Computed Tomography Process - 5

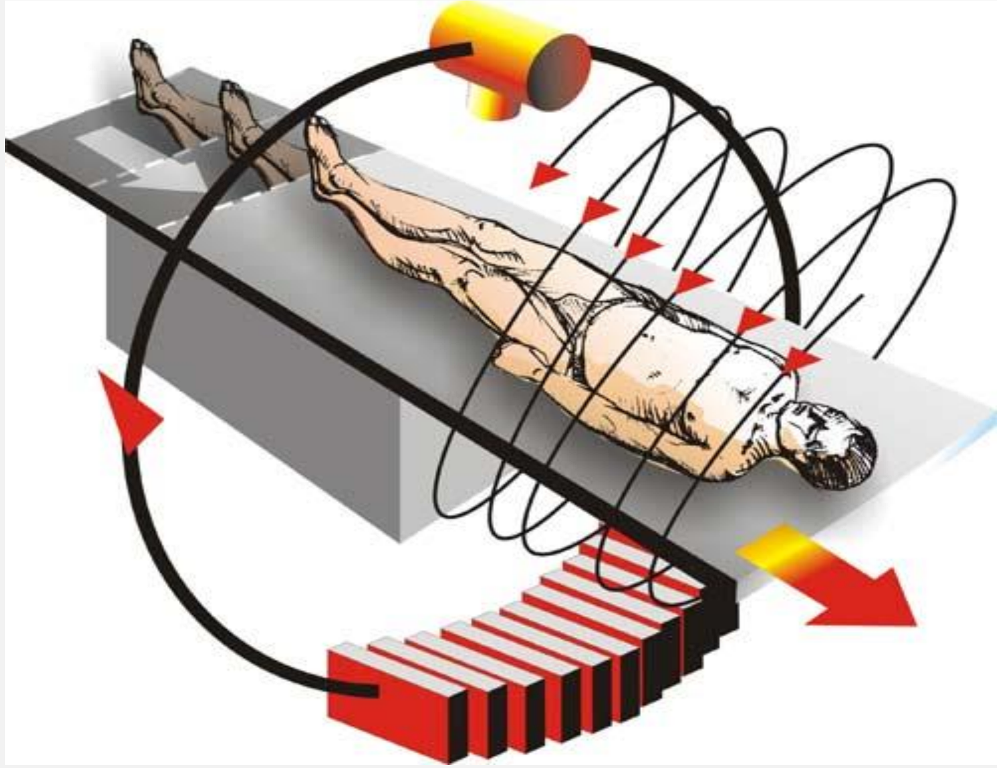
Image production – Image Formation

Methods of Data Acquisition

Localizer Scanning

Step-and-Shoot (axial) Scanning

Helical or Volumetric Scanning



Localizer Scans

Most CT studies begin with one or more localizer images

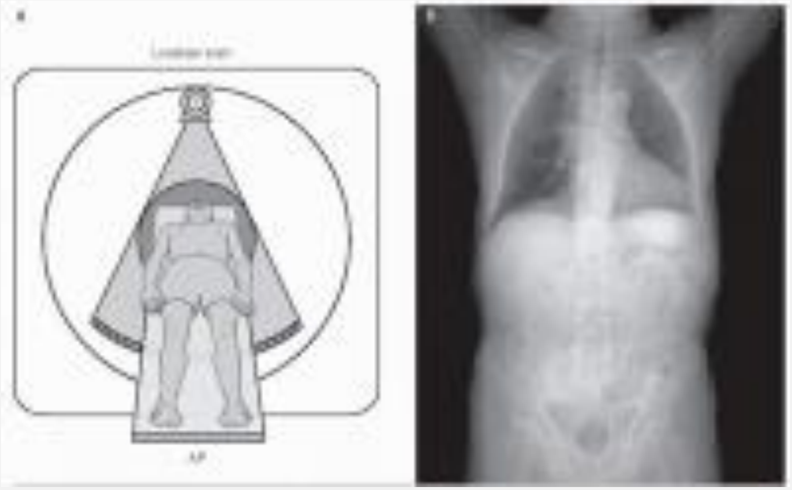
They are very similar to images acquired with conventional radiographic projection techniques

Compared with general x-ray images CT localizer images are of slightly poorer image quality

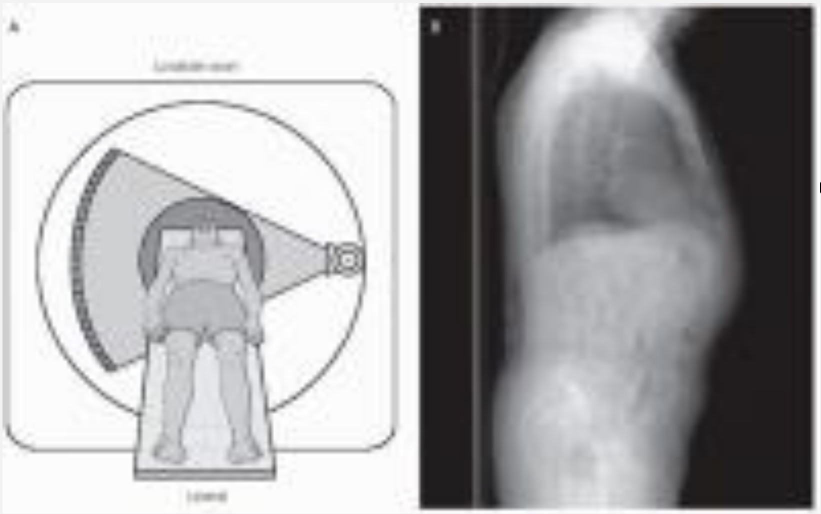
Deliver an approximately equal radiation dose as a comparable radiograph

Localizer Scans

- The position of the tube determines the orientation of the image
- Also called the tube azimuth



- 0 azimuth = AP



- 90 azimuth = Lat.

Localizer Scans

- The optimal localizer scan includes all areas to be scanned
- Anatomy to be imaged must be placed within the scannable range (*z* direction)
- The patient must also be centered appropriately in the gantry in both *x* and *y* directions
- Mis-centering can result in out-of-field artifacts and increased radiation dose
- Proper centering is also important when automatic exposure control techniques are used

Localizer Scans

- On all CT systems it is imperative that the technologist input the correct directional instructions before data acquisition is initiated

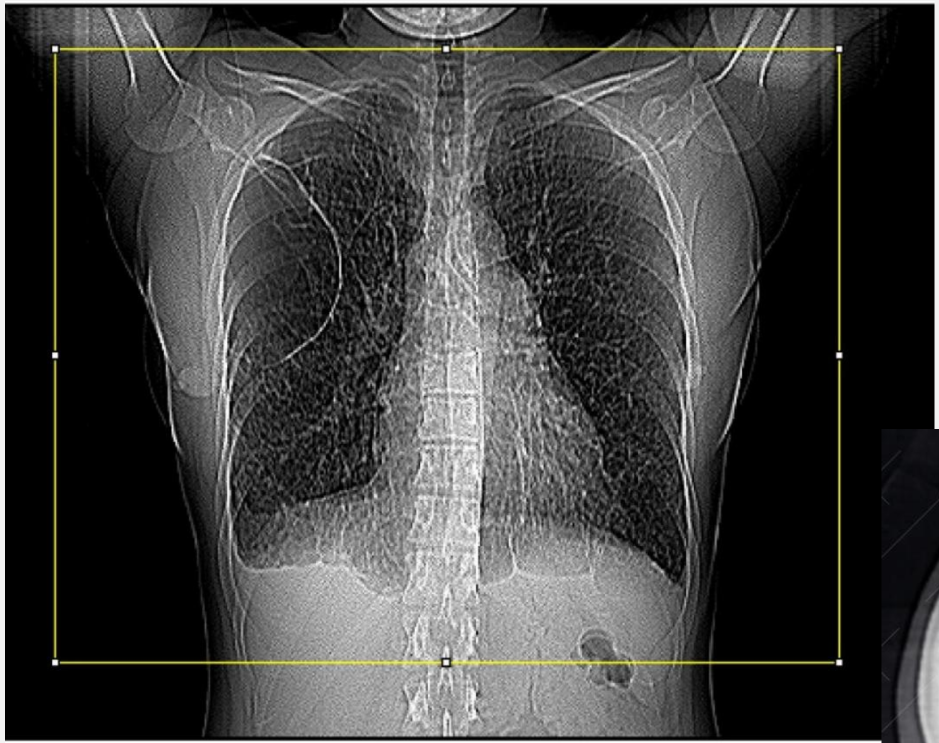
    - Headfirst vs feet first
    - Supine, prone, or decubitus

