DAY 2
CT PREP & EXAM REVIEW

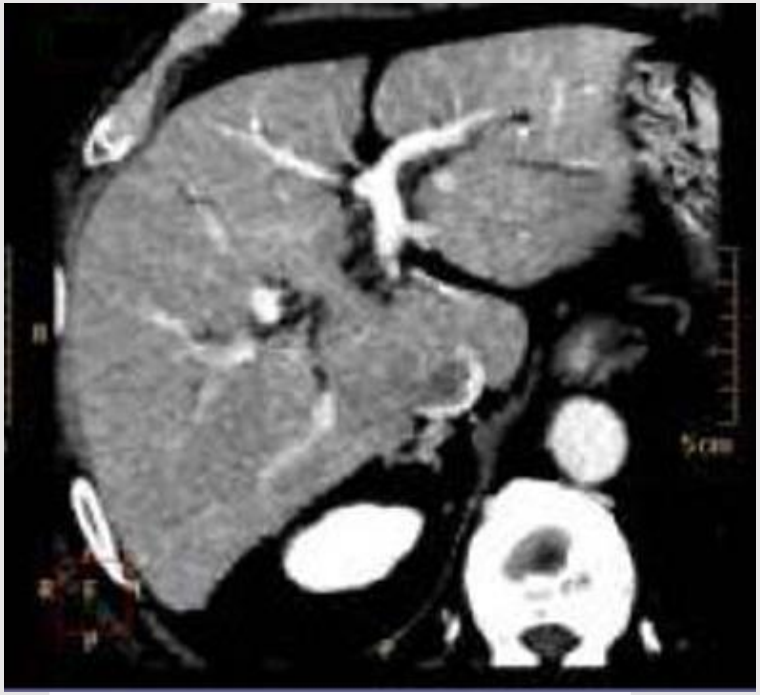
BY: THERESA LOBRIN, MHA, RT, (R)(CT)

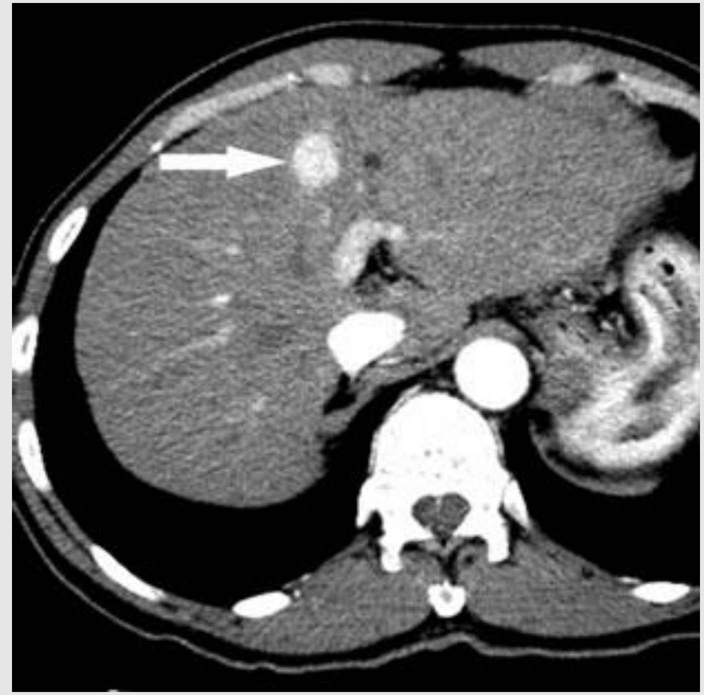
Introduction

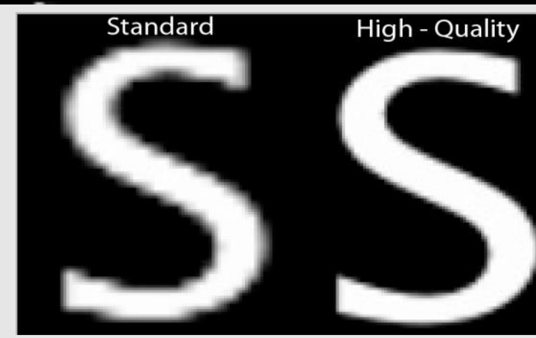
- Theresa Lobrin, RT, (R)(CT)
- Houston Community College
- Capella University
- CT Coordinator HCC

Image Quality in CT

IMAGE QUALITY







Scan Parameters And Image Quality

- Many factors affect image quality. Those controlled by the operator are:
  - Milliampere level (mA)
  - Scan time
  - Field of view
  - Reconstruction algorithm
  - Kilovolt-peak (kVp)
  - Pitch

Other Influences of Image Quality

- Motion
- Subject Contrast
  - Size of pt., contrast media, density of tissue
- Image Receptor (detectors)
- Focal Spot
- Viewing Conditions
- Observer Performance
- Pixel size
- Type and Generation of Scanner
- Beam Geomery

Milliamperes and Scan Time

- Referred to as mAs (mA X time)

- mA and time together define the QUANTITY of the x-ray energy

  - 200 mA x .5 sec = 100 mAs
  - 100 mA x 1 sec = 100 mAs

- Higher mA settings allow shorter scan times to be used
  - A short scan time is critical in avoiding image degradation as a result of patient motion

Heat And The Tube

- Heat Is The Limiting Factor In All Scanners

- Usually 2 filaments are available
  - Small for mA's less that 350
  - Larger for mA's greater than 350

- Larger body parts require more mAs than smaller

- Significant factors that distinguish various Scanners
  - Maximum mA
  - Minimum interscan delay
  - Heat dissipation rates

Tube Voltage or Kilovolt Peak

- Commonly referred to as kVp
- Defines the QUALITY (average energy) of the x-ray beam
- In CT, kVp does not change contrast as directly as it does in film-screen radiography
- Compared with mA selection, choices of kVp are more limited
- Usually fixed at 80, 100, 120 or 140 kVp

mAs and kVp and Radiation Dose

- **Selection of mAs and kVp is critical to optimize radiation dose and image quality**

- **It is more common to manipulate the mAs, rather than the kVp, when modifying the radiation dose, because**
  - **The choice of mA is more flexible**
  - **The effect of mA on image quality is more straight-forward and predictable (high kVp is needed for penetration)**

The Uncoupling Effect

- **With digital technology, image quality is not directly linked to radiation dose, so even when the mA or kVp setting is too high a good quality image is produced**

- **This is not true when a setting is too low. An unacceptable image will result due to Quantum Noise (discussed later)**

- **This fact makes CT physics somewhat different from that of film-screen radiography**

Automatic Tube Current Modulation

- Software that automatically adjusts the mAs to fit the specific anatomic region

- Results in a 15% to 40% reduction in dose, without degrading image quality

- In some CT units this is done based on the AP and Lateral scout Views

- Other CT Units adjust in Real Time

- Currently only the mA is adjusted but future designs may adjust the kVp also

Slice Thickness and Field of View

- Slice thickness
- In discussion of Image Quality,
  - it is the slice thickness (how the data were acquired) rather than image thickness (how the data are reconstructed)

- Scan field of view (SFOV) determines the area, within the gantry, for which raw data are acquired

- Display field of view (DFOV) determines how much, and what section, of the collected raw data are used to create an image

Kernel (Covolution Algorithm)

- This is used to in projecting data prior to the back projection during image reconstruction in a CT scanner.

- Affects the image structure by sharpening the image.

- Examples:

✓Soft tissue (Standard kernel)

✓Bone (Bone kernel) – has a higher spatial resolution

Reconstruction Algorithm and Pitch

- By choosing a specific algorithm, the operator selects how the data are filtered in the reconstruction process
  - Can only be applied to raw data

- Pitch
  - The relationship between slice thickness and table travel per rotation during a helical scan acquisition
  - Greater Pitch produces loss of quality

Beam/Scan Geometry

- ***Beam geometry*** refers to the size and shape of the x-ray beam emanating from the x-ray tube and passing through the patient to strike a set of detectors that collects radiation attenuation data.
- **Tube rotation during the acquisition for each slice**
  - **Full scan (360°) is most common**
- **Partial scan (180° + degree of arc of the fan angle)**
  - **Also referred to as half-scans**
- **Overscans (400°)**
  - **Used mainly in fourth-generation scanners to reduce motion artifact**

Beam/Scan Geometry

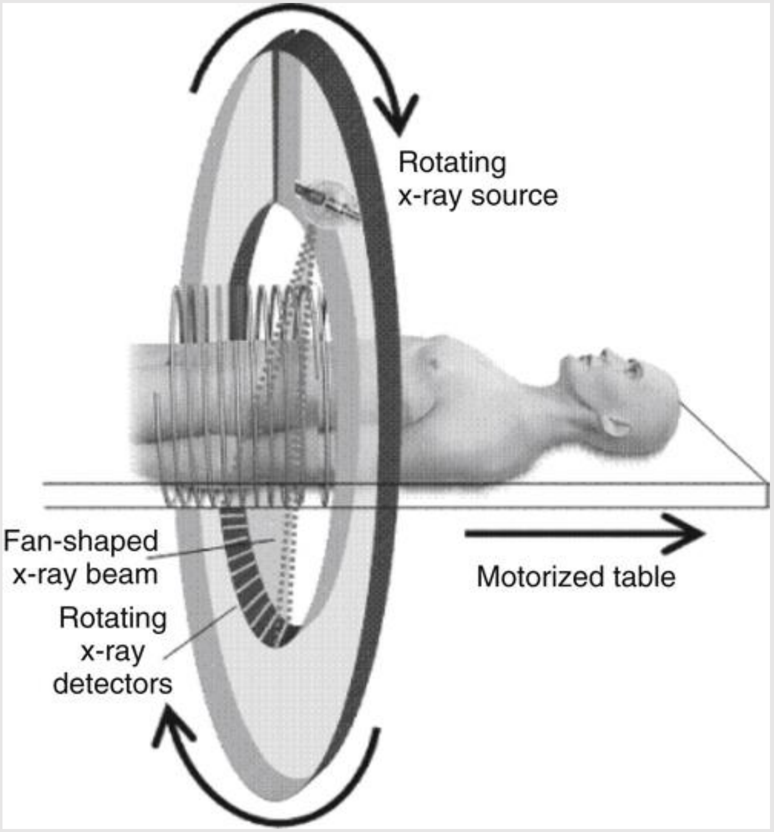


Image Quality Defined

- Image Quality is the comparison of the image to the actual object
- In many regards “quality” is a subjective notion and is dependent on the purpose for which the image was acquired
- We will only consider those that are more objective
- In CT, the image quality is directly related to its usefulness in providing an accurate diagnosis
- These measures help to compare one imaging system to another

Image Quality

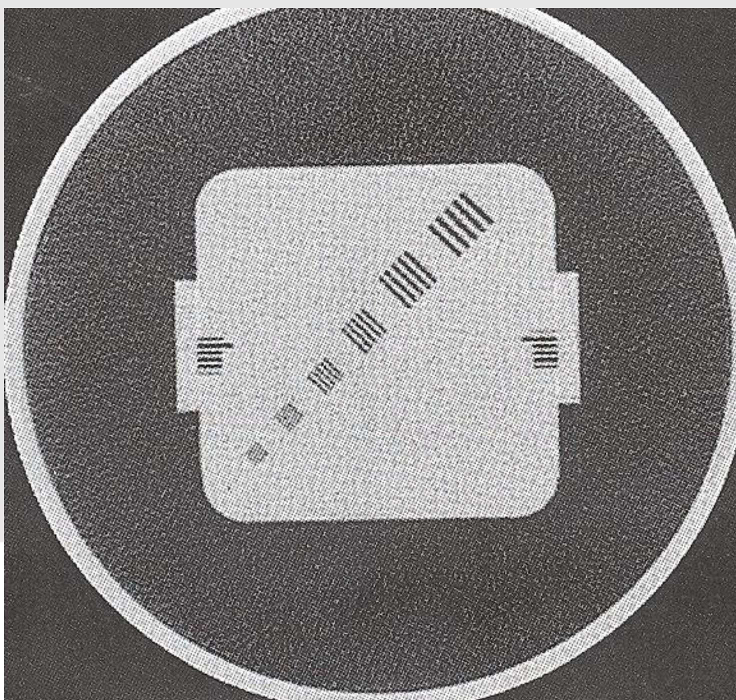
- **Two main features are used to measure image quality**
  - **Spatial resolution: the ability to resolve (see as separate objects) small, high-contrast objects**
  - **Contrast resolution: the ability to differentiate between objects with very similar densities to their background**

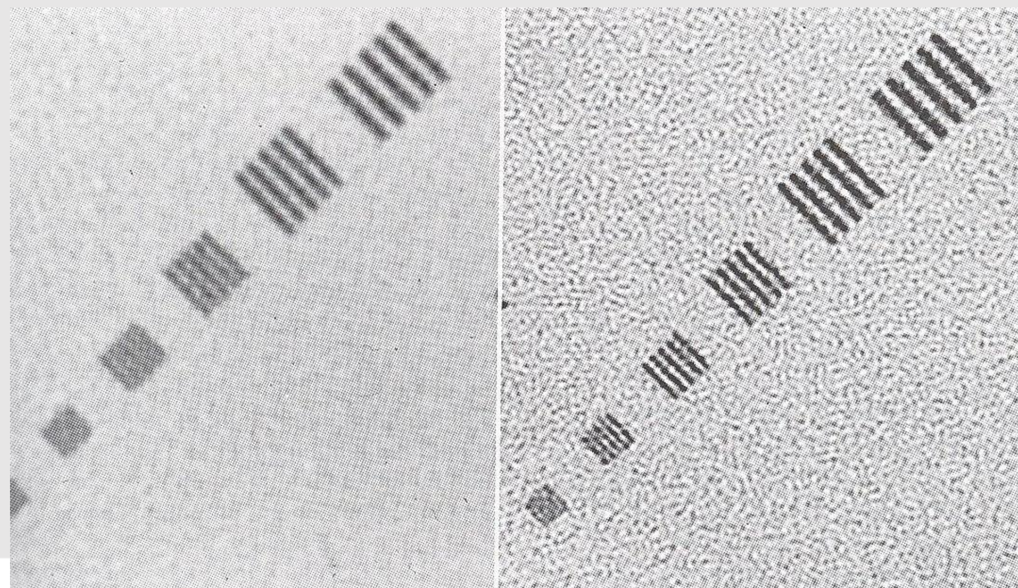
Spatial Resolution

- Also called detail resolution
- Measured using two methods
  - Directly
    - using a line pairs phantom
  - Data Analysis
    - Modulation Transfer Function (MTF)
    - MTF is often used to graphically represent a system's performance
    - MOST commonly used descriptor of spatial resolution in CT and radiography

Direct Measurement -- Line Pairs per CM or MM

- Spatial resolution using a line pair phantom
- Phantom Scanned and visible strips are counted





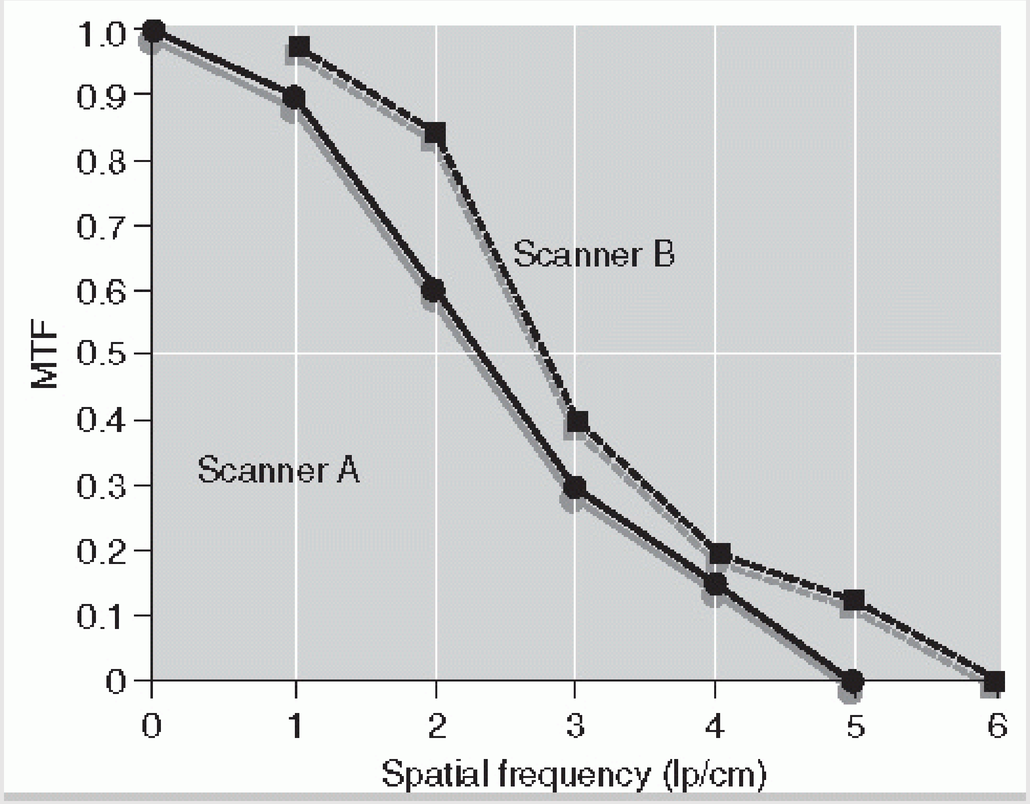
Standard Bone

MTF (Modulation Transfer Function)

- Used in CT to describe spatial resolution ability.
- Used as a graphical representation of a CT scanner's capability to pass information to the observer.
- Ex: if an object is too large, it may not fit and will cause low spatial resolution.
- Ex: if an object is small, the item seen will be considered high spatial resolution.

