube is about 4 MJ and heat exchangers are provided to cool oil, air, and to maintain gantry at low temperatures.
- ✚ The multi-slice CT tube is large in size, anode disk is larger in diameter and thickness. The anode heat capacity is > 8 MHU and the anode cooling is about 1 MHU. It can be energized up to 60 s continuously, and need high instantaneous power capacity. It requires high speed rotors for best heat dissipation.

Collimation and Filtration

- Collimator device for producing a beam of parallel rays which reduces patient dose and improves image contrast, by limiting scatter radiation.
- The collimator width is about 50 cm at the center, to cover the full patient and the thickness in the Z-axis is about 1–10 mm.
- The X-ray beam is not mono-energetic and hence filters are used to remove low energy photons.
- Aluminum (2.5 mm) + copper (0.4 mm) are used as filters.

- Bowtie filter reduces unnecessary radiation dose to the peripheries of a patient and equalizes radiation signal to the detector.



Detectors

- The requirements of CT scan detector are
 - (i) small with good resolution (600–900 for Single slice, width < 1.5 mm)
 - (ii) high detection efficiency
 - (iii) fast response, negligible afterglow
 - (iv) wide dynamic range
 - (v) stable noise free response.
- Currently, two types of detectors are in use, namely,
 - (i) ionization chamber: Xenon gas filled detectors (single slice)
 - (ii) solid state detector: Scintillation detectors with photo multipliers or photodiodes (Multi-slice).

High Voltage Generator

The high voltage generator is mounted on the gantry, which takes 0.3 s for 360° rotations. The gantry can tilt up to 30° and weighs about 500 kg. The generator is a high frequency generator with capacity of 60 kW. It provides stable tube current and the voltage is controlled by the microprocessor. The generator can give a tube current of about 800 mA at 125 kV with pulse duration of 2- 4 ms.

2. Generation of CT scanners

- ❖ A variety of CT geometries have been developed to acquire the X-ray transmission data for image reconstruction. These geometries are commonly called generations.
- ❖ The main objective of different generation is:
 - (i) scanning time reduction
 - (ii) simplification of mechanical motion

First generation

✚ The first generation CT scanner is a rotate/translate, pencil beam system. It had two X-ray detectors and used parallel ray geometry with NaI detector