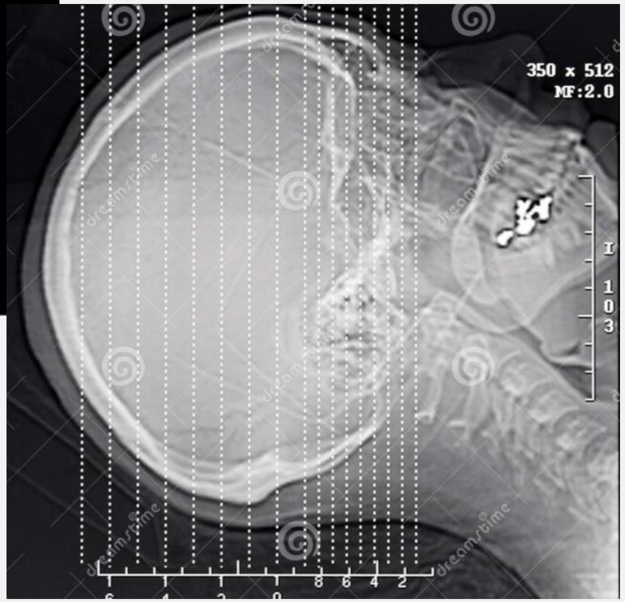
- Incorrectly inputting any directional instruction into the CT scanner can result in

    - Mislabeled Images
    - Misdiagnosis and serious medical errors

Localizer Scans: *Z*-Axis Coverage

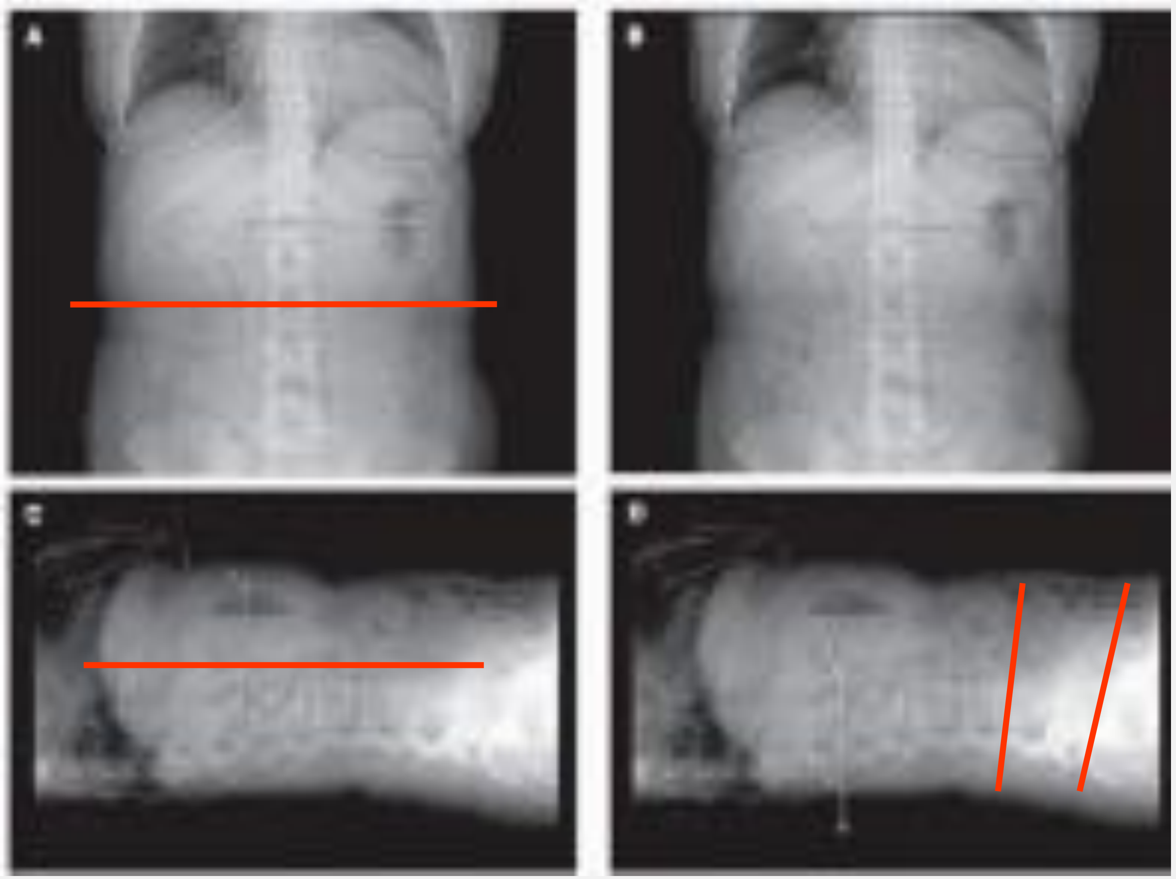
- The localizer scan is used to prescribe the location of cross-sectional slices
- The localizer scan should extend slightly beyond the starting and ending location of the exam
- Most procedures rely on beginning and ending landmarks that can be readily identified on the localizer image





Localizer Scans: DFOV and Image Center

- **Localizer images are also used to select the optimal DFOV and image center. (DFOV should be slightly larger than the object)**
- **DFOV and image center selection is often improved by including both AP and lateral localizer scans**
- **Lateral scouts can be used to determine the gantry angulation**



Angulation
Of Gantry

Step-and-Shoot Scanning

- Earlier scanners operated exclusively in this way

- Also called:
  - axial scanning
  - conventional scanning
  - serial scanning
  - sequence scanning

Step-and-Shoot Scanning

- Key aspects
  - CT table moves to desired location
  - Table remains stationary while the x-ray tube rotates within the gantry
  - Slight pause in scanning as the table moves to the next location
    - Referred to as the interscan delay
- Early systems, which contained only a single row of detectors in the *z* axis, obtained data for one slice with each rotation

Step-and-Shoot Scanning

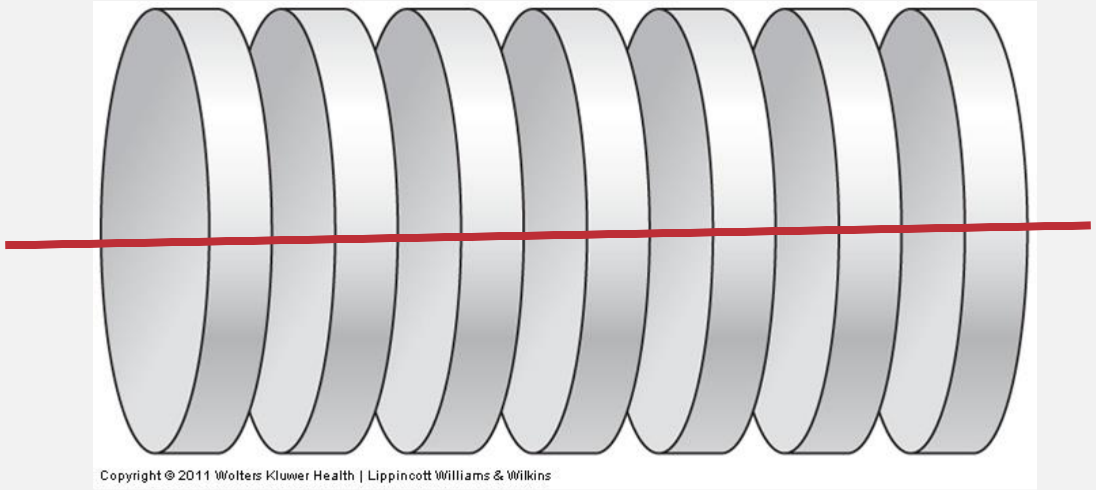
- **In early scanners the time for a complete cycle was relatively long (>6 seconds)**

- **Allowed only a single scan to be acquired each time the patient's breath was held**

- **Newer scanners are much faster and allow axial scans to be "clustered."**
  - **More than one scan can be taken in a single breath-hold**

Step-and-Shoot Scanning

- Scans produced with the step-and-shoot method result in images that are perpendicular to the *z* axis and parallel to every other slice, like slices of a bread



Step-and-Shoot Advantages

- Advantages
  - On phantoms, step-and-shoot methods result in the highest image quality
  - Axial scans can be contiguous (touching)or noncontiguous (spaces between)
  - Axial scans can be programmed to repeat scans at the same slice location
    - Called *cine* or *dynamic* methods
    - Used in CTAs to determine iodine level