Spatial Resolution Using MTF (Modulation Transfer Function)

- The MTF is the ratio of the accuracy of the Image compared with the Actual Object Scanned
- MTF scale from 0 to 1
- 1 being perfect
- MTF curve farther to Right has Higher Resolution
- Scanner B has a Better Resolution



Factors Affecting Spatial Resolution and are controlled by the technologist

- Matrix size
- Display field of view
- Pixel size
- Slice thickness
- Reconstruction algorithm
- Focal spot size
- Pitch
- Patient motion

Matrix Size DFOV & Pixel Size

- **Matrix Size and DFOV determine Pixel Size**

- **Pixels are square (x and y dimensions)**

- **Matrix size refers how many pixels are present**

Calculating Pixel Size

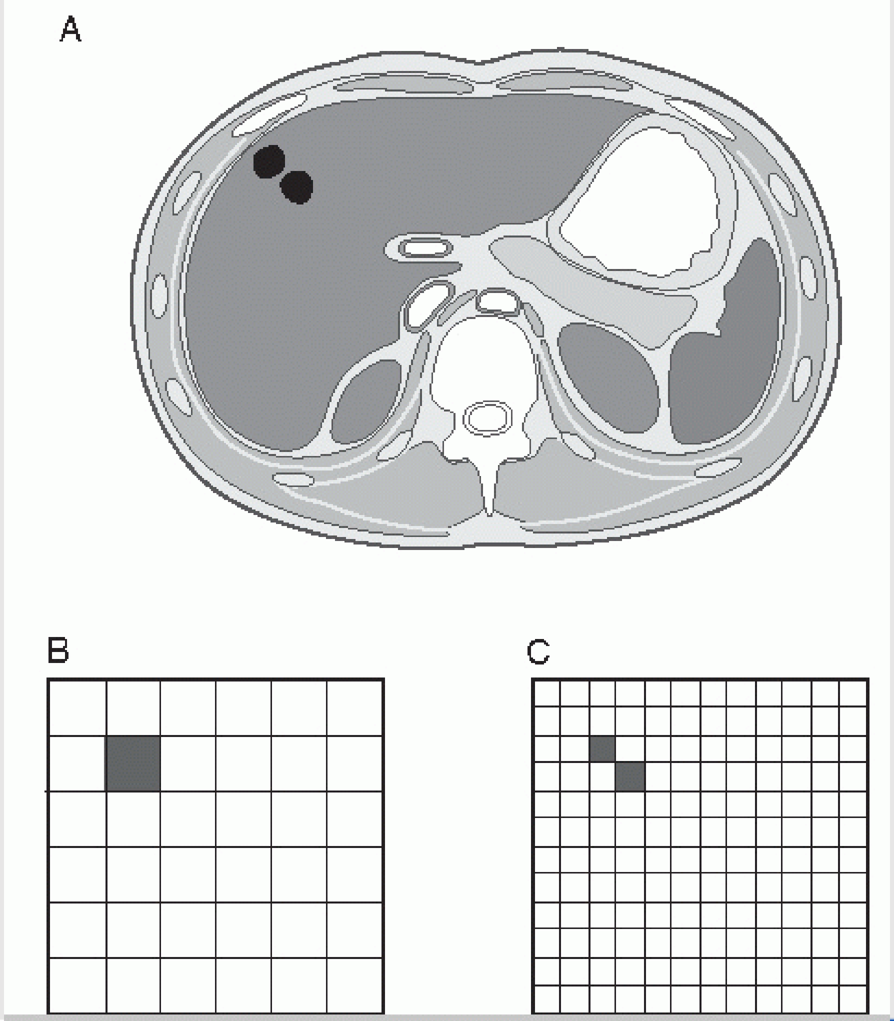
- Pixel Size (mm)= DFOV / Matrix Size
  - DFOV may be given in cm or mm
  - If given in cm multiply by 10 to convert to mm

- DFOV of 50cm (10)/matrix of 512= .97 mm pixel
- DFOV of 25cm (10)/matrix of 512= .48 mm pixel
- DFOV of 50cm (10)/matrix of 256= 1.9mm pixel
- DFOV of 25cm (10)/matrix of 256= .97mm pixel

- Best detail Image obtained by:
  - Small FOV
  - Large matrix

Pixel Size and Detail

- A. Two small objects in the patient
- B. When reconstructed to lie within a single pixel, they will be represented on the image as a single object
- C. If a smaller pixel is used, the objects can be displayed as two distinct shapes.



Slice Thickness (Voxel)

- Thinner slices produce sharper images
- To create an image the system must flatten the scan thickness (volume) into two dimensions (a flat image)
- The thicker the slice the more flattening necessary

Calculating Voxel Size

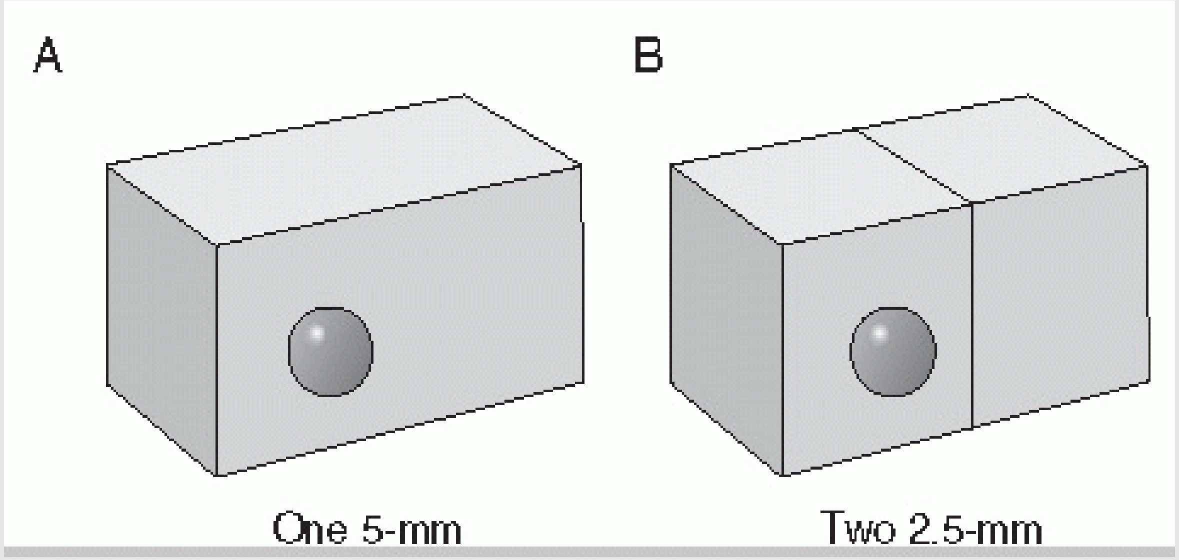
(DFOV x 10) divided by Matrix times Slice Thickness

- DFOVmm / Matrix X Slice thickness
- DFOV of 500/matrix of 512= .97mm X 5mm = 4.88mm2 Voxel
- DFOV of 500/matrix of 512= .97mm X 2mm = 1.95mm2 Voxel
- DFOV of 500/matrix of 256= 1.9mm X 5mm = 9.76mm2 Voxel
- DFOV of 250/matrix of 256= .97mm X 2mm = 1.95mm2 Voxel

- **Best Detail or Resolution:**
  - Small pixel
  - Thin slice thickness

Voxel Size and Detail

- A. A 2-mm object is contained in a 5-mm slice, resulting in significant volume averaging on the image.
- B. Slice thickness is decreased to 2.5 mm and volume averaging is significantly decreased.

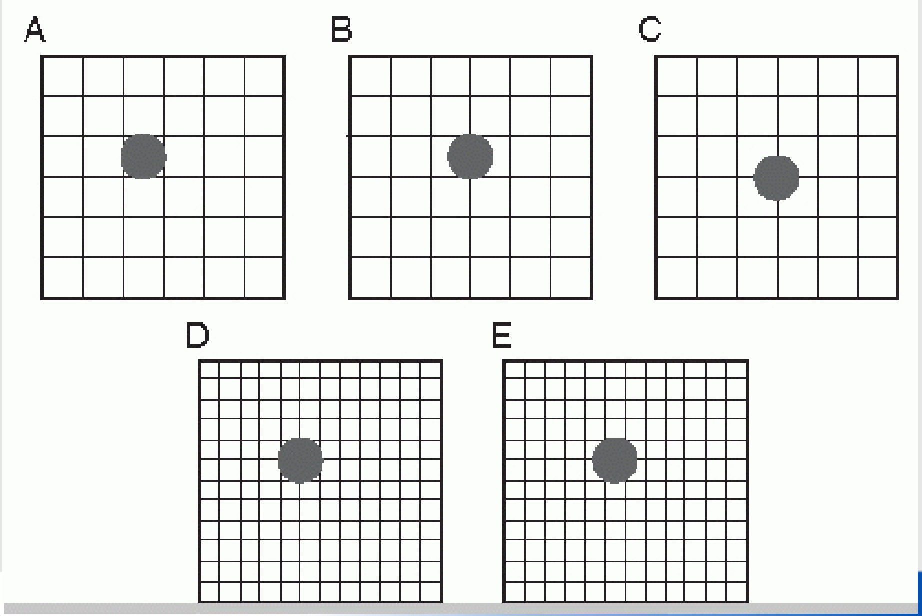


Sampling Theorem

- Random chance plays a role in whether a small object will be seen on the reconstructed image.

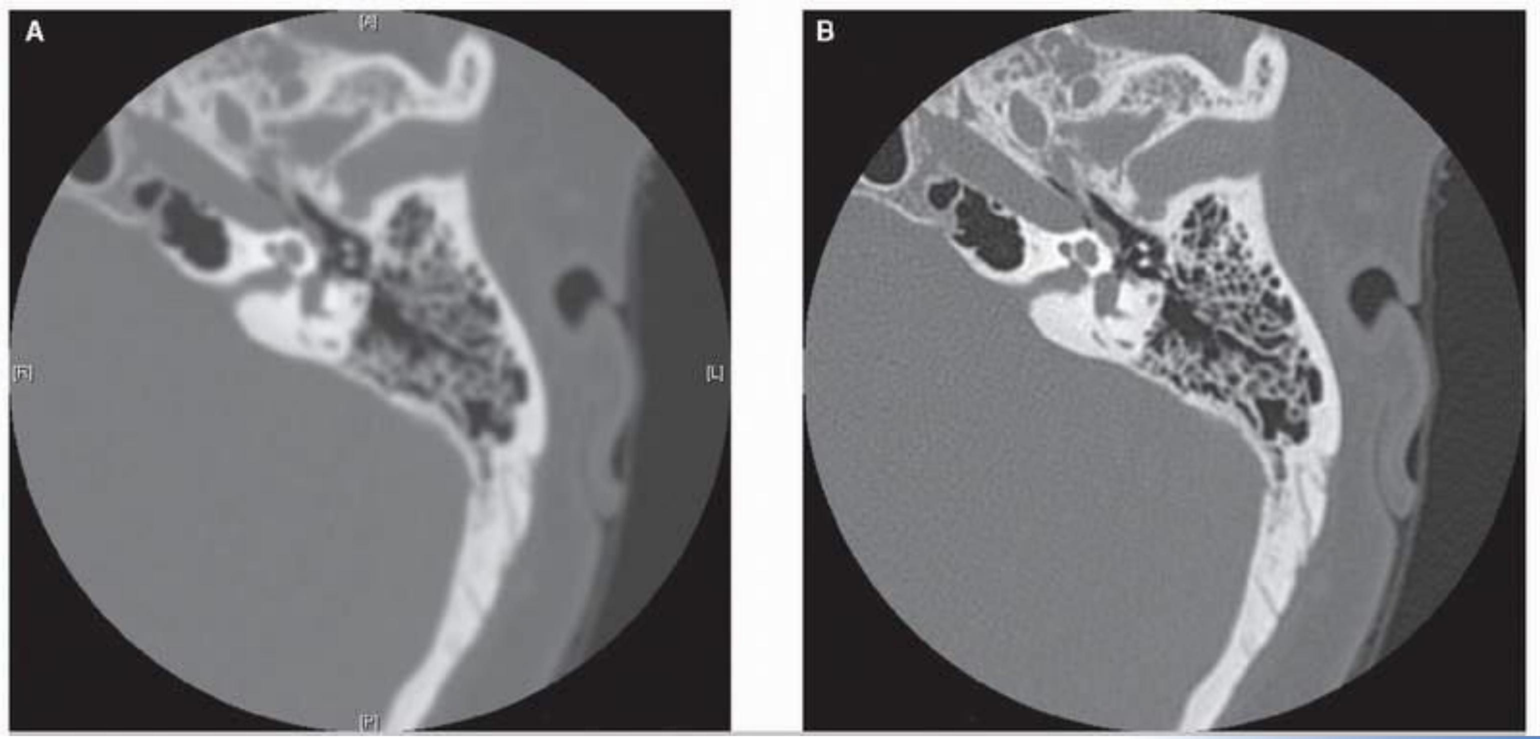
- In (A), (B), and (C) the object to be displayed is the same size as the pixel. The three figures show different scenarios as to how the object could be reconstructed, each resulting in a different level of volume averaging.

- In (D) and (E), a smaller pixel size is used, and the scenarios regarding the likelihood of volume averaging improve.



Detail and Reconstruction Algorithm

- (A) was reconstructed using a standard filter.
- (B) was reconstructed with a bone filter
- Notice the increased spatial resolution



Focal Spot and Pitch

- Smaller Focal spot gives better detail but in CT the effect is minimal
- Increasing Pitch reduces resolution or detail
- In practice, pitch may vary from 1 to 2

Spatial Resolution

Contrast Resolution

- Also called low-contrast detectability or system sensitivity

- CT is superior to all other clinical modalities in its contrast resolution

  - For comparison, in screen-film radiography, the object must have at least a 5% difference in contrast from its background to be discernible on the image.

  - On CT images, objects with a 0.5% contrast variation can be distinguished

  - 1% contrast difference corresponds to a difference of 10 HU

Contrast Resolution (cont'd)

- CR is measured using phantoms that contain objects of varying sizes and with a small difference in density (typically from 4 to 10 HU) from the background

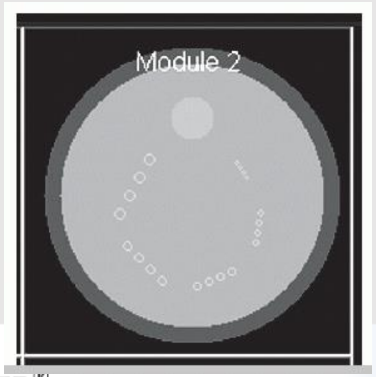
- Noise plays an important role in low-contrast resolution
  - Noise is the undesirable fluctuation of pixel values in an image of homogeneous material
    - "salt-and-pepper" look
  - The presence of noise on an image degrades its quality

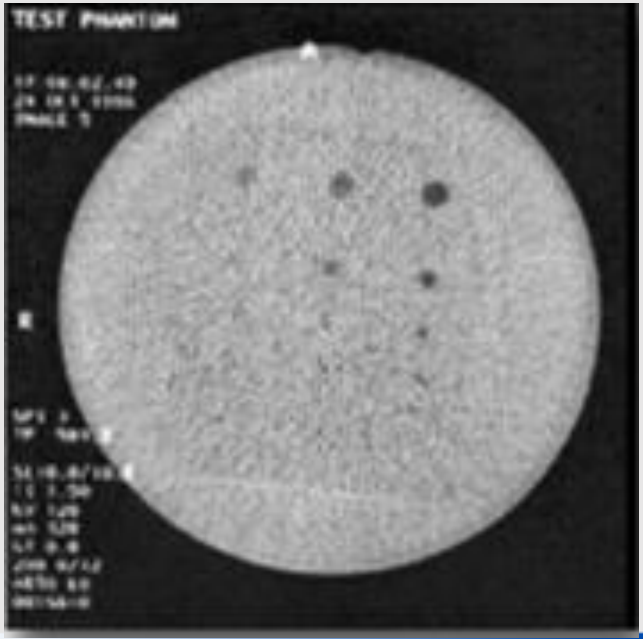
Contrast Resolution (cont'd)

- Contrast Resolution is Improved by using:
  - Higher mAs
  - Thicker slices
  - Smaller patients
  - Larger pixels (large FOV and small matrix)
  - Smoothing filters
- Note that some of these factors make spatial resolution worse
- Quantum Noise decreases contrast resolution

Contrast Resolution Phantom

- A scanner's low-contrast resolution can be measured using a phantom that contains objects of varying sizes and with a small difference in density from the background.
- The more objects visible, the better the system's low-contrast resolution capability.





Distortion

- **Any error in an image.**
- **Because CT numbers represent gray shades in the image, incorrect measurements will produce incorrect CT numbers that do not represent the attenuation coefficients of the object. These errors result in various artifacts that affect the appearance of the CT image.**

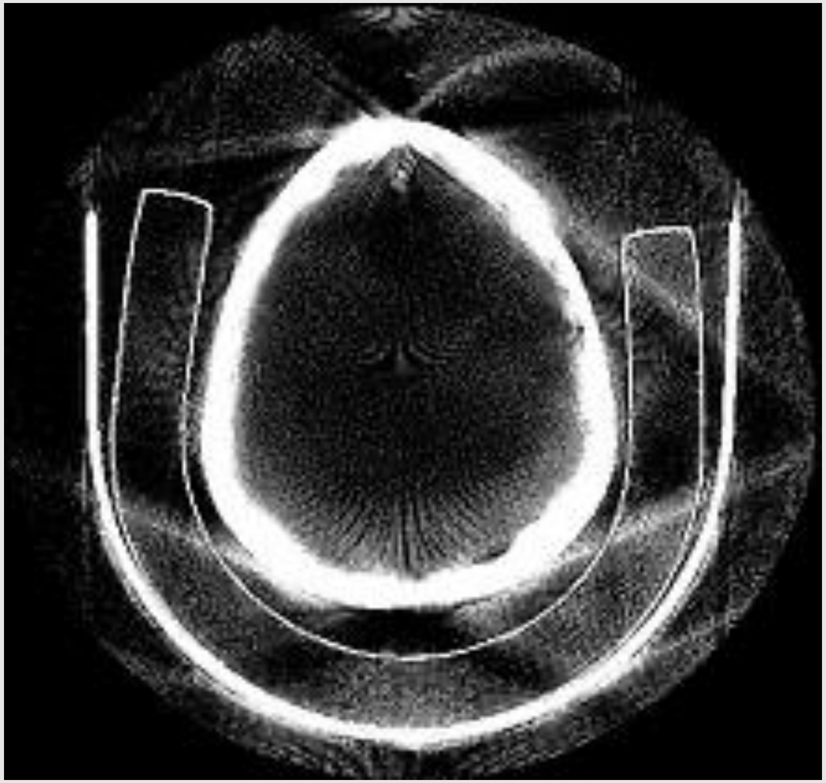


IMAGE NOISE

- Noise is the fluctuation of CT numbers between points in the image for a scan of uniform material
- Noise may be measured by scanning a water phantom and computing a mean and a standard deviation by use of an ROI
- Signal to Noise Ratio (SNR) is an expression of the desired signal to the background
- Higher the ratio the better the image
- Scatter radiation results in image noise
- Increasing slice thickness, pixel size, and patient dose*mAs* results in less noise
- High noise images appear blotchy, grainy, or spotty.
- Low noise images appear very smooth
- Anything that will reduce noise will improve contrast resolution.