Step-and-Shoot Scanning Disadvantages

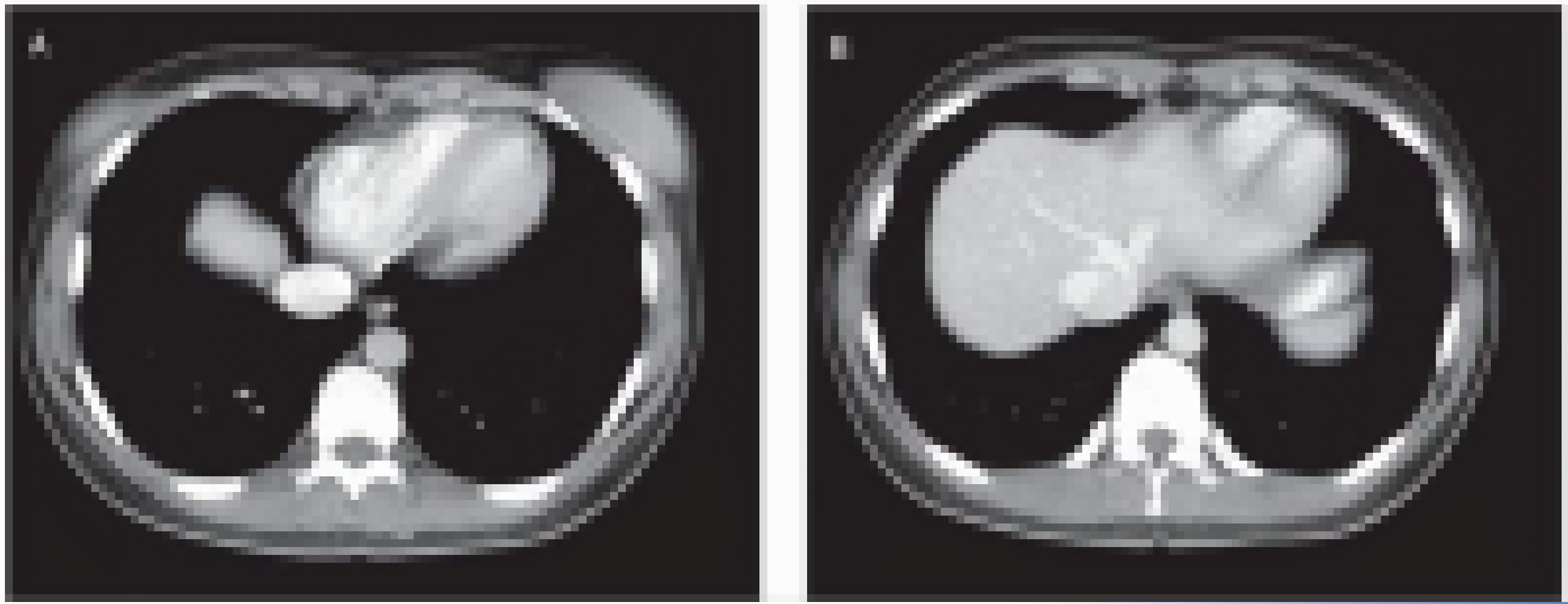
- Disadvantages

  - The cumulative effect of the pauses between each data acquisition adds to the total examination time

  - The interscan delay is very problematic for CT Angiography, because blood vessels remain contrast-filled only briefly

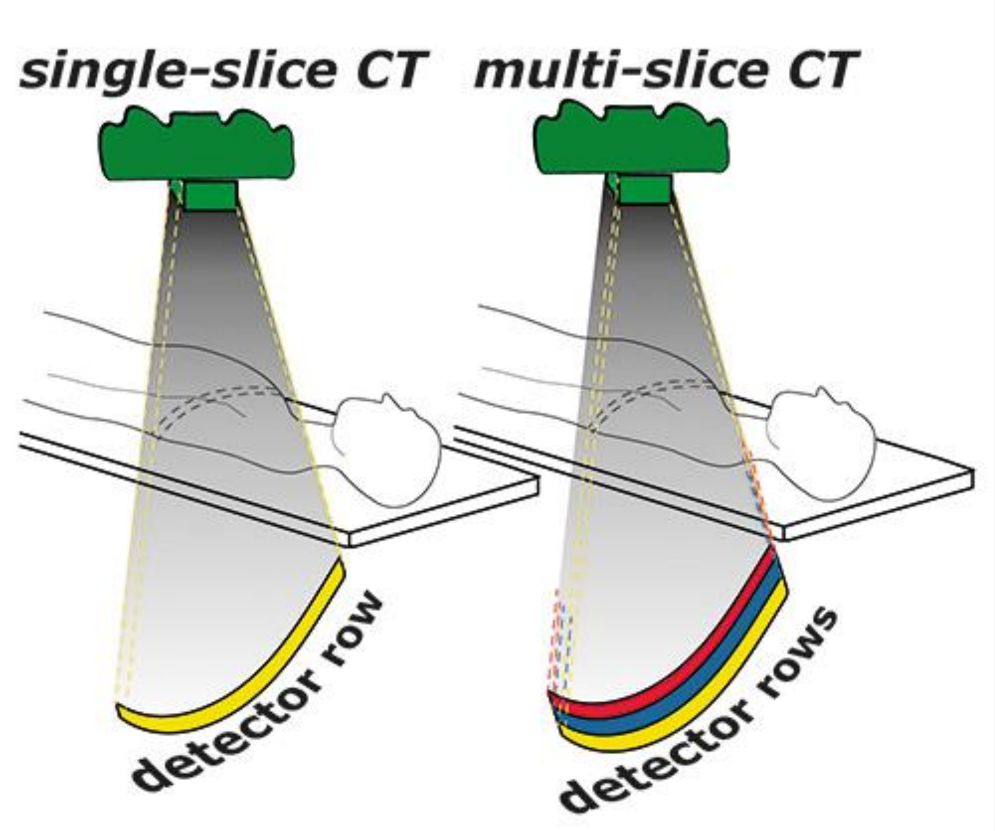
Disadvantages

- Slice misregistration
  - occurs when the patient breathes differently with each scan acquisition
  - Ex: these 2 slices are next to each other but appear to be far apart.



Single-Detector Row Systems

- Before 1990 all scanners contained detector elements aligned in a single row

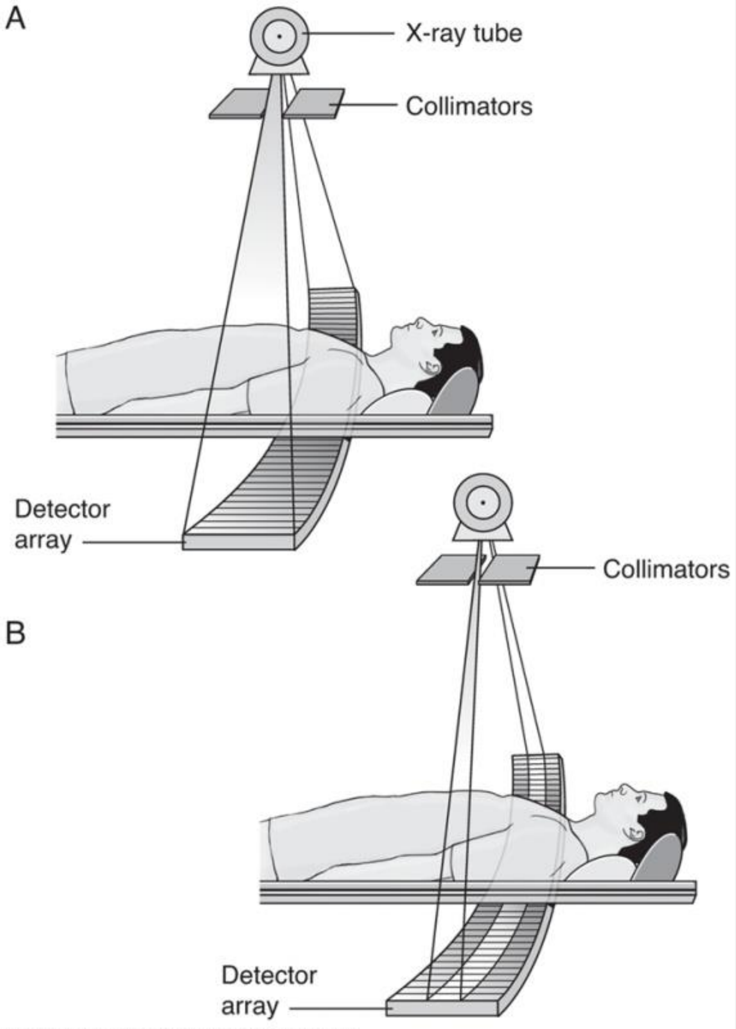


Single-Detector Row Systems

- **Each detector element is quite wide in the *z* direction (15 mm)**

- **Pre and Post collimators are set to the same width**

- **Opening or closing the collimator is what controls the slice thickness by controlling the portion of the detector's width that is exposed**
- **Entire width is not always used**