Other Contrast Resolution Factors

- Subject contrast
  - Size of the object (small object harder to see)
- Inherent contrast
  - Physical properties of the object and its background
- Displayed contrast
  - Window settings used to display the image

Patient Centering

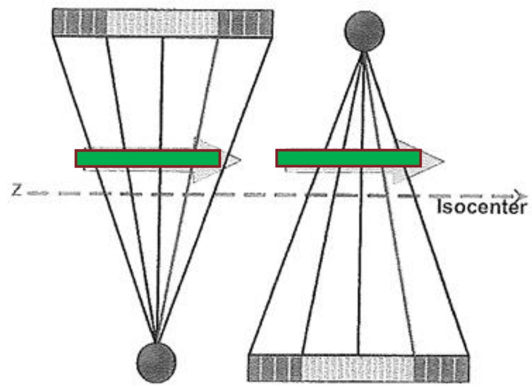
Patient Positioning

Correct positioning of the patient within the aperture of the gantry is of paramount importance with multi-slice CT.

Because of the divergent characteristics of the X-ray beam in the Z-direction, it is important to place the patient so that the body is evenly distributed around the ***isocenter*** (exact center) of the gantry. Doing so will insure that the dose is uniformly distributed around the patient. This also will insure that the beam "sees" the anatomy in a consistent manner.

Non Isocenter Positioning

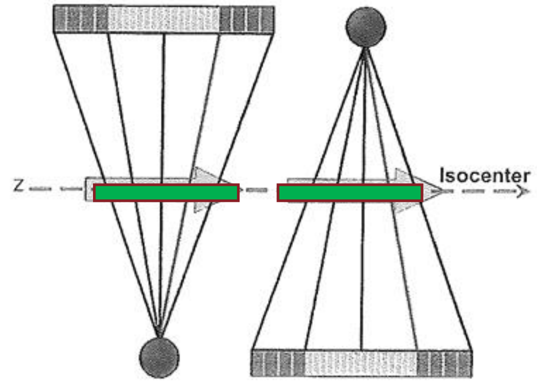
- In the diagram to the left, the patient (blue-green arrow) is positioned slightly above isocenter.
- In the left diagram, notice where the X-ray beam passes through the blue-green colored arrow when the tube is at the bottom position (red line).
- In the right diagram, the beam passes through a different part of the arrow. The beam in effect "sees" the arrow from a different position.



- Regardless of positioning, the system can calculate the correct spatial information for the area scanned and produce diagnostic images, but may display artifacts in the resulting images. This type of artifact is called ***cone beam*** artifact. The severity of the artifact, if seen, will depend on how off-center the patient is and beam width in the z-direction.

Isocenter Positioning

- When the patient is centered properly, it is much easier for the system to spatially encode what it sees and therefore cone beam correction is more effective.
- **Positioning your patients at isocenter is one of the most important image quality steps you can take.**



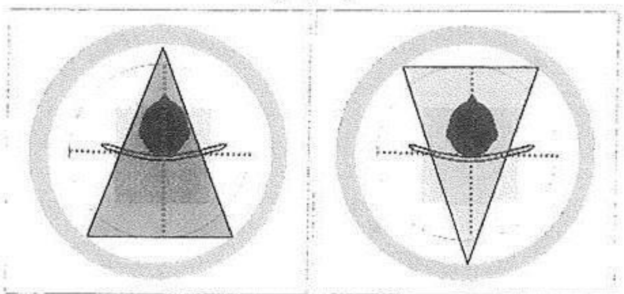
Patient Positioning (continued)

To further demonstrate the importance of positioning, we can look at scanning the head. In the head you may want to angle the gantry to match a particular radiographic baseline.

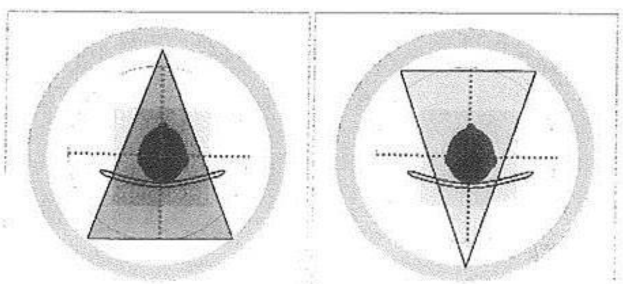
As with many scanners, the amount of angle that can be achieved will depend on how high the table is raised; the higher it is, the more angle available. All Siemens scanners can tilt to a maximum of ±30° (the Spirit tilts up to ±25°) when using Sequence and, on some systems, Spiral scanning.

However, **angling of the gantry should not take priority over placing the head at isocenter!** If you are raising the table to get more angle, you may be placing your patient away from isocenter. If you cannot get the desired alignment without moving your patient above isocenter, then you may want to consider using angle sponges to tilt the head rather than relying on the gantry tilt.

- As in the previous diagrams, the drawings to the left show the same type of situation, the beam is not evenly distributed around the head; it does not "see" it in the same position as it goes around.
- Another factor to consider is the effects of the ***inverse square law***.
- When the beam is at the top, it penetrates the head with more intensity than it does when the tube is at the opposite angle.
- These conditions will often lead to image quality issues.



- Compare these images to ones above.
- Better dose distribution.
- Better use of the beam as it rotates around the head.



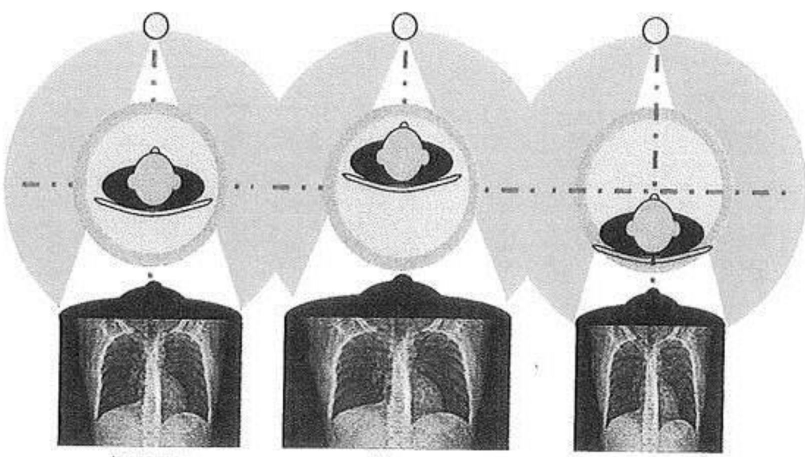
Isocentering and CARE Dose 4D™

One of the most important image quality practices that you can employ is placing your patient at isocenter. It is also important to insure that your patient is placed at isocenter for CARE Dose 4D™ to accurately estimate the attenuation curve for any given patient. To do otherwise may actually create a situation where the dose is estimated either too high or too low.

Because CARE Dose 4D™ uses the topogram to determine the attenuation curve, eccentric positioning will cause CARE Dose to misinterpret the patient's true size, thereby creating an inaccurate curve.

If a patient in positioned too high in the aperture, the resulting topogram will magnify the patient's width and, thus, create an attenuation curve for a person the systems sees as larger, causing a higher than necessary mAs to be estimated. Similarly, if the patient is too low in the aperture, the system sees the patient as thinner, causing lower mAs to be estimated. The Patient Protocol page below demonstrates the problem with non-isocenter positioning.

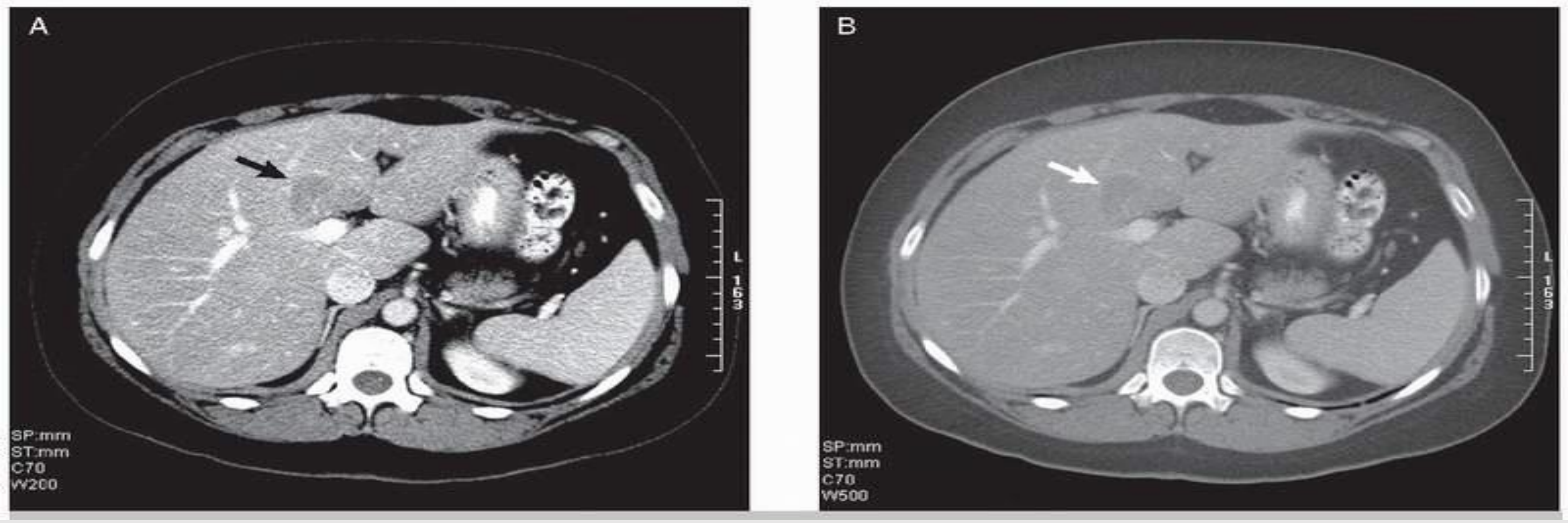
	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position H-SP							
Topogram	1	120				5.3	0.6
Isocenter	2	120	88 / 160	6.78	165	0.5	0.6
Patient Position H-SP							
Topogram	1	120				5.3	0.6
Above Isocen.	2	120	95 / 160	7.33	178	0.5	0.6
Patient Position H-SP							
Topogram	1	120				5.3	0.6
Below Isocen.	2	120	54 / 160	4.16	101	0.5	0.6



Isocenter   Above   Below

Effects of Window Settings on Contrast

- The effect of window settings on low-contrast resolution. An oblong, hypo-attenuating mass is seen in the medial segment of the left hepatic lobe (arrow).
- In (A) the liver lesion is more easily discernible when the image is displayed with a narrow window width.
- In (B) the same image is displayed with a wider window width—the liver lesion is nearly indistinguishable



Temporal Resolution

- How rapidly data are acquired
- Controlled by
  - Gantry rotation speed
  - Number of detector channels in the system
  - Speed with which the system can record changing signals

- Reported in milliseconds
  - 1,000 milliseconds = 1 second

- Temporal resolution is of particular importance when scanning rapidly moving parts (heart) or for contrast flow studies

Image Artifacts

- Defined as anything appearing on the image that is not present in the object scanned

- Have many different presentations and causes

- They can be broadly classified as
  - Physics-based
  - Patient-based
  - Equipment-induced

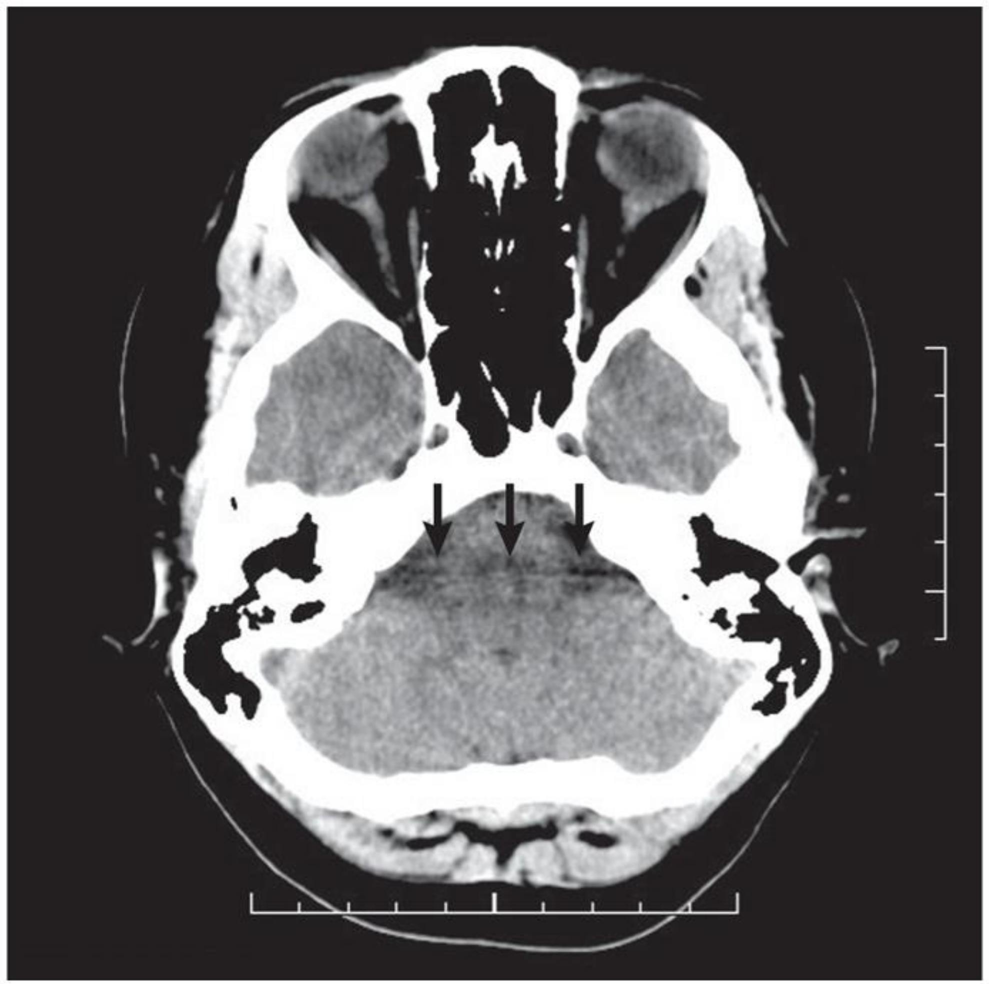
Beam-Hardening Artifacts

- Caused by the polychromatic nature of the x-ray beam used in CT
  - As an x-ray beam passes through an object, lower-energy photons are preferentially absorbed
  - Creates a "harder" beam that cannot be adjusted for by the system
- CT systems minimize beam hardening in three ways
  - Filtration
  - Calibration correction
  - Beam-hardening correction software

Example of Beam-Hardening Artifacts

- Cupping artifacts
  - Lighter at edge and darker at center

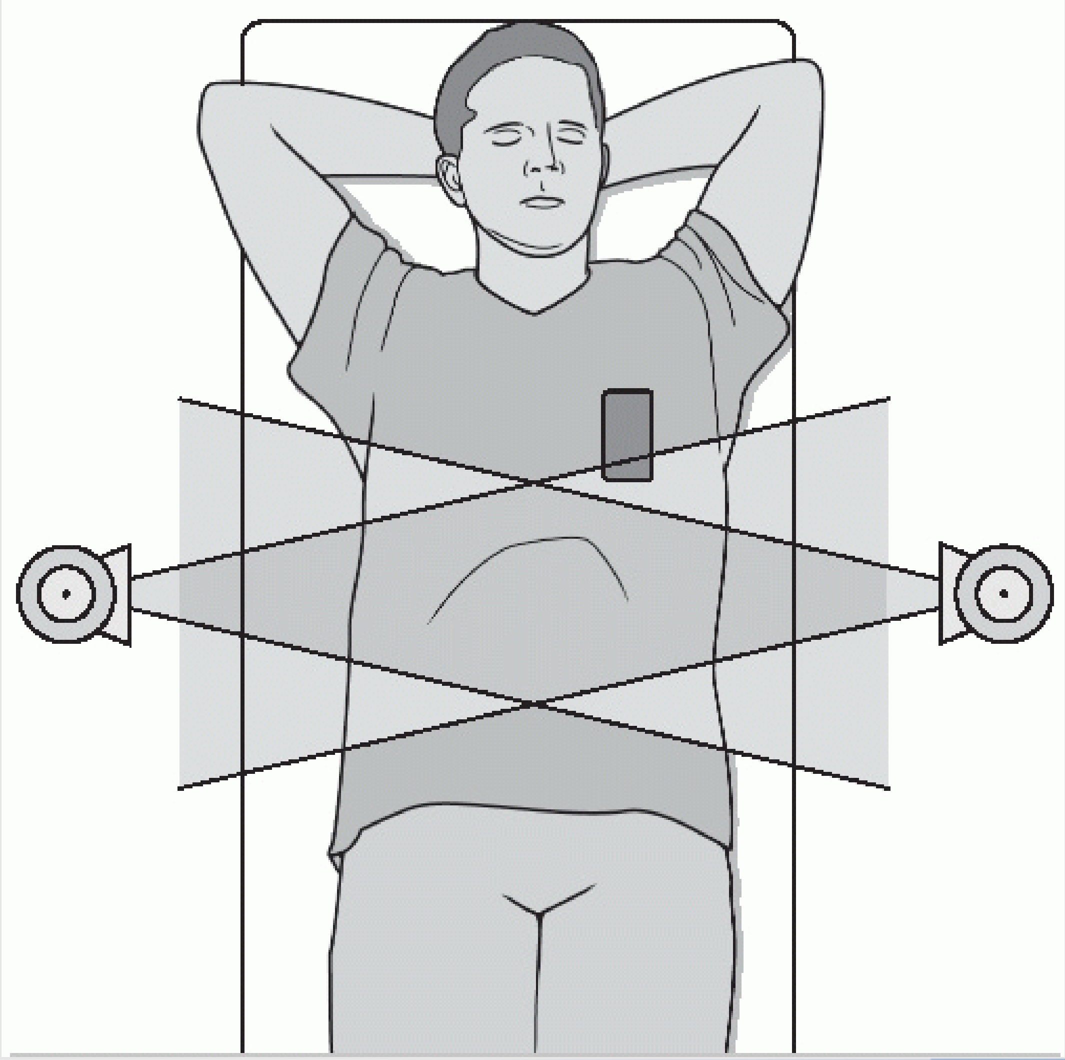
- Dark bands or streaks between dense objects in the image



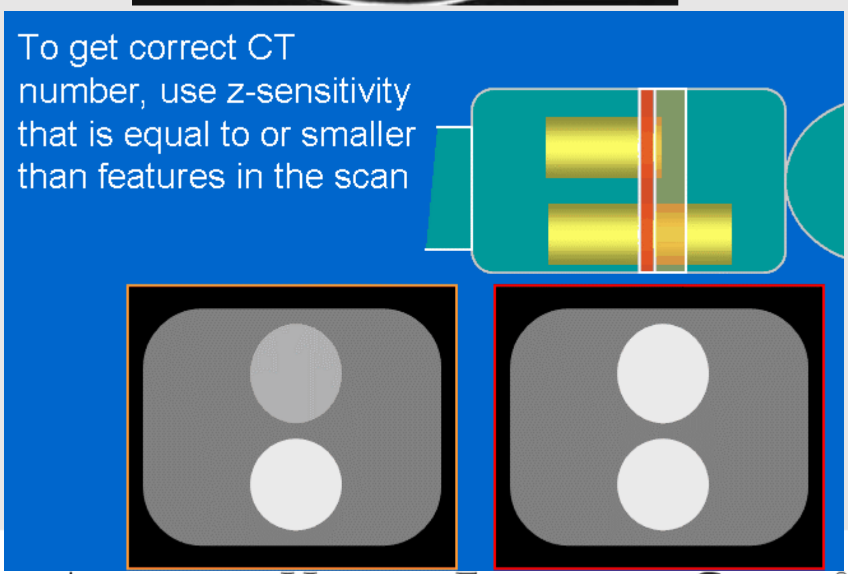
Partial Volume Artifacts

- Occurs when more than one type of tissue is contained within a voxel

- Partial volume artifacts can occur when dense objects lie to the edge of the SFOV and are only present in some of the views used to create the image.



PARTIAL VOLUME



- Partial volume averaging- CT number calculations of several types of tissue for one voxel (It is due to the scanner being unable to differentiate between a small amount of high-density material (e.g. bone) and a larger amount of lower density (e.g. Soft tissues). The processor tries to average out the two densities or structures, and information is lost)
- The object is not fully within a slice thickness
- Reduced with thinner slices and computer algorithms

Aliasing Artifacts

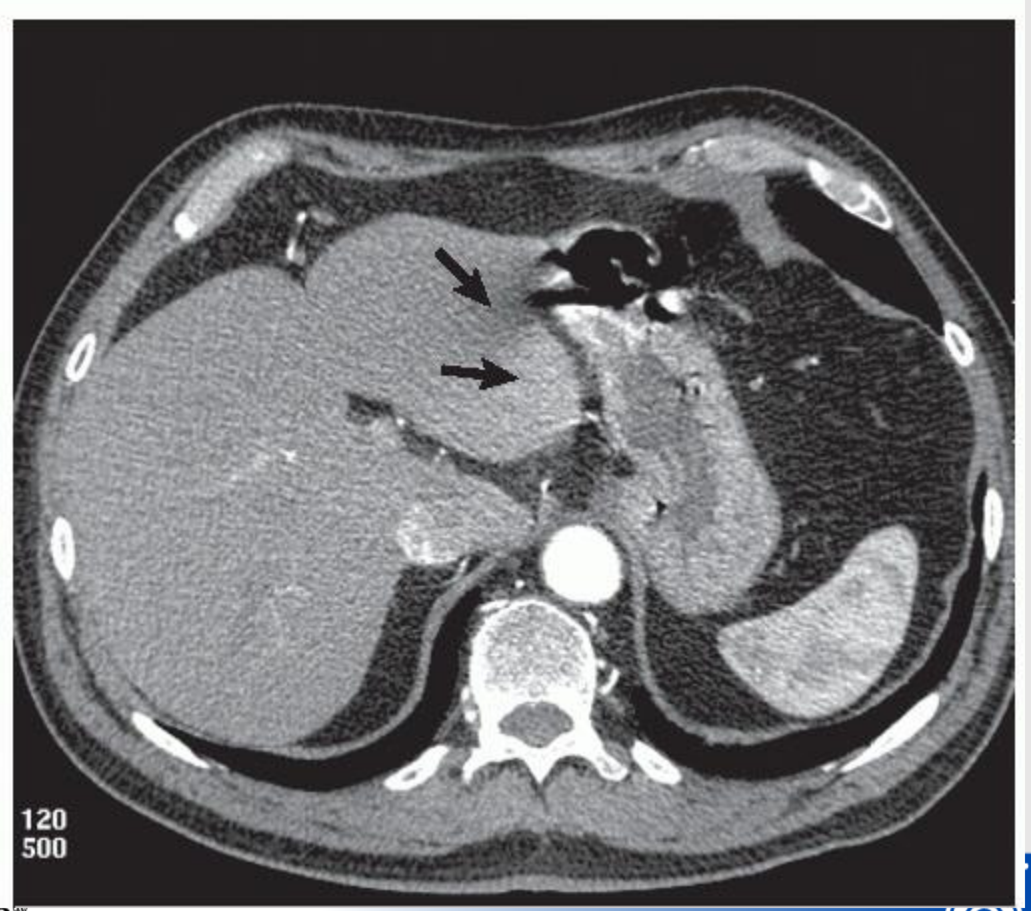
- **Caused by:**
  - Inadequate number of projections (too great a pitch)
  - Inadequate amount of data from a projection
- **Results in fine lines radiating from a dense structure**
- **Corrected by reducing Pitch and/or slowing gantry speed**

Edge Gradient Artifacts

- Appear as streaks
- Caused by irregularly shaped structures with a density very different from surrounding structures
- The inconsistent attenuation information causes errors in the reconstruction process
- Seen at the interface of bone and soft and air and barium and sometimes the edge of the table
- Reduce the artifact by repositioning the patient and obtaining thinner slices or using water as contrast

Edge Gradient and Beam Hardening

- The irregular shading in the left lobe of the liver (indicated by arrows) in this image is caused by a combination of edge gradient effect and beam hardening. The artifacts arise from the pronounced difference in density between the air and barium in the stomach.



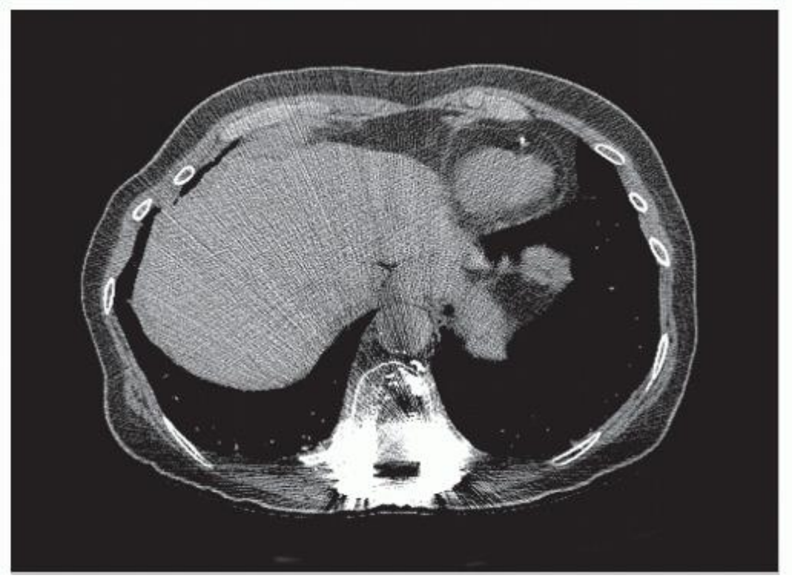
Motion Artifacts

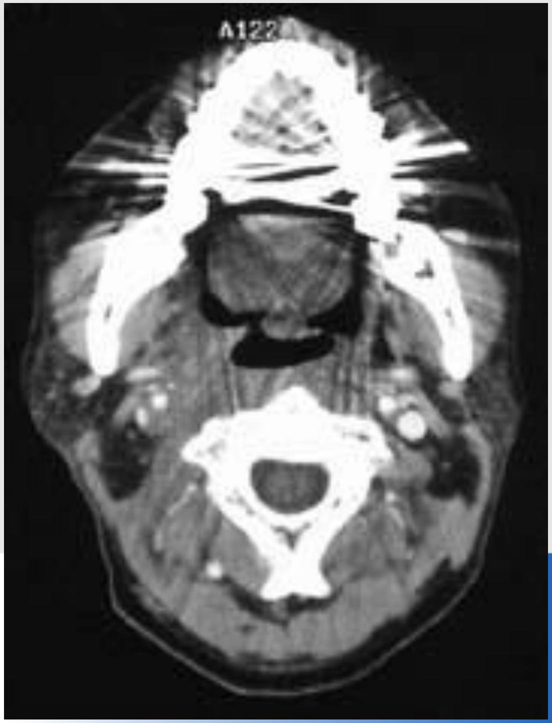
- **Artifacts from patient motion appear as shading, streaking, blurring, or ghosting**

- **Overt patient motion is reduced by adequately preparing the patient**
- **Involuntary motion is reduced by using the shortest scan time possible**

Metallic Artifacts

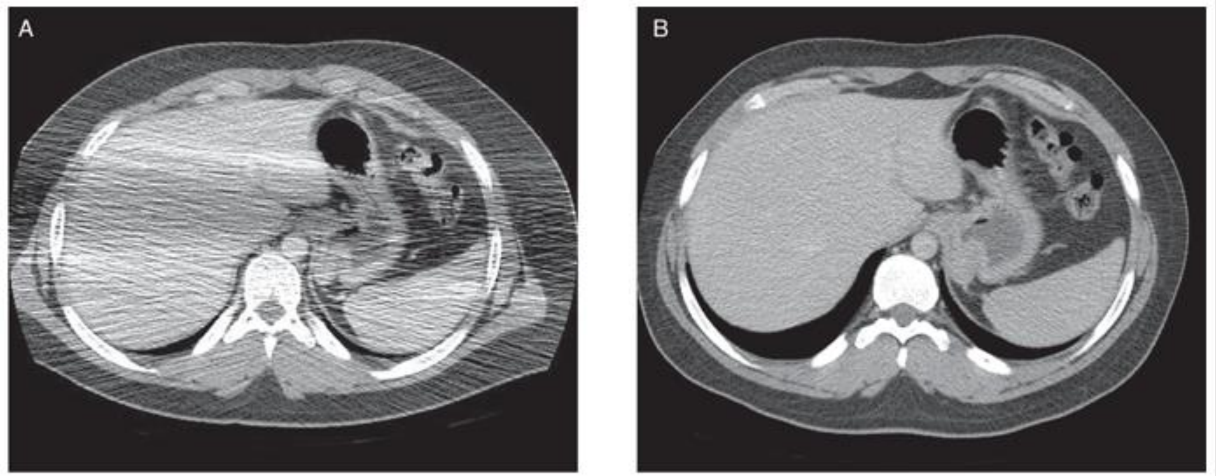
- Metal objects in the SFOV will create streak artifacts
- Best reduced by removing the metal
- Nonremovable objects can sometimes be avoided by angling the gantry





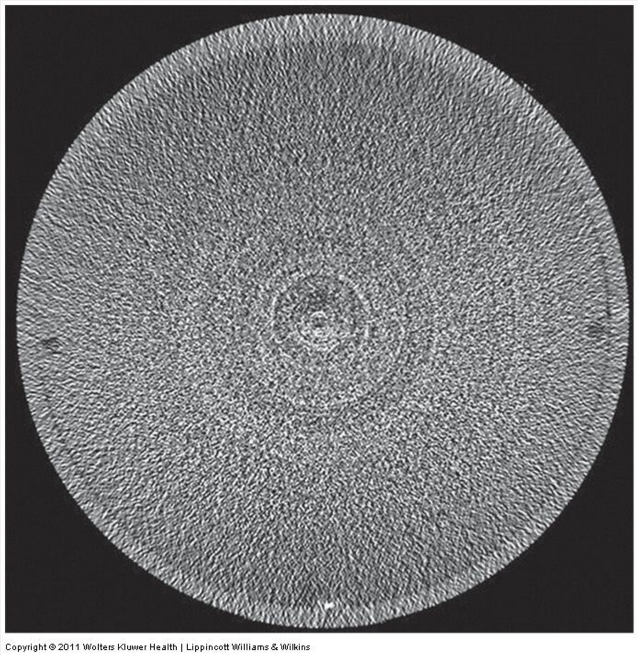
Out-of-Field Artifacts

- Caused by anatomy that extends outside of the selected SFOV
- Appear as streaks and shading on the image
- Image A – Arms at side of patient outside SFOV
- Image B -- Arms raised out of SFOV



Ring Artifacts

- Caused by imperfect detector elements
- Appear on the image as a ring or concentric rings



- Most often seen in 3rd generation scanners
- Can sometimes be eliminated by recalibrating the scanner

Tube Arcing

- **From electrical surges within the x-ray tube**
- **Also called high-voltage arcing**
- **No specific pattern in their appearance**
- **Can be minor or severe**
- **Typically produce an error message**
- **Require a service call**

Spiral and Cone Beam Effect

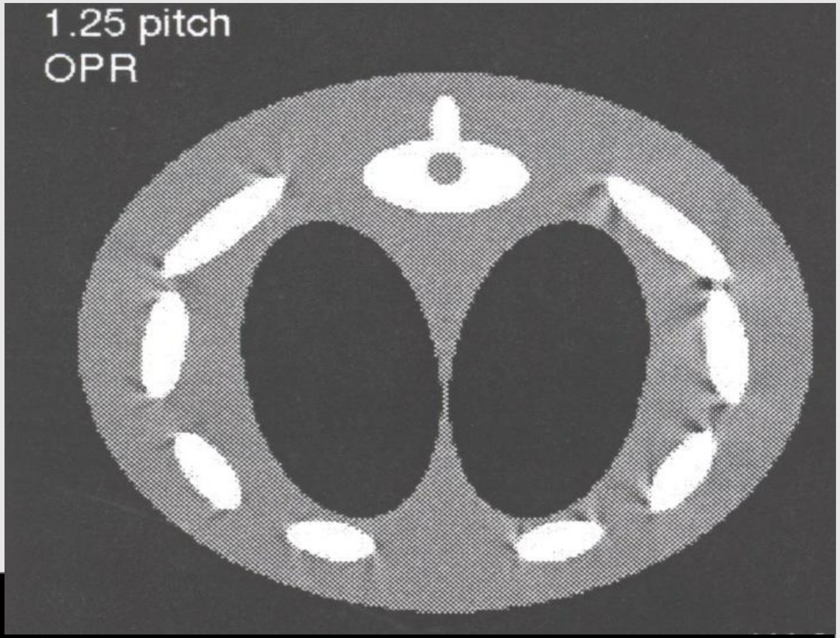
- Only on helical scans
- Attributable to the interpolation and reconstruction process
- Result in subtle inaccuracies in CT number and can be easily misinterpreted as disease
- Avoidable by using a low pitch

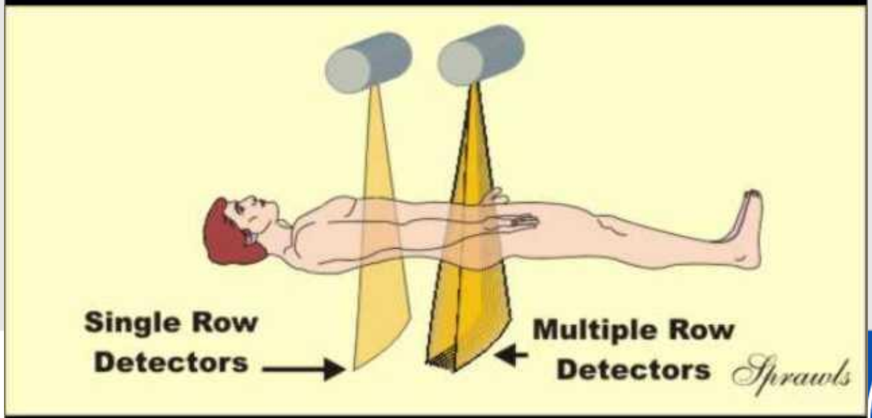
Spiral and Cone Beam Effect (cont'd)

- Helical MDCT systems may also experience windmill artifacts
- Caused by the cone-shaped (rather than fan-shaped) beam
- Appear as either streaks or as bright and dark shading near areas of large density differences
- More pronounced for the outer detector rows
  - The more the detector channels, the more of a problem
- Explains why some 64-detector row protocols use only half of the detectors located in the center of the detector array

Cone Beam Artifacts

- Cone beam artifacts arise from early models of multi-row detector.
- The fan shaped beam became cone shaped as it widened along the Z axis.
- This caused “star” or “spoke” like artifacts on peripherally located structures
- Corrected by using <u>Cone Beam Reconstruction Algorithms</u>





ADVANCED HEALTH EDUCATION CENTER®
EDUCATION ▲ STAFFING ▲ CONSULTING

Troubleshooting Artifacts on the CT

Manifestation	Possible Cause	Corrective Steps
Beam-hardening artifact (broad streaks, cupping, vague areas of low density)	X-ray beams are composed of different energies	Use appropriate filtration, calibration, and correction software. Increase kVp setting
Aliasing effect (fine lines)	Too few samples	If a partial scan was used, rescan using a complete arc. Increase scan time. Reduce pitch.
Edge gradient effect (straight line radiating from high-contrast areas, such as barium adjacent to air)	Angle of x-ray beam varies between two similar views	Largely unavoidable. Somewhat reduced by thinner slices. Use low or neutral HU-value oral contrast in place of barium.
Motion (shading, streaking, blurring, or ghosting)	Voluntary or involuntary patient motion	Give breathing instructions use positioning or immobilization devices, consider sedation, reduce scan time For cardiac protocols, consider β-blockers.
Cone beam effect (lines appear in a windmill formation)	Only on MDCT, from the cone-shaped x-ray beam	Use pitch selections recommended by manufacturer

Troubleshooting Artifacts on the CT Image

Manifestation	Possible Cause	Corrective Steps
Metallic (streaks)	Objects present that are beyond the dynamic range of the scanner	Remove metallic objects from SFOV. Angle gantry. Increase technique, particularly kVp. Use thin slices.
Ring (a single ring or concentric rings)	Detector problem	Recalibrate; if rings persist, call service
Tube arcing (no specific pattern; can range from a single streak to severe mottling)	Electrical surge within the x-ray tube	Call service
Spiral interpolation artifacts (subtle inaccuracies in CT number)	Images are created from views that are not all in the same plane	Lower pitch

Summary

- There is a compromise between Spatial and Contrast Resolution
- Image Quality is linked to dose
  - Usually better quality equals higher dose
- Manipulating scan protocols is the responsibility of the technologist to obtain the best image in a given clinical situation

"Who's been fooling around with these x-rays?"