Single-Detector Row Systems

Calculating the area of patient anatomy to be covered

- Simple process of multiplying the slice increment (table movement) by the number of slices acquired
- 40 slices with a 5mm table movement = 200 mm of body scanned.
- Slice thickness and table movement do not have to be the same, but a loss of data occurs if they are not
- Ex: slice thickness of 5 mm and table movement of 7 mm
- 40 slices table movement of 7mm = 280 mm

Applications for Axial Scanning

- Axial scans are used in protocols in which the acquisition speed is NOT a major concern and optimal resolution is required

- Axial scans are used when slices are spaced or when exposure will be interrupted

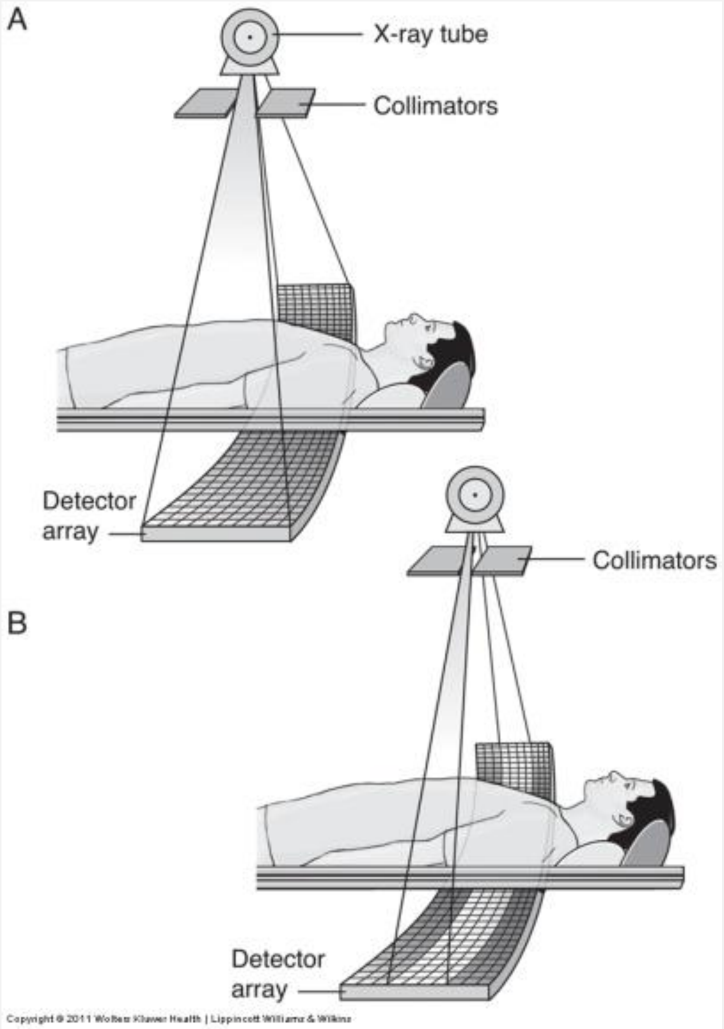
Multidetector Row Systems (MDCT)

- **MDCT may contain from 4 to many parallel rows**

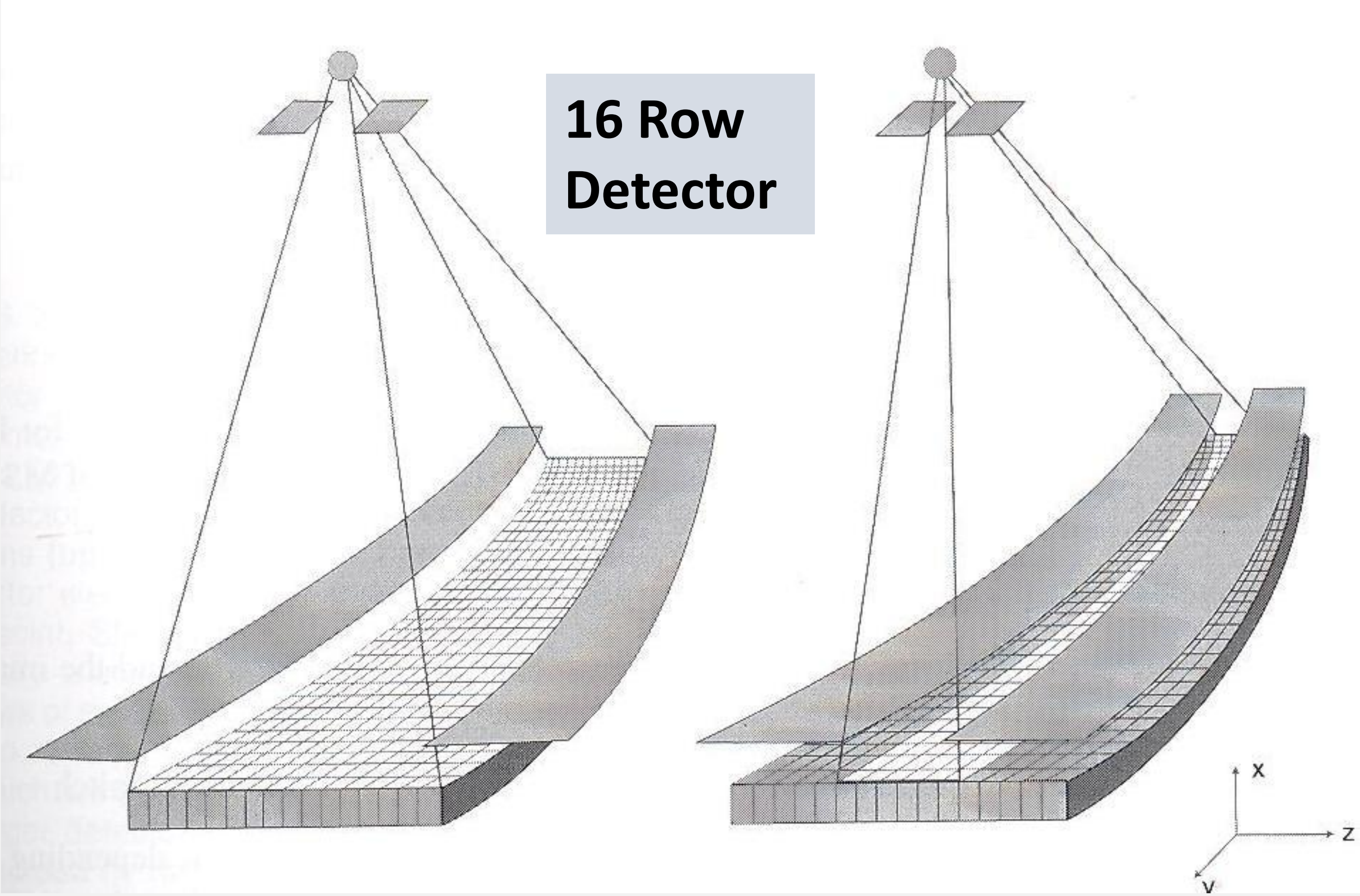
- **MDCT provides longer and faster**

  ***z* axis coverage per gantry rotation**

- **Slice thickness is determined by a Combination of the x-ray beam width and the detector configuration**