Q & A

Question 1

True or False: Spatial Resolution is detailed resolution that is measured in a line pair phantom.

- **Answer: TRUE**

Question 2

True or False: Image noise is beneficial to image quality.

- **Answer: FALSE**

Question 3

What effects spatial resolution?

- **Answer:**
- **Matrix size**
- **Display field of view**
- **Pixel size**
- **Slice thickness**
- **Reconstruction algorithm**
- **Focal spot size**
- **Pitch**
- **Patient motion**

QUALITY CONTROL

What Is Quality Assurance?

- A program that periodically tests the performance of a CT scanner and compares its performance with some standard
- Goal is to ensure that every image created by the scanner is a quality image
- Routine QC can help ensure the equipment is operating appropriately so that dose is optimized for the necessary image quality. Furthermore, careful development and routine review of clinical protocols by a team that includes the radiologist, the medical physicist, and the lead CT technologist will also help to avoid the inadvertent use of an inappropriate dose.

Quality Assurance Methods

- Designed to ensure that the CT system is producing the best possible image quality using the minimal radiation dose to the patient
- Provides a method for the systematic monitoring of the system's performance so problems can be identified and corrected
- Responsibility for QA programs are shared between CT technologists and medical physicists

Three Basic concepts of QA

1. The QC must be performed on a regular periodic schedule.

2. Results must be documented in a consistent format

3. The test should indicate whether the tested parameter is within specified guidelines.

Quality Control Tests

- Choosing a technique for QC measurement
  - A good rule of thumb is to use a technique that matches a frequently used clinical technique
- Test frequency
  - Some daily, weekly or monthly
  - complex tests done annually or with major part replacements, or deterioration of image quality is suspected
- Limits of a 'Passing' test
  - Depends on manufacturer and type of scanner
  - Most important it should have approximately the same results from day to day

Types of QC Tests

There are QC tests described below ranging from:

- CT number calibration
- standard deviation of CT number in water
- high-contrast resolution
- low-contrast resolution
- accuracy of distance-measuring device
- uniformity or flatness of CT number
- hard copy output
- accuracy of localization device
- CT bed indexing and CT bed backlash
- light field accuracy to **pitch** and slice width (spiral/helical scanner)
- CT number versus patient position
- CT number versus patient size
- CT number versus algorithm
- CT number versus slice width
- noise characteristics
- radiation scatter and leakage.

* It is important to note that since the use of film has become obsolete, computed radiography (CR) cassettes can be used in the tests that mention the use of film.

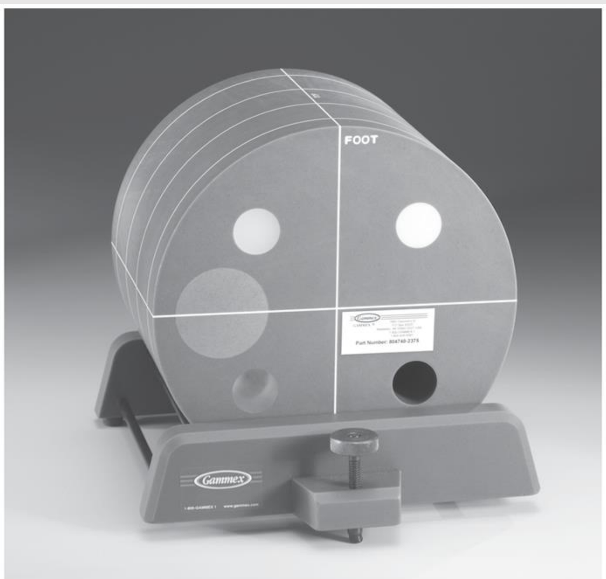
QC Test Frequency

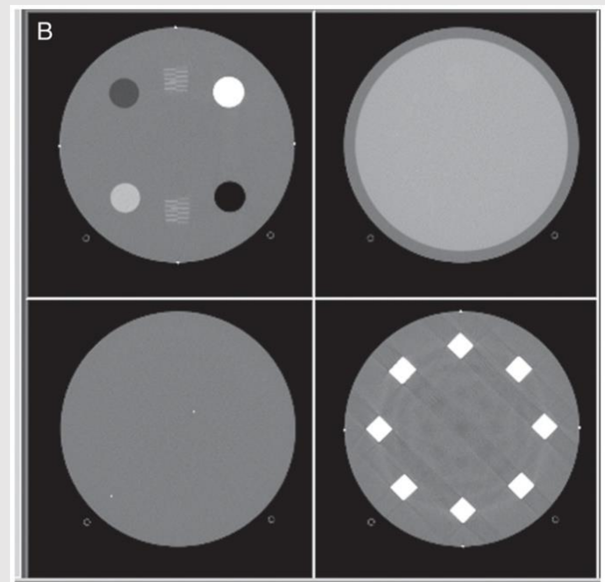
Table 1. QC Test Frequency

TEST	FREQUENCY
Qualified Medical Physicist Survey	
Participation in Review of Clinical Protocols with the CT Protocol and Management Team	Annually
Scout Prescription and Alignment Light Accuracy	Annually
Table Travel Accuracy	Annually
Radiation Beam Width	Annually
Low-Contrast Performance	Annually
Spatial Resolution	Annually
CT Number Accuracy	Annually
Artifact Evaluation	Annually
CT Number Uniformity	Annually
Dosimetry	Annually
CT Scanner Display Calibration	Annually
Radiologic Technologist QC	
Water CT Number and Standard Deviation	Daily
Artifact Evaluation	Daily
Wet Laser Printer Quality Control	Weekly
Visual Checklist	Monthly
Dry Laser Printer Quality Control	Monthly
Gray Level Performance of CT Scanner Acquisition Display Monitors	Monthly

QA Phantoms

- **Many aspects of image quality can be evaluated using phantoms**
- **Most phantoms are designed with many components so that a single phantom can be used to examine a broad range of scanner parameters**





Average CT Number of Water

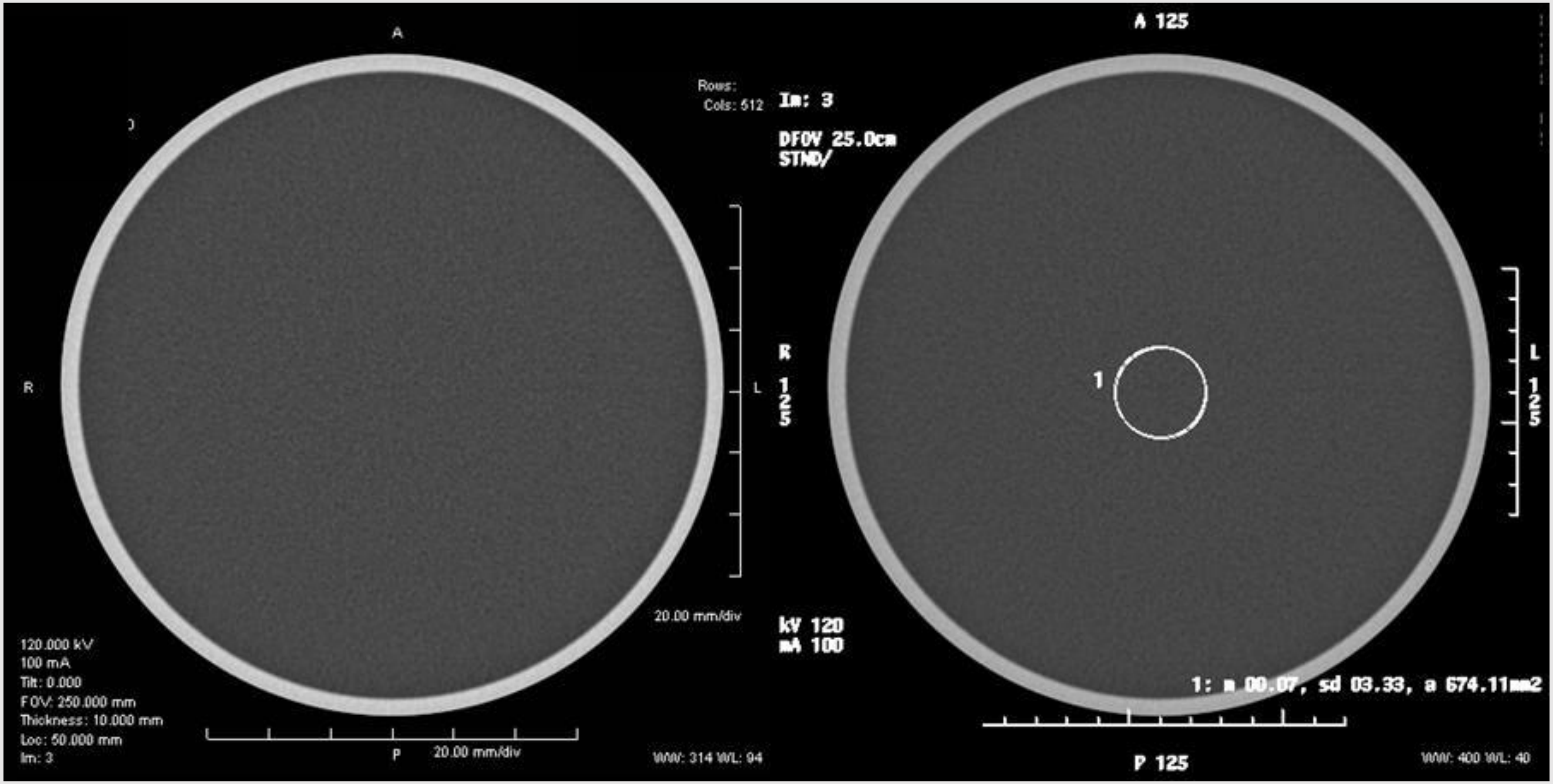
- CT number calibration
- Use a water phantom

- Measurements should be close to zero
- Acceptable measurements (+ -) 3
  - Maximum of (+ or -) 5

- Failure can be caused by miscalibration of the algorithm that generates the CT number

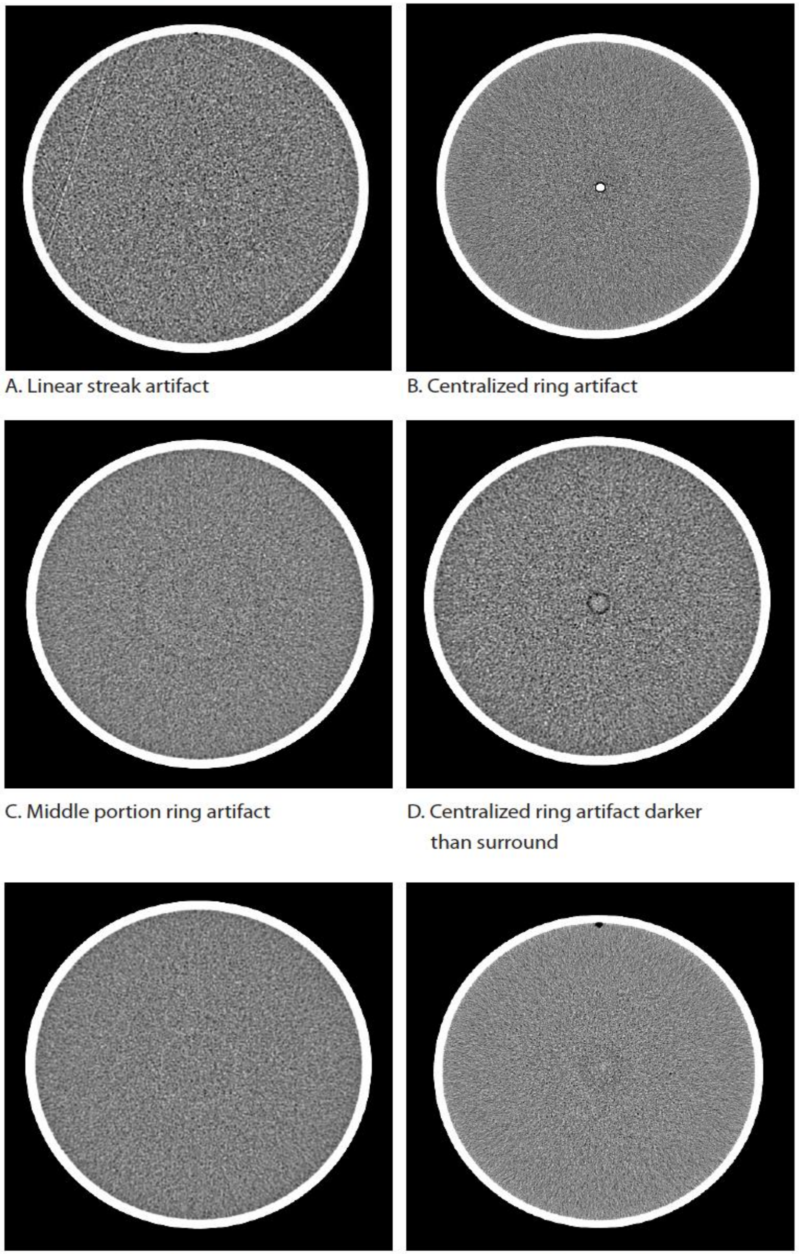
- PERFORMED DAILY

Water Phantom



Water Phantom Artifact

Figure 2. Example Artifacts from Water Phantoms



A. Linear streak artifact

B. Centralized ring artifact

C. Middle portion ring artifact

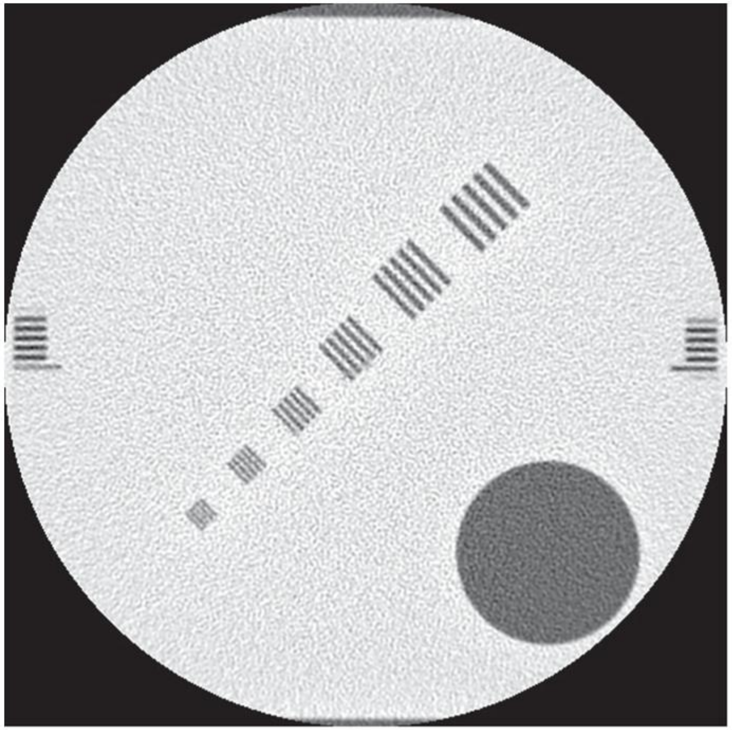
D. Centralized ring artifact darker than surround