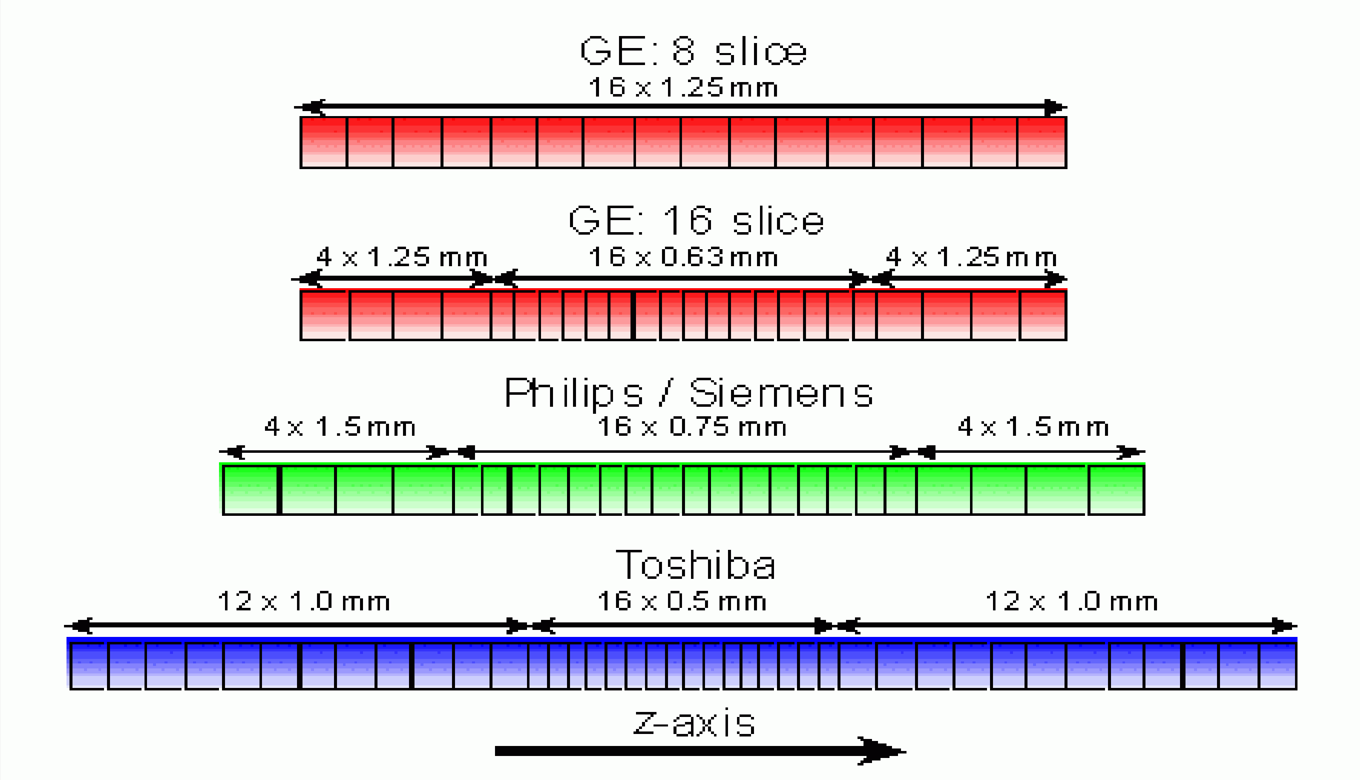
Example of Beam to Cover Multiple Detectors



16 Row Detector

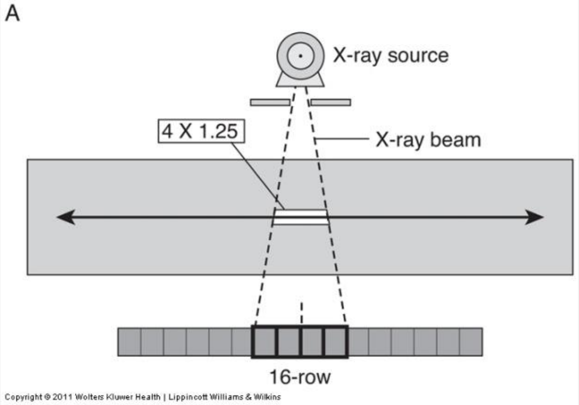
Multislice CT Detector

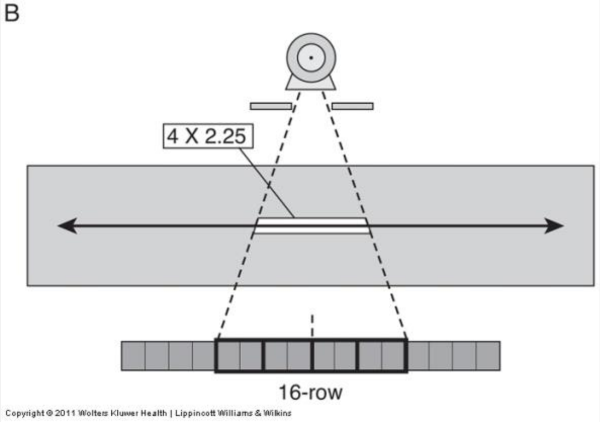
- 2 Types of Multislice detectors
  - Uniform or fixed-array or linear-array
  - Non-uniform or variable array detectors

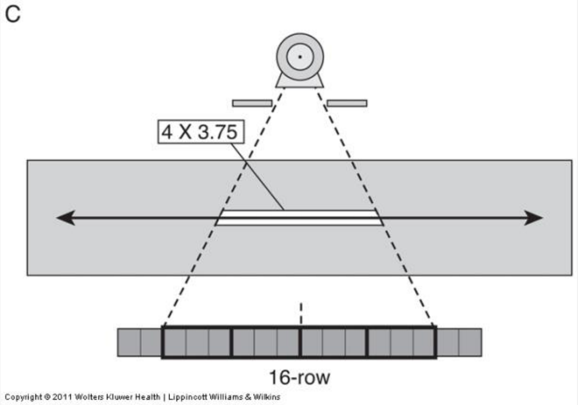


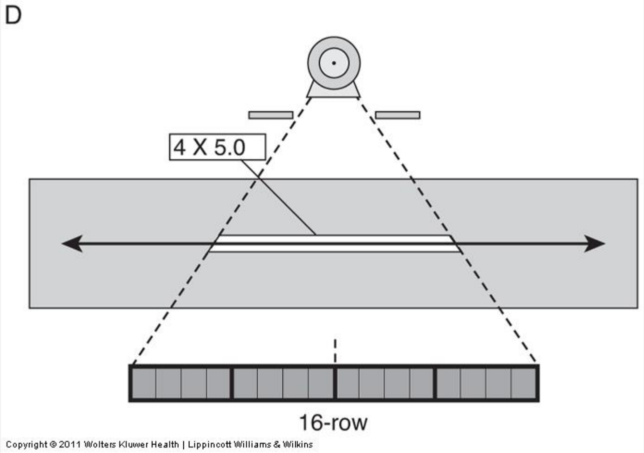
Multidetector Row Systems

- The multiple parallel rows of detector elements can be combined in various ways to yield different slice thicknesses
- Consider the possibilities with a specific four-slice system









Multislice Beam Geometry

- As the number of detector rows increase, the beam becomes wider (cone shaped).

- The beam must cover the width of the detector array

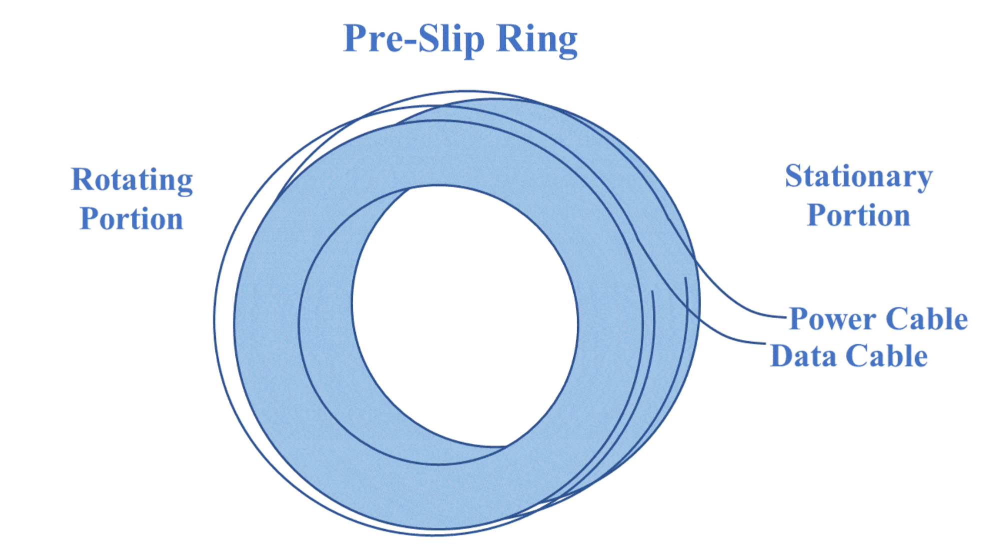
- A larger number of rows will result in a wider beam --large cone beam— in the Z-axis direction.

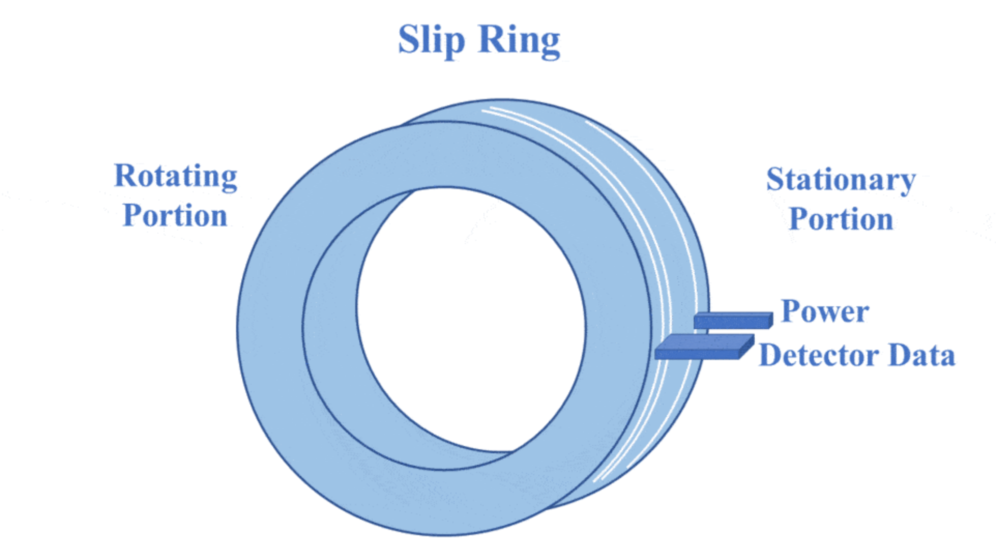
- A cone beam geometry produces more beam divergence along the z axis compared with fan beam geometry.

- Increasing the number of detector rows creates a need for a different approach to the interpolation process

Helical Scanning

- Introduced in the late 1980s
- Also called Spiral or Volumetric Scanning
- Key aspects
  - Continually rotating x-ray tube
  - Constant x-ray output
  - Uninterrupted table movement
- This required the use of Slip Rings vs Cables





Helical Scanning

- **Eliminates the interscan delay**

- **Advantages**
  - **Ability to optimize iodinated contrast agent administration**
  - **Reduces respiratory misregistration**
  - **Reduces motion artifacts from organs**

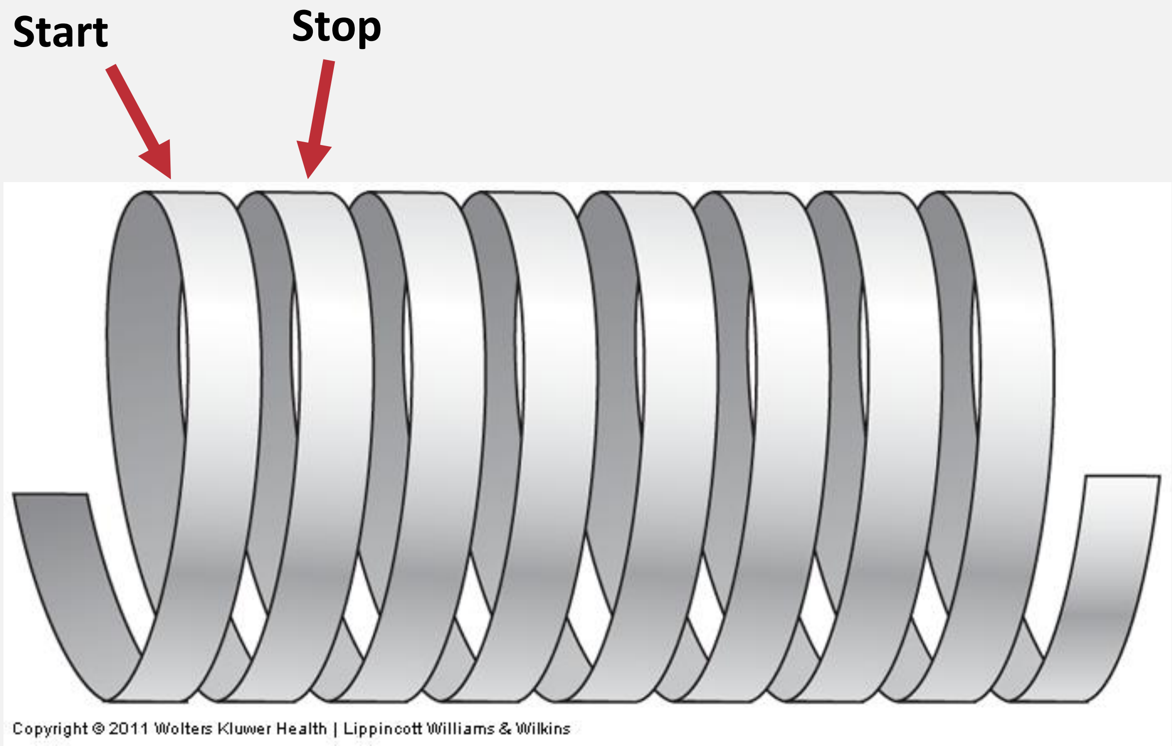
Helical Scanning

- **The Major Improvements Leading To The Development Of Helical Scanning**
  - **X-ray Gantries With A Slip Ring Design**
  - **More Efficient Tube Cooling**
  - **Higher X-ray Output (I.E., Increased Ma)**
  - **Smoother Table Movement**
  - **Software That Adjusts For Table Motion**
  - **Improved Raw Data Management**
  - **More Efficient Detectors**

Helical Scanning (cont'd)

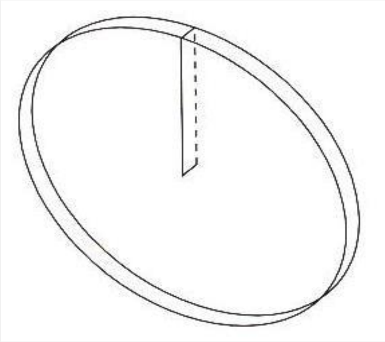
- Helical scanning produces slices in which the beginning point, and the end point are not in the same *z* axis plane.

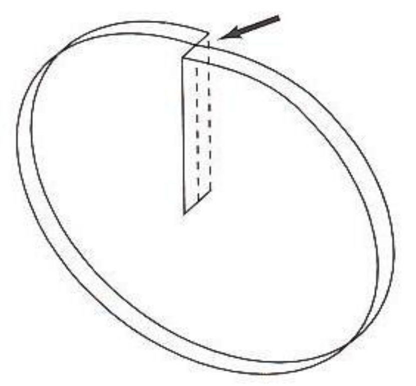
- Slices are produced at a slight tilt, like the rungs in a spring

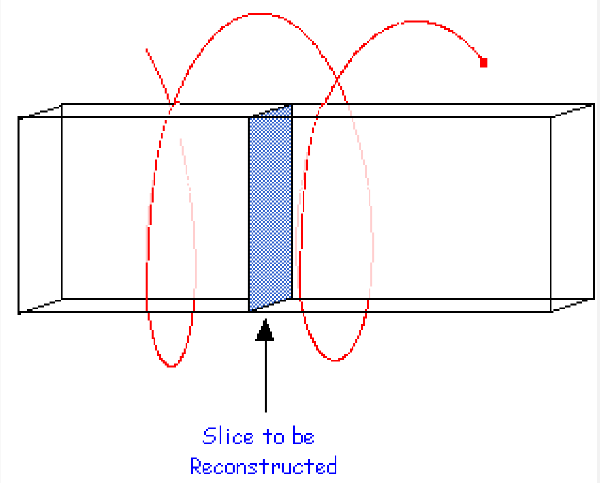


Problems With Helical Scanning

- No defined slice and thus localization of a particular slice is difficult
- The geometry of the slice volume is different for spiral/helical scans compared with conventional CT.
- In conventional CT, the data set is consistent as it is collected from one slice.
- In helical CT, the data are collected from different regions in the volume and not through a particular plane.
- The effective SLICE THICKNESS INCREASES because it is influenced by the width of the fan beam and the speed of the table
- Streak artifacts akin to motion artifacts are apparent on images where inconsistent projection data are used with a standard reconstruction process
- Solved with dedicated reconstruction algorithms by interpolation and extrapolation