C. Middle portion ring artifact

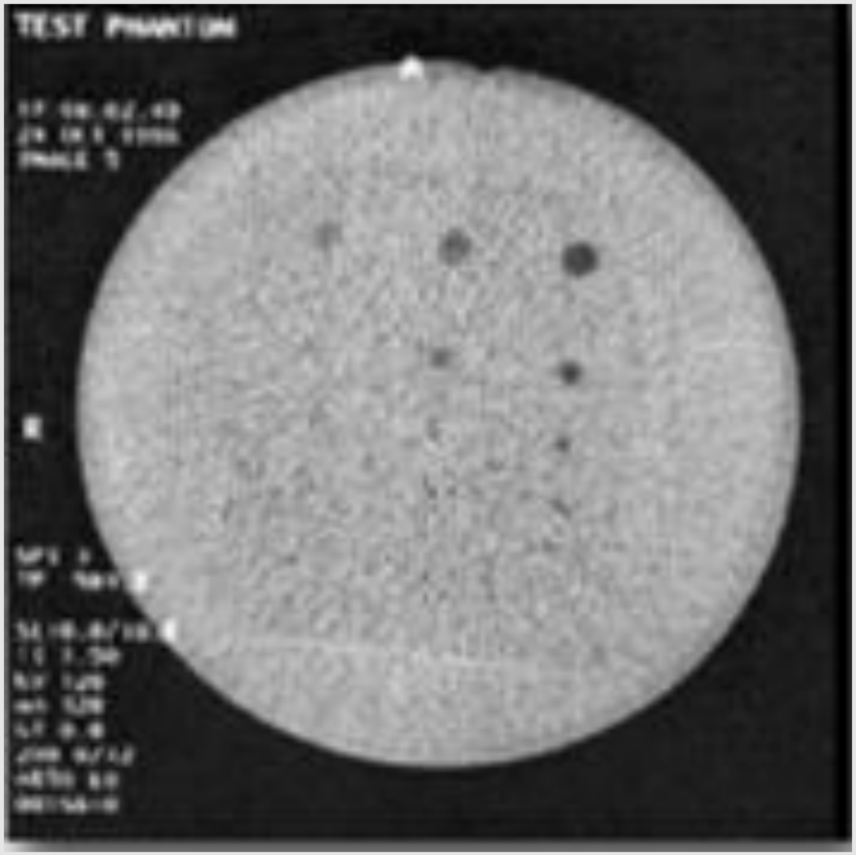
D. Central portion ring artifact darker than surround

Spatial Resolution – High Contrast

- Can be evaluated using a line pairs phantom
  - This phantom contains groups of lead strips
  - Results are given as the maximum number of visible line pairs/mm
  - The minimum resolution should meet the manufactures specifications
  - Performed at least monthly



Contrast Resolution – Low Contrast



- Evaluated using a phantom that contains objects of varying sizes and only small differences in density from the background
  - Phantom is scanned at different mAs settings
  - The most common method requires an observer to detect the objects as distinct
  - Minimum of .5% density difference in 5 mm object
  - Performed at least monthly

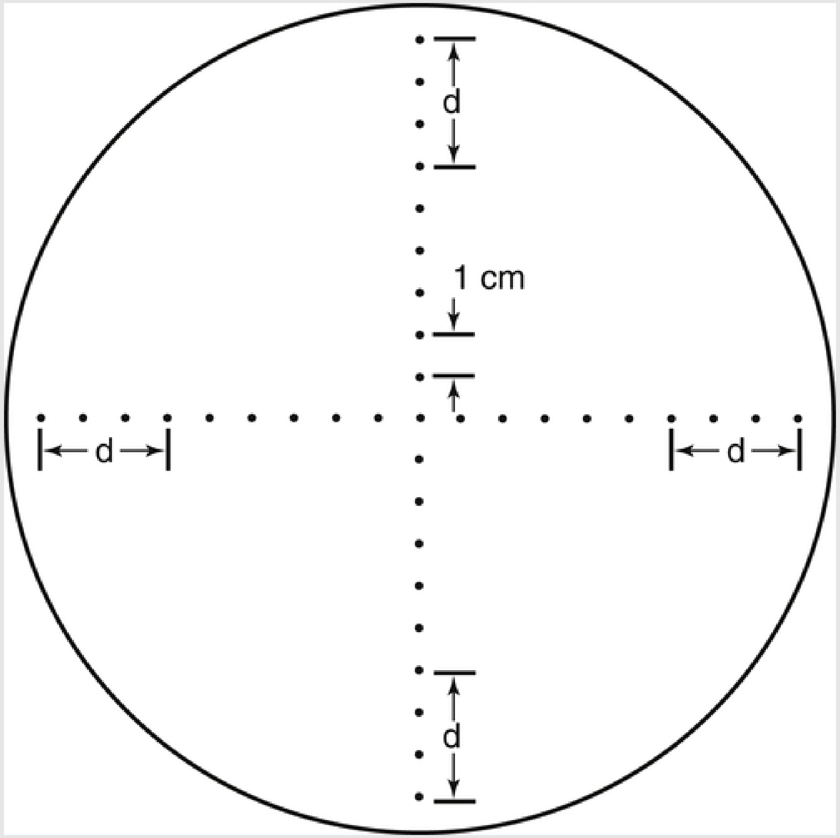
Accuracy of distance measuring device

- Evaluates 2 or more small objects that has a precise known spatial relationship.

- With use of the distance-measuring feature available on the video monitors of most scanners, measure the **distance** between two well-visualized holes near the periphery of the phantom, one near the top and one near the bottom

- Acceptance: Disagreement of 1 mm or less is good. Disagreement of greater than 2 mm should be corrected.

- Frequency: At the time of installation and monthly



Hard Copy Output

- Display the SMPTE pattern on the display monitor. Adjust the display contrast so that both 95% and 100% patches are clearly separated. The 5% patch should just be visible inside of the 0% patch. The area of the 0% patch should be almost black. The 95% patch should be visible inside the 100% patch. Print the image and display on a viewbox to ensure the visibility of the 5% and 95% patch.

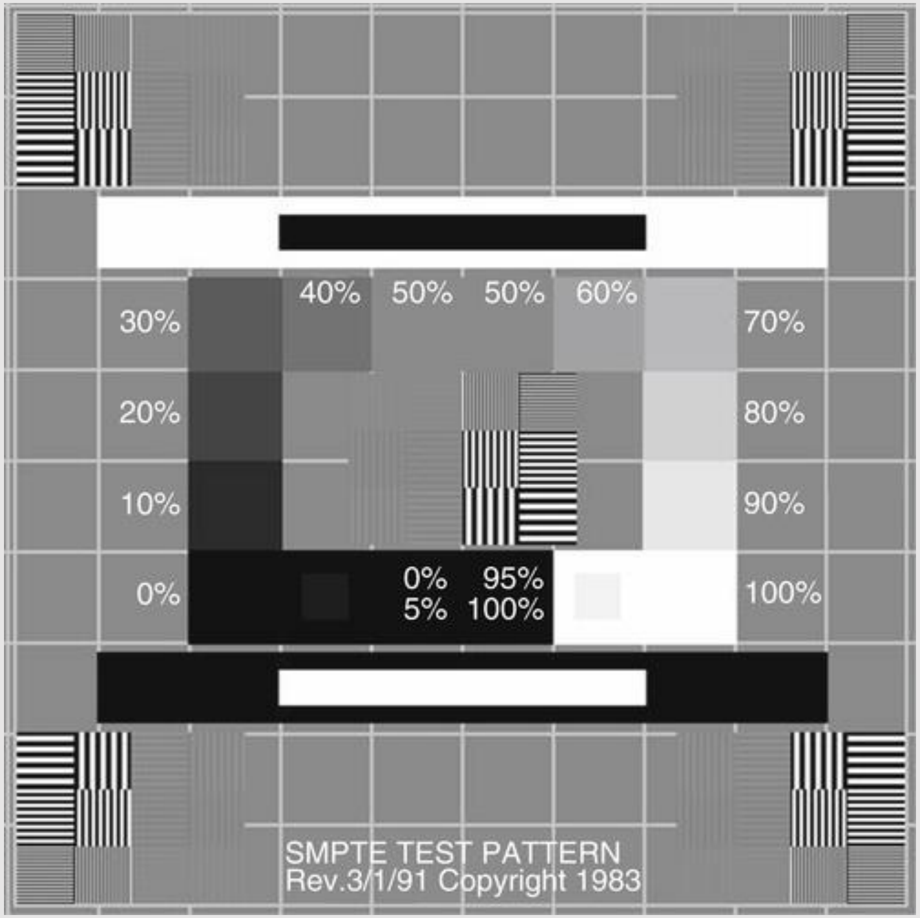
- Acceptance: If the hard copy image is unable to display both 5% and 95% patches, examine the display setting and also the printer setting. If the condition still exists, then investigate further with a service person to reset the hard copy printer settings.

- Frequency: This should be performed at the time of installation as part of the acceptance test and annually thereafter.

Hard Copy Output / Distortion of Video

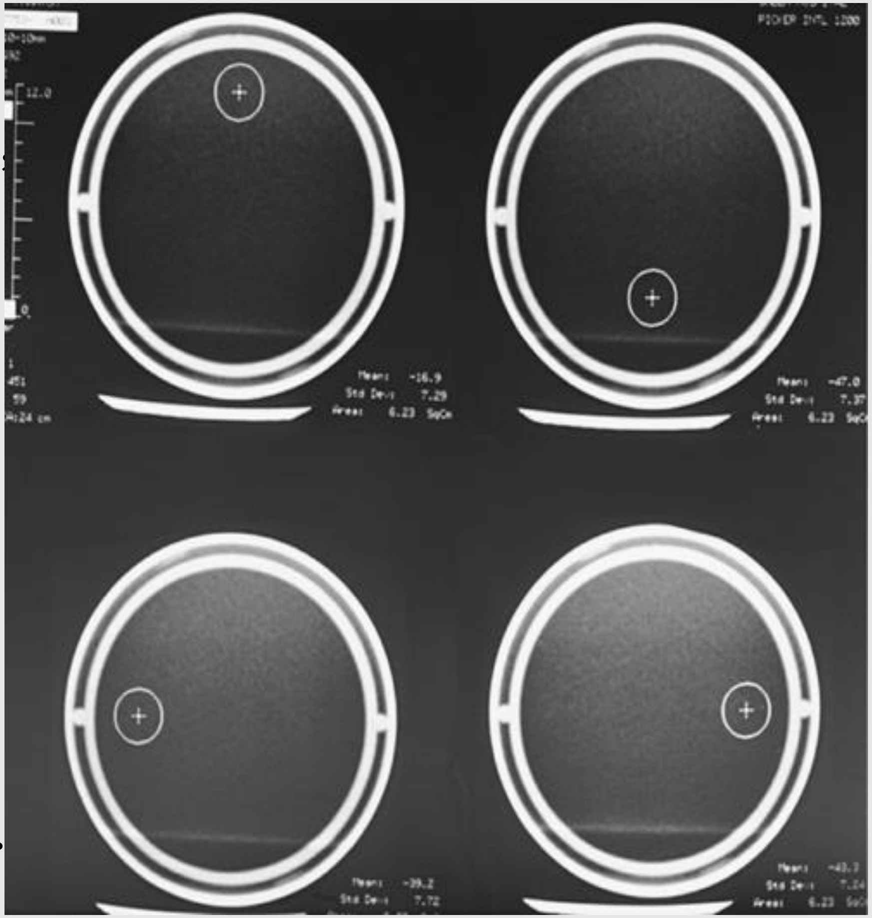
- SMPTE image for checking hard copy output. A film image of this pattern is processed and visualized to examine the visibility of 5% and 95% squares.

- Video Display Monitors should be checked daily for any distortions or pixel lost.



CT Number of Flatness

- Using the ROI feature available on most CT scanners, measure the CT number of water near the top, bottom, right, and left of the phantom. Use an ROI large enough to cover an area of 200 to 300 pixels.
- Expected results: Ideally, the CT number of water will be zero at all points in the phantom.
- Acceptance limits: If the CT number anywhere in the phantom differs by more than five CT numbers from the average CT number collected from all measurements, then the CT image does not have a uniform or flat image.
- Should be performed monthly

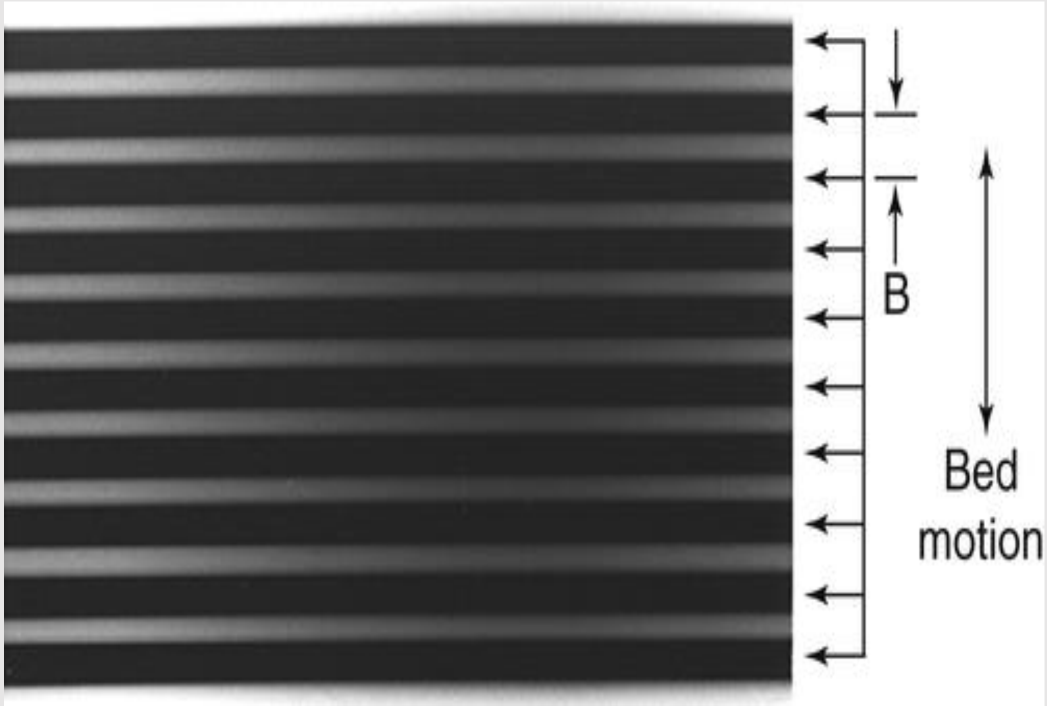


Accuracy of Localization Device

- Local Scout image is performed.
- With this localization image, set up the scanner to make a single scan at a certain thickness so that the center of the scan is directly on the intersection of the holes.
- Make a scan and reconstruct the image. At the very least, both holes should appear in the CT image.
- If they do not, then the localization device is so poorly adjusted that the width of the x-ray beam does not intersect the plastic section in which the holes are drilled.
- If the localization device is working properly, the image of the two holes should appear exactly side by side
- Acceptance limits: If the measured value of *L* is 3 mm or greater, the localization device is out of adjustment and a service person should be called.
- Frequency: This should be performed at the time of installation as part of acceptance test and annually thereafter.

CT Couch Indexing

- Measurement of bed indexing from an exposed x-ray film. The series of dark lines on the film are produced by several scans through a piece of x-ray film, moving the bed after each scan. The distance between the lines (*B*) is a measure of the distance that the patient bed has moved between scans.
- No longer done



Bed Backlash

- The patient bed is loaded with at least 100 pounds (50 kg) of material to simulate the weight of a patient.

- The bed is moved to a convenient location to serve as a zero point. Two strips of masking tape are placed adjacent to each other, one on the edge of the movable part of the bed, the other on a part of the bed that does not move.

- A pencil mark is placed on each piece of tape so that the two marks are exactly opposite each other. The CT scanner is programmed to move the bed automatically about 150 to 200 mm in 10- or 44920-mm increments in one direction (for example, bed into scanner), and then return to its original (zero) starting location.

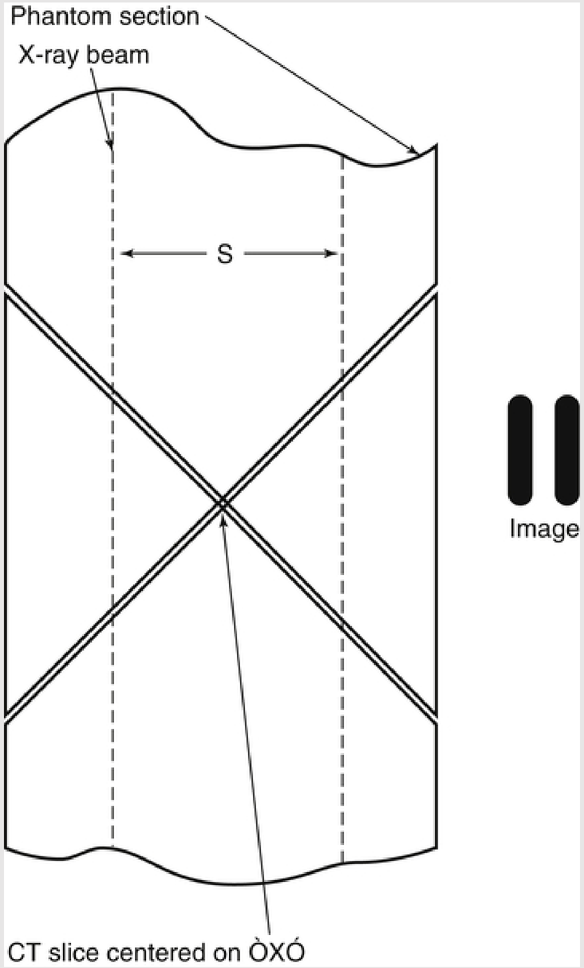
Bed Backlash

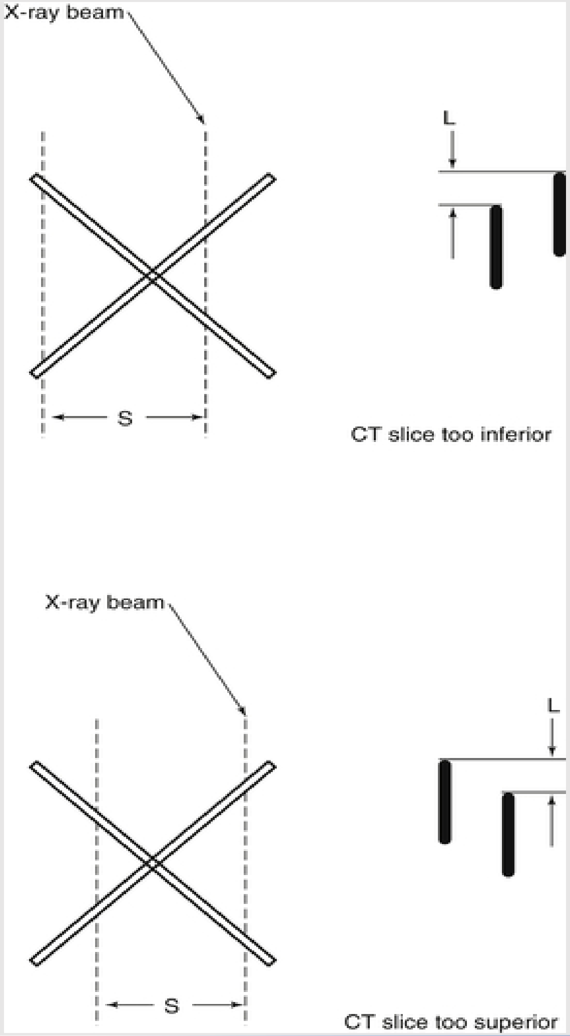
- After all the motions, the mark on the moving bed should return to its original position opposite the stationary mark. A measurement of the distance between the two marks indicates if there are mechanical discrepancies ("backlash") in the patient bed.

- If the bed does not return to its starting position within 1 mm, then a service person should be notified.

- Performed annually.

Accuracy of Localization Device





Laser Light Accuracy

- **Most often measured using a specific phantom designed for the purpose and provided by the scanner manufacturer**
- **These lights both inside and outside the gantry are used for patient positioning**
- **The light should coincide with the radiation field within 2mm**
- **Performed semiannually**

Slice Thickness Accuracy

- **Measured using a phantom that includes a ramp, spiral, or step-wedge**
  - **It contains objects with known measurements and provides a standard to compare with the scanner**
  - **For a slice thickness of 5mm the variance should be no more than ±1mm**
  - **For less than 5mm slice thickness it should vary no more that ±.5mm**
  - **Performed semiannually**

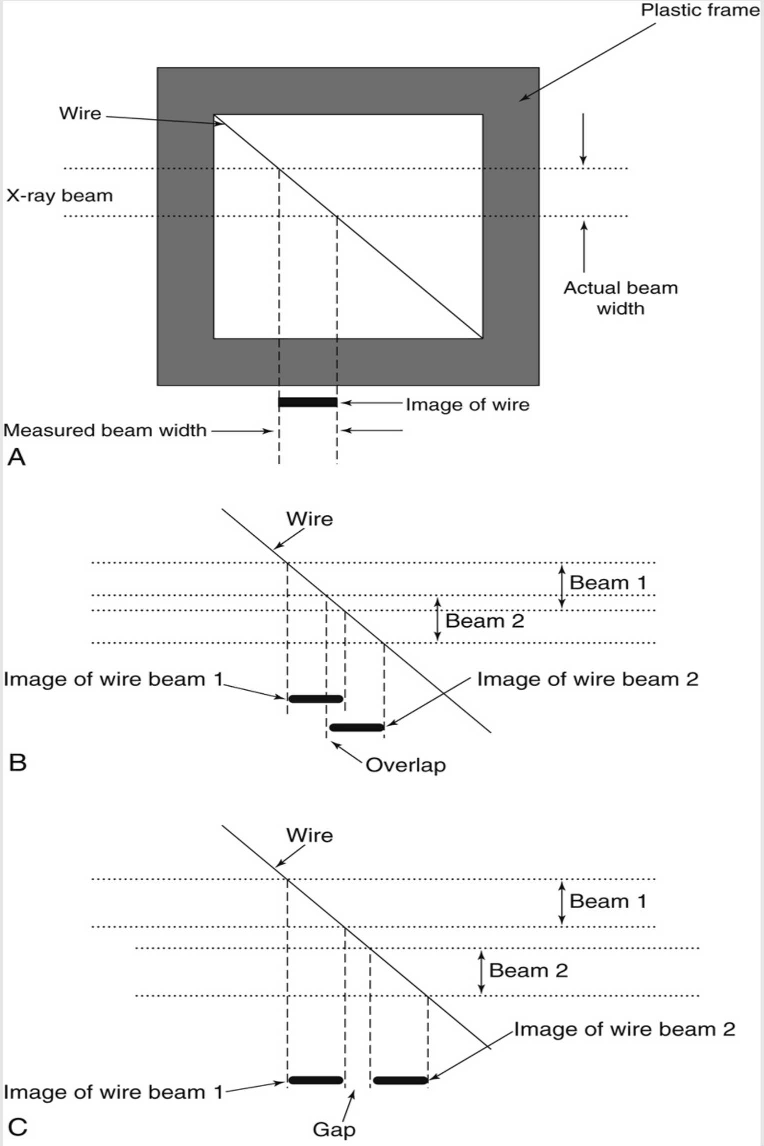
Pitch & Slice Width

- For spiral/helical scans from a single array CT scanner, set the bed index the same as the slice width (pitch = 1). For a multidetector CT scanner, set the bed indexing equal to the slice width multiplied by the number of detector arrays used. Perform the scans of the wire and reconstruct the images. For spiral/helical scans, make sure that the data from the same 360-degree arc are used to reconstruct each image. To measure the slice width, use the distance-measuring device on the reconstructed image. Measure the length of the wire visible on the image. When the wire is oriented at 45 degrees to the incoming radiation beam, the projection of the wire onto the CT image is the same length as the width of the x-ray beam that strikes the wire

- The gap or overlap between adjacent slices should be less than 3 mm. Unfortunately, at narrower slice widths and bed-index settings, the discrepancy between nominal and measured often becomes greater and these values may be relaxed somewhat.

- Performed annually

Pitch & Slice Width



- **A,** A several centimeters long (e.g., 10 cm) piece of wire stretched 45 degrees diagonally across a plastic frame serves as an object that projects the beam width directly to the CT scanner image. **B,** Overlaying the images from adjacent slices allows a comparison of the relative location of the adjacent slices. If adjacent slices overlap, the ends of the wire on the overlaid images will also overlap. **C,** If the adjacent slices are too far apart, a gap will appear in the overlaid images.

CT Number vs Patient Position

- At least five scans of the same phantom at the same technique are performed. However, the position of the phantom in the gantry should be changed for each scan. Place the phantom near the center of the gantry (use this image as the "standard"), top, bottom, and right and left sides. Set the ROI feature available on the video monitor to about 200 to 300 mm^2 (or 200 to 300 pixels) and measure the average CT number of water at the center of the phantom (not the center of the image) in each image.

- If the average CT number varies by more than five CT numbers from the CT number at the center of the CT scanner, there may be a problem with the symmetry of the CT scanner.

- Performed annually

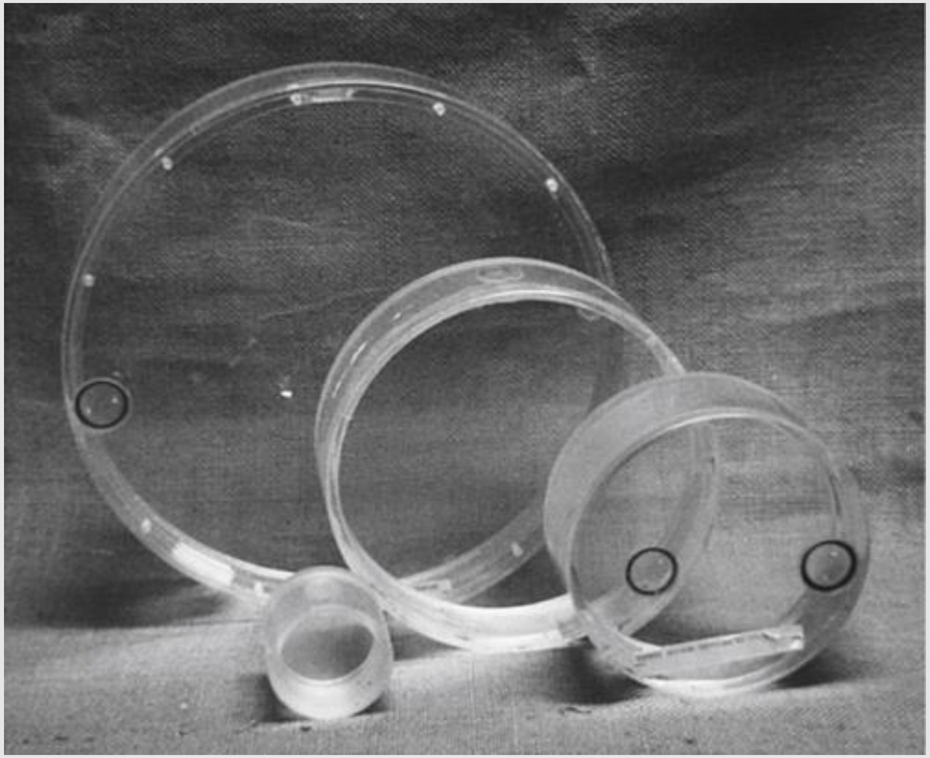
CT Number vs Patient Size

- A scan of each phantom size at the same technique is performed. The size of the phantoms should cover the sizes of the anatomy used clinically. For each CT scan, set the CT scanner field of view just large enough to view the entire phantom. Set the ROI feature available on the video monitor to about 200 to 300 mm^2 (or 200 to 300 pixels) and measure the average CT number of water at the center of each phantom image.

- The average CT number of water should vary no more than 20 CT numbers from the smallest to the largest phantom.

- Performed annually

CT Number vs Patient Size



- Water phantoms of several diameters. A selection of water phantom sizes is used to test whether the CT number of water changes as the phantom (patient) size changes.

CT Number vs Algorithm Selection

- Perform a single scan of the phantom. If possible, use the same raw data to construct the image several times, each time using a different reconstruction algorithm or filter. If it is not possible to use the same data for several reconstructions, rescan the phantom using a different algorithm for each image.

- Should always be near 0. The average CT number should vary no more than three CT numbers from one algorithm to the next.

- Performed annually or daily

CT Number vs Slice Width

- A few scans of the water phantom are performed at the same technique; however, the nominal slice width is changed between each scan. The slice widths used should cover the sizes of slice widths used clinically. Set the ROI feature available on the video monitor to about 200 to 300 mm2 (or 200 to 300 pixels) and measure the average CT number of water at the center of each phantom image.

- The average CT number should vary no more than three CT numbers from one slice width to the next.

- Performed annually or more.

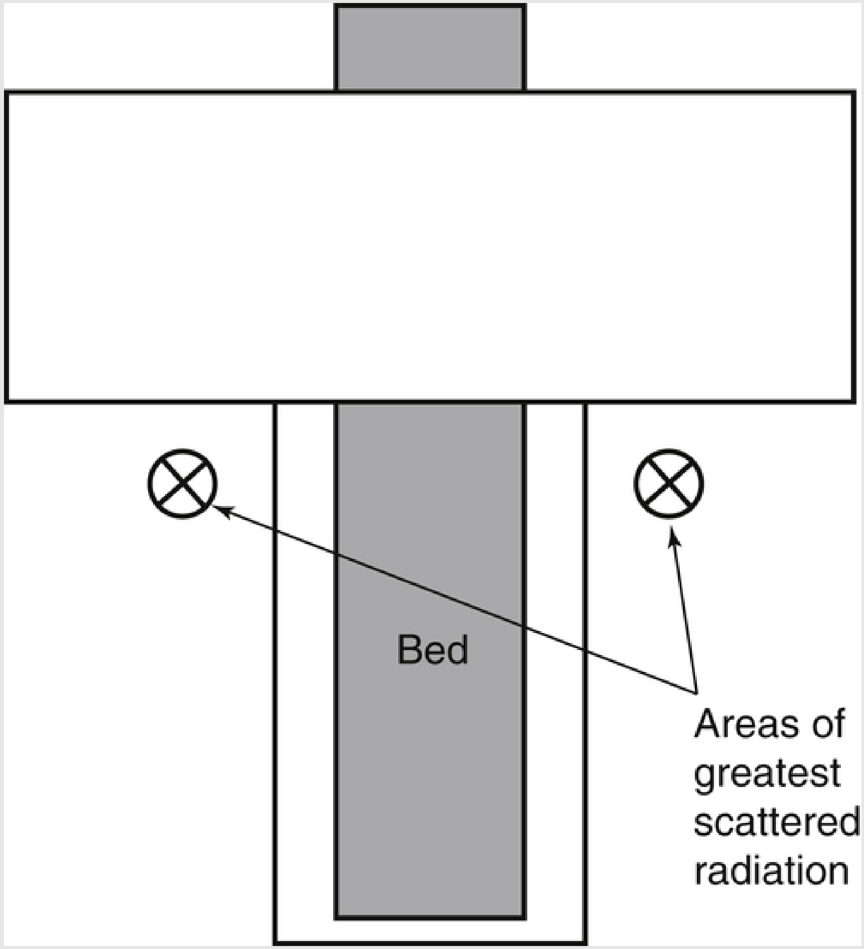
Radiation Leakage & Scatter

- Insert the head phantom into the scan plane to provide radiation scatter for the measurements. Put on a lead apron normally used for fluoroscopic procedures. Position the radiation detector at the location where the radiation measurement will be performed, and initiate a scan. It may be helpful to have a colleague initiate the scan during these measurements. Measure the total radiation emitted at that location per one complete scan.

- The results will vary according to location and distance from the scanner. Usually, the highest exposure rate will be next to the patient and close to the scanner.

- Performed annually

Radiation Leakage & Scatter



- Top view of a CT scanner suite showing areas of highest radiation intensity near a CT scanner (f).

Noise and Uniformity

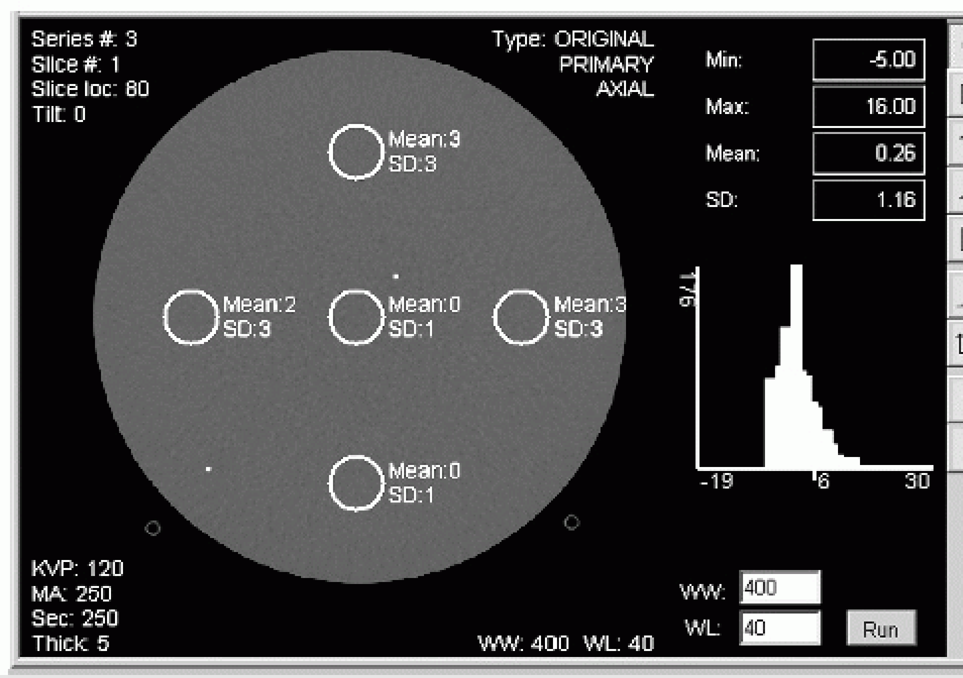
- Both noise and uniformity are measured using a water phantom

- Noise is measured by obtaining the standard deviation of the CT numbers within an ROI
  - For noise the standard deviation of an ROI should not exceed 10

- Uniformity (Cross-Field Uniformity) refers to the ability of the scanner to yield the same CT number regardless of the location of an ROI within a homogeneous object
  - Measured by placing ROIs at center and around perimeter
  - The ROI readings on the perimeter should not vary more than $\pm$2 from the center.