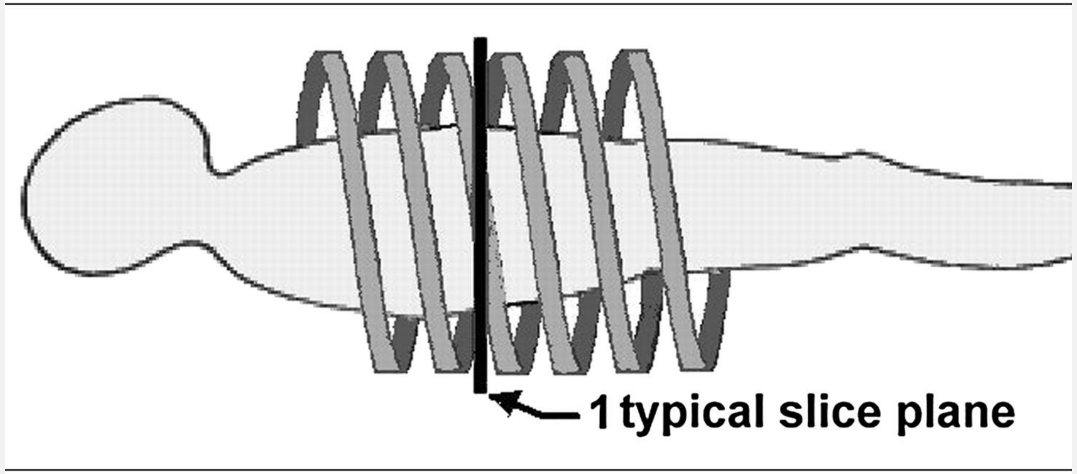


Helical Interpolation

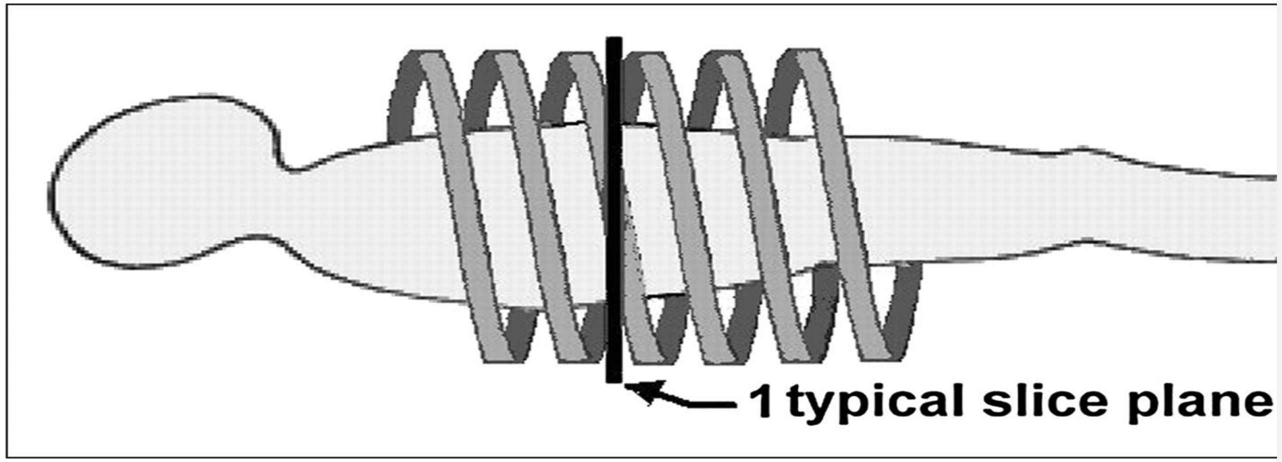
- Used to take the slant and blur out of the helical image
- These complex statistical methods result in images that closely resemble those acquired in a traditional axial mode
- Different interpolation techniques are used
- Interpolation is Always associated with some loss of image resolution

Helical Interpolation

- The steeper the angle of the slice, the more interpolation required
  - More interpolation increases the loss of image resolution



- Interpolation methods can result in a scan that is wider than that selected by the operator. This is referred to as
  - Slice thickness blooming
  - Degradation of the slice-sensitivity profile



Interpolation

360 degree and 180-degree linear interpolation algorithms are used.

360 linear interpolation

- **Originally used**
- **The planar slice is interpolated by use of data points measured 360 degrees apart. (complete circle)**
- **can substantially increase the effective slice thickness**

180 linear interpolation

- **Currently used**
- **The planar slice thickness is interpolated by use of data points 180 degrees apart. (half circle)**
- **image quality is improved because effective slice thickness is reduced**

Pitch in SDCT

- Pitch:
  - defined as the distance in millimeters that the CT table moves during one revolution of the x-ray tube.
  - Used to calculate the pitch ratio.
- Pitch Ratio
  - Ratio of the pitch to the slice thickness or beam collimation

Pitch Equation

Pitch – distance in millimeters (mm) table moves in one complete revolution of the tube (360 degrees)

Pitch Ratio= distance the table travels during 360-degree revolution
slice thickness or beam collimation

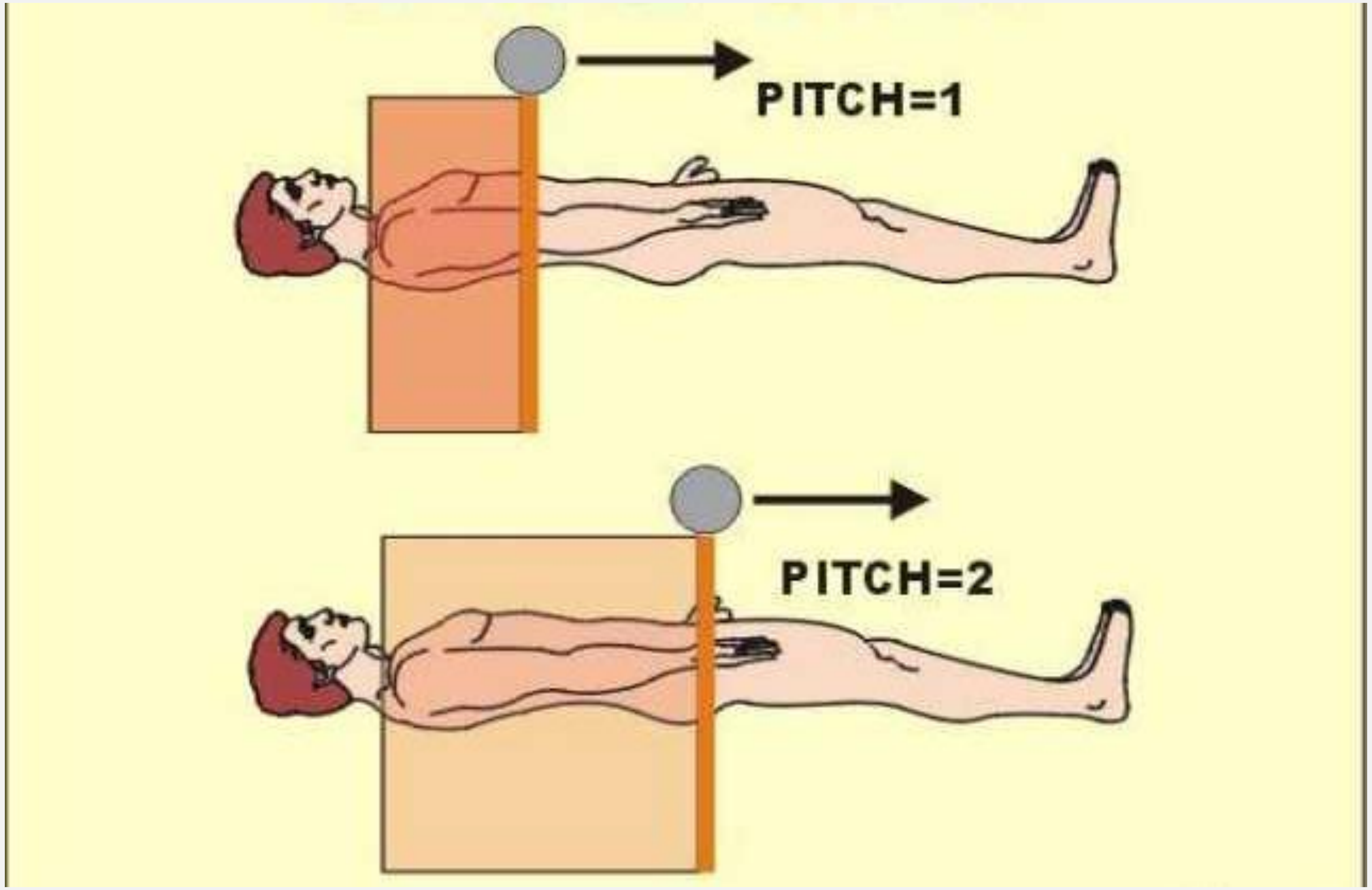
Example: 1
- Table movement of 10 mm
- Slice thickness of 5 **10 / 5 = 2 so pitch of 2**

Example 2
-Table movement of 5 mm
-Slice thickness of 10 **5 / 10 = 0.5 so pitch of 0.5**

Pitch

- When the distance the table travels during one complete revolution of the x-ray tube equals the slice thickness or beam collimation, the pitch ratio (pitch) is 1:1
- Pitch can be increased to increase volume coverage and speed up the scanning process
- Pitch in excess of 2 is NOT recommended for any clinical examination
- Low pitch (less than 1) results in better z-axis resolution but more radiation

Examples of Pitch and Anatomy Covered



Pitch in SDCT vs MDCT

Increasing the pitch will result in a scan covering more anatomy lengthwise for a given total acquisition time

- **It will reduce the radiation dose to the patient (if other scan parameters are held constant)**

- **Decreasing the pitch slows down the table speed and decreases the anatomy covered**
- **It will increase the radiation dose to the patient**

- **The concept of pitch must be expanded on for MDCT systems**

- **Although pitch is still the relationship between slice thickness and table travel, in MDCT the terms collimation and slice thickness are no longer synonymous**

- **We now must multiple by number of slices obtained in one revolution of the tube.**

Pitch in MDCT

- In MDCT, pitch is defined as table movement per rotation divided by Beam Width

- Beam width is determined by multiplying the number of slices by slice thickness

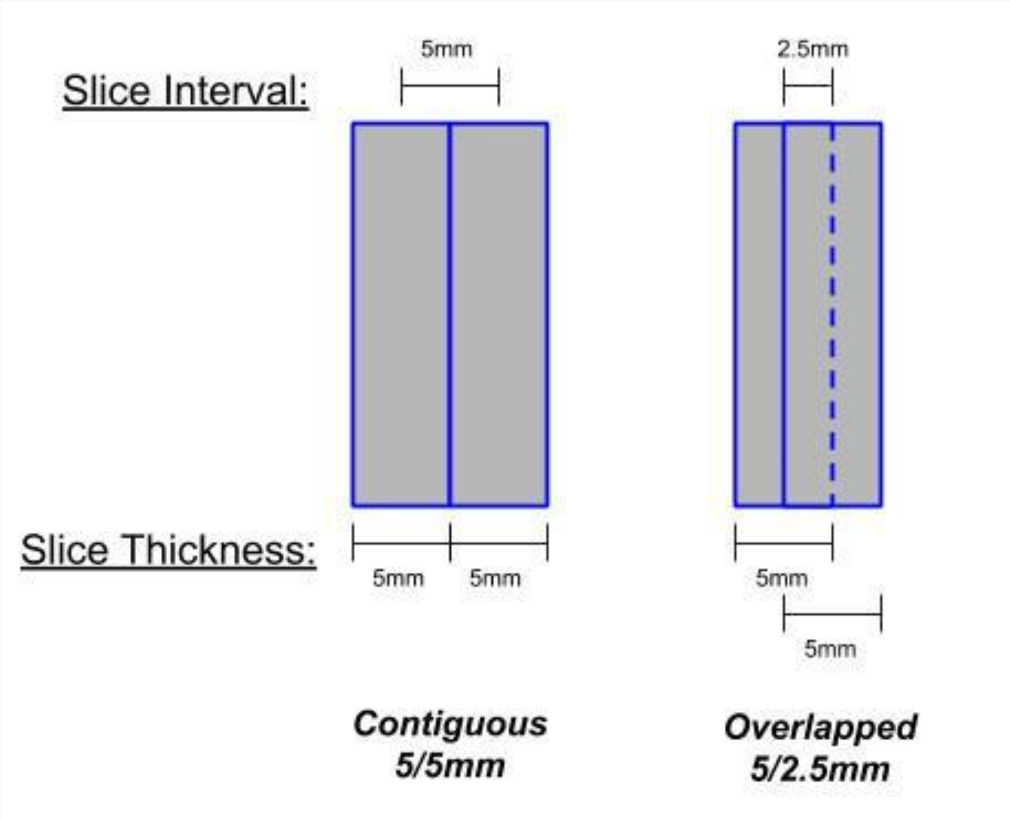
- Example: table movement of 6 mm
  slice thickness of 1.25 mm
  4 slices (4 row detector)

$$\frac{\text{Table Movement}}{\text{Beam Width}} \qquad (\#\text{ of slices x slice thickness})$$

So $\dfrac{6}{4 \times 1.25}$ $\dfrac{6}{5}$ = 1.2 pitch

Changing Slice Incrementation

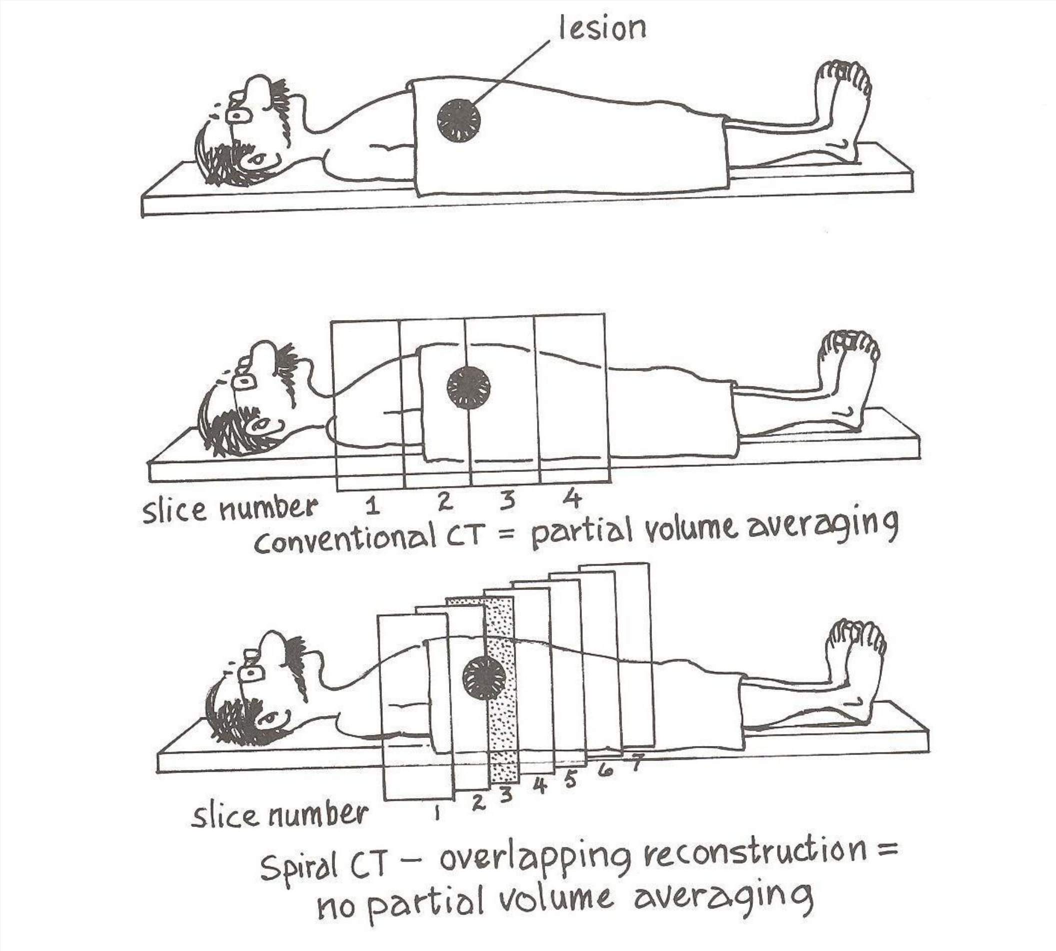
- **Helical data allow the slice incrementation to be changed retrospectively**
    - **Allows the creation of overlapping slices, without increasing the radiation dose to the patient**
    - **In some instances, changing the slice incrementation can reduce the partial volume effect**



Example of changing Slice Increment Or Spacing

- **Also known as the reconstruction interval or reconstruction spacing**

- **Slice increment determines the degree of sectional overlap used to improve image quality**



Dual-Source CT

- **This design uses two sets of x-ray tubes and two corresponding detector arrays in a single CT gantry**
- **The primary goal of this design is increased scan speed**
- **A second potential advantage is that the two x-ray tubes can use different kVp settings**
    - **This allows additional information to be collected about attenuation of contrast as compared to tissue**