Cross-Field Uniformity

- CT values should be uniform throughout the field of a phantom of uniform density



- Cupping- the reduction in CT number toward the middle of a uniform test object

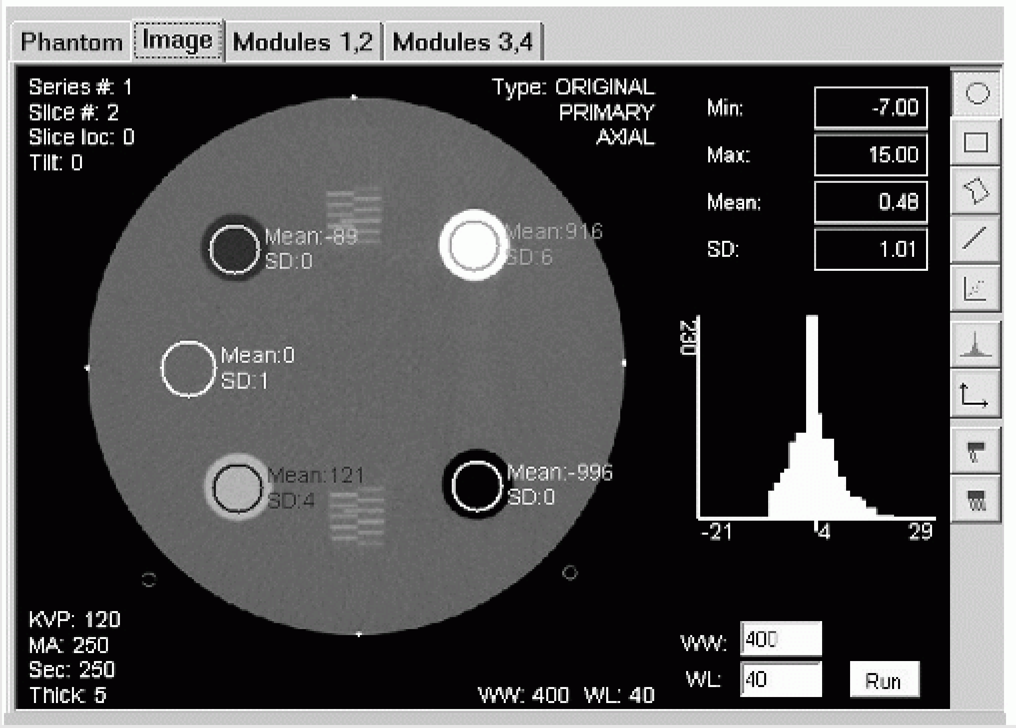
- Peaking- the increase in CT number toward the middle of a uniform test object

Done with a water phantom

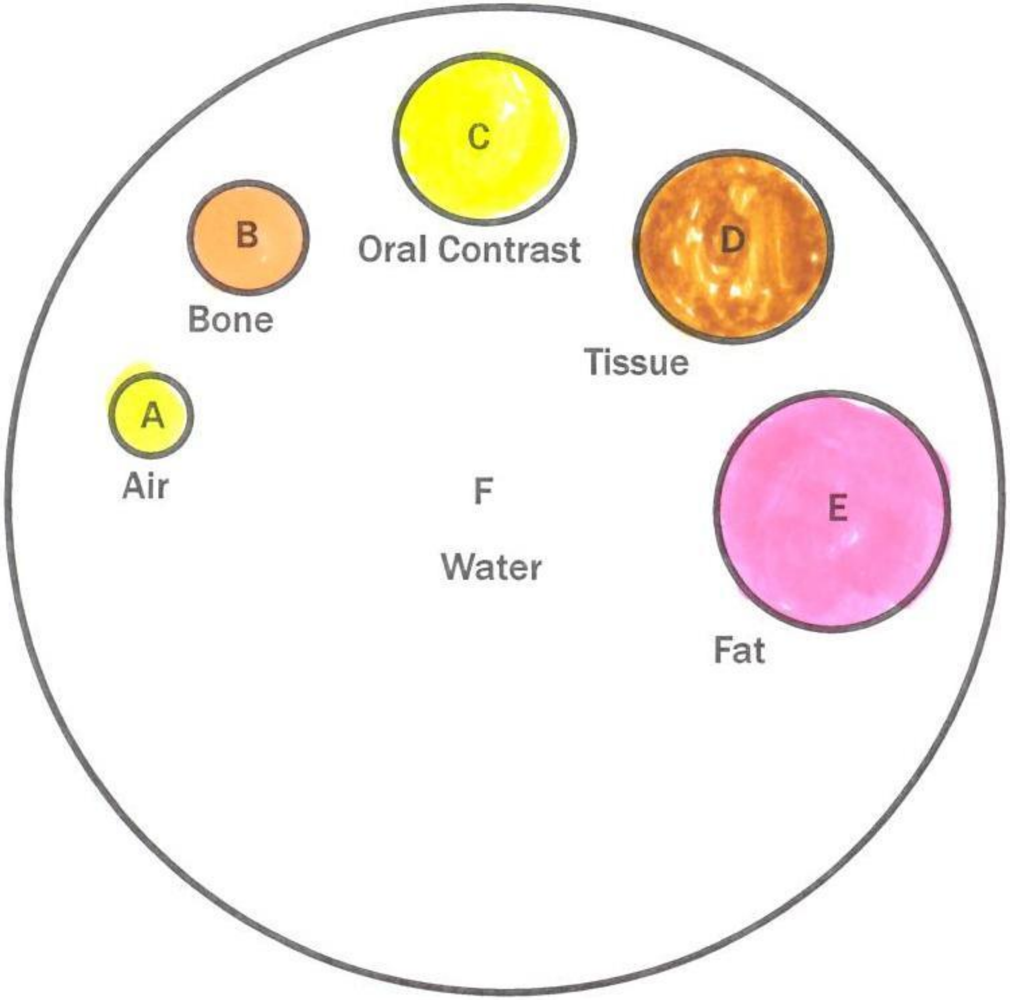
- Performed Weekly

Linearity

- **The relationship between CT numbers and the linear attenuation values of the scanned object at a designated kVp value**
- **Measured using a phantom that contains a variety of objects with known densities**
- **Daily calibrations help to avoid changes**
- **Done Semiannually (done more often)**



Linearity Phantom



A: AIR	-995±20
B: BONE	340±10
C: ORAL CONTRAST	130±10
D: TISSUE	100±10
E: FAT	-105±10
F: WATER	0±5

ROI SHOULD BE 25 X 25mm

Q & A

Question 1

True or False: Contrast Resolution is evaluated by varying sizes.

- **Answer: TRUE**

Question 2

True or False: Linearity is measured using a phantom that contains a variety of objects with known densities.

- **Answer: TRUE**

Question 3

Water has a hounsfield unit for water is

A) -995 +/- 20

B) 340 +/- 10

C) 130 +/- 10

D) 0 +/-5

- **Answer: D**

10 MIN BREAK

RADIATION PRACTICES / CT DOSE

RADIATION DOSIMETRY IN CT

Basic Dose Concepts

Two components regarding radiation dose to the patient

- **Appropriate patient selection**
  - **This is mainly controlled by the radiologist or ordering doctor following ACR guidelines**
- **Minimizing the radiation dose while maintaining diagnostic image quality**
  - **The technologist has a great hand in this area**

Measurement Terminology

- The unit of x-ray exposure in air
  - Roentgen (R)
- Unit of absorbed dose
  - Radiation absorbed dose (rad)
  - Amount of energy absorbed per unit of mass
- The International System (SI) is the Gray (Gy)
  - 1 rad = 1 cGY
  - 100 rad = 1 Gy

Effective Dose

- Rem (roentgen equivalent man) is the effective dose

- Rem takes into account type of radiation and radiosensitivity of the tissue

- International unit is the sievert (Sv)
    - 100 rems = I Sv

Quality Factor

- Quality factor (Q)
  - Accounts for different types of ionizing radiation
  - Diagnostic radiography has a factor of 1
  - Rad and Rem are equal if measuring dose from X-ray only

- Effective dose
  - Attempts to account for the effects particular to the patient's tissue that has absorbed the radiation dose
  - The dose to patients is reported in rads or centigray (cGy)

- Manufacturers are required by law to provide a dose table showing doses to patients from their scanners, and a radiation scatter distribution chart.

- Physicists create CT dose parameter charts

Radiation Effects

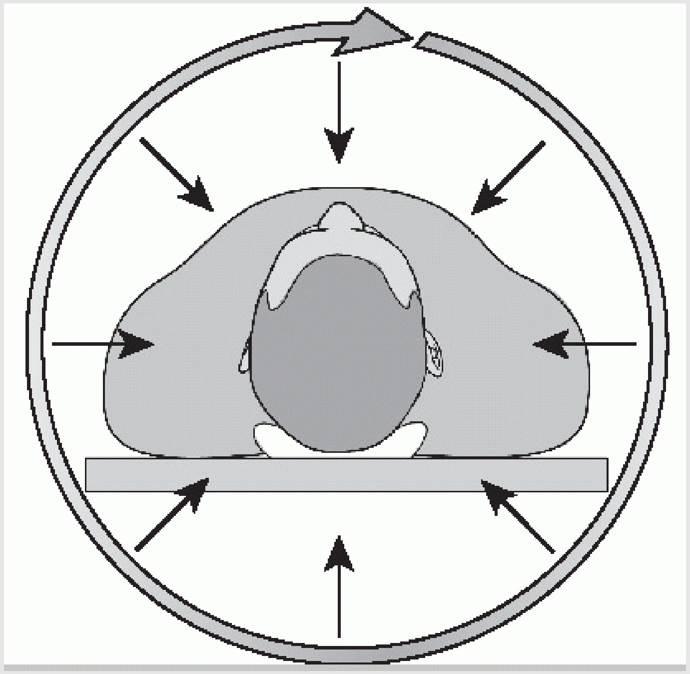
- **Stochastic Effects (non-threshold)**
  - The **probability** of the effects occurring (not severity) depends on the dose
  - No threshold for this effect (they could occur at any dose)
  - Risk increases as dose increases
  - There is no risk-free dose
  - Stochastic effects are late effects such as
    - **cancer, leukemia and genetic changes**

Deterministic Effects (Threshold)

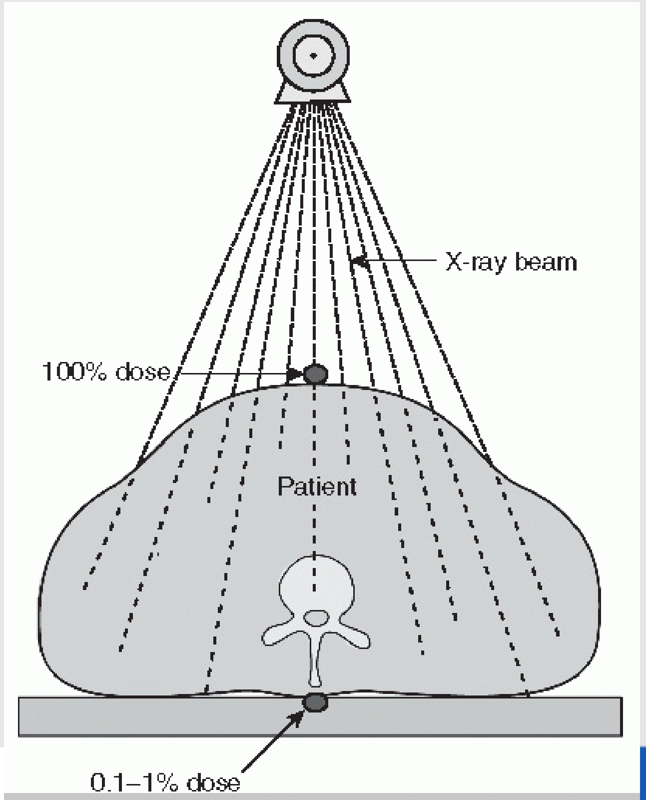
- The **severity** (not probability) of the effects increase with the increase in dose
- These are threshold doses
- Below the threshold no effect is observed
- These are considered relatively high doses and can kill cells and cause degenerative changes
- Examples of deterministic effects are:
  - **Cataracts, skin erythema epilation and pericarditis**

CT Dose vs Conventional X-Ray

- Entry and Exit more uniform
  - Because of higher kVp & rotational beam



- Entry much higher than exit (.1 to1%)



Dose Geometry

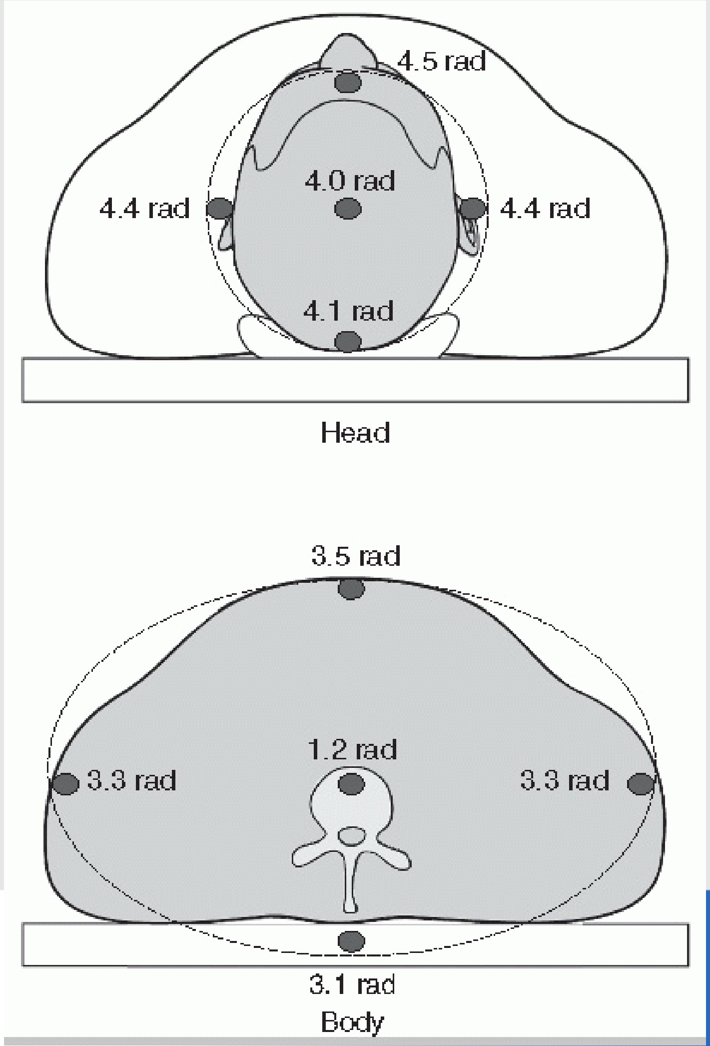
- The uniformity of the dose decreases as the **SFOV** and **patient thickness** increase
  - Body scans are **less** uniform than head scans
  - The central dose of a body scan is approximately **one third to one half** that of the peripheral dose

- This accounts for the fact that organ doses are higher for children (or small adults) compared with (larger) adults

Variation in Radiation Distribution of Head and Body Scans

** 1 RAD = 1 cGy or 10

- For Head Scans
  - the center of the head can receive nearly as much radiation as the periphery.
- For Body Scans
  - This is not as true for body scans because the dose uniformity decreases as the scan field of view and patient thickness increase



Dose Geometry

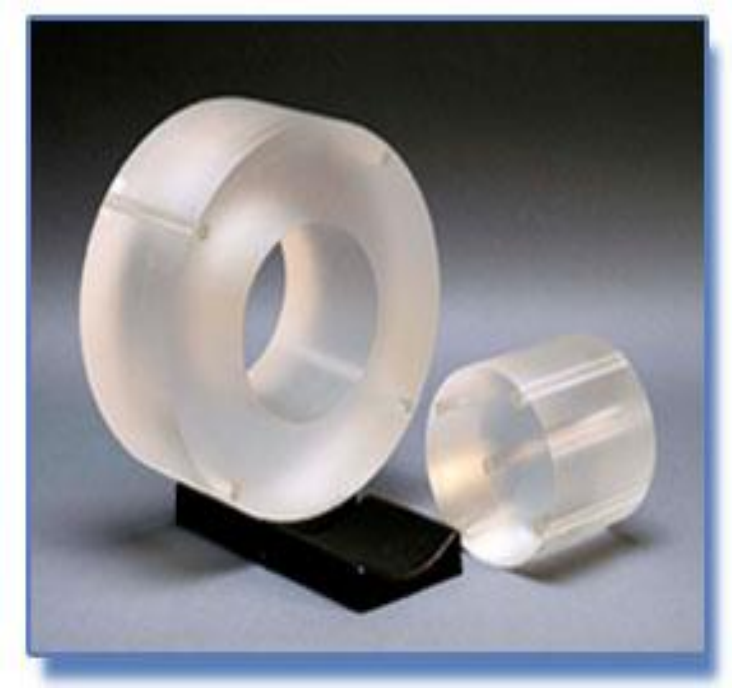
- *Z* axis dose distribution profile
  - Describes variations that occur along the length of the patient
- Total dose is from the radiation to the selected slice and from scatter radiation, or “tails,” from neighboring slices
- In general, the tails will contribute approximately 25% to 40% to the total dose

Method of Measuring Patient Dose

- Computed Tomography Dose Index (CTDI)
  - Reported to FDA
  - Slices must be contiguous
  - Used to estimate the MSAD
- Multiple scan average dose (MSAD)
  - Dose calculated from multiple scans
- Dose Length Product (DLP)
  - Looks at the dose on the entire scan length

CTDI - CT DOSE INDEX

- Patient dose is measured with a pencil ionization chamber of 100 mm. in a head or body phantom
- Gives the $CTDI_{100}$



CTDI Terms

- $CTDI_w$
  - Is a weighted average that adjusts for the difference in center dose and periphery
- $CTDI_{vol}$
  - Is a volume that takes into account the adjacent exposures along the *Z* axis
  - For Helical Scanning the $CTDI_{vol} = CTDI_w$ / Pitch
  - The $CTDI_{vol}$ is now the preferred expression of Radiation Dose

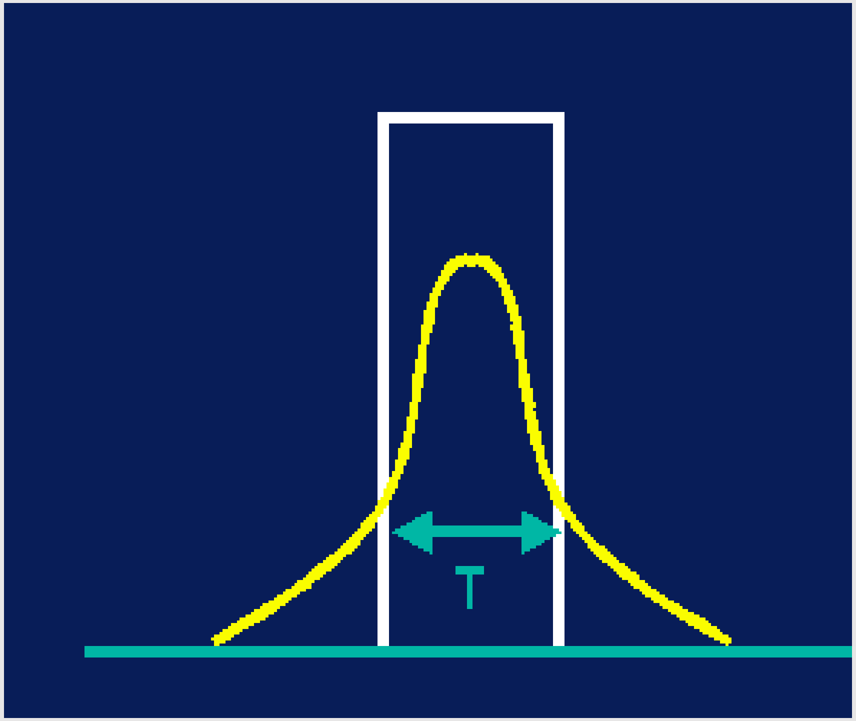
CTDI-CT Dose Index

- <u>**For a single Slice dose**</u>

- **Patient dose in CT is described by the CT dose index**

- **The CTDI is equal to the multiple scan average dose (MSAD) if the slice thickness (ST) is equal to the table increment (TI)**

- **MSAD= CTDI (ST/TI)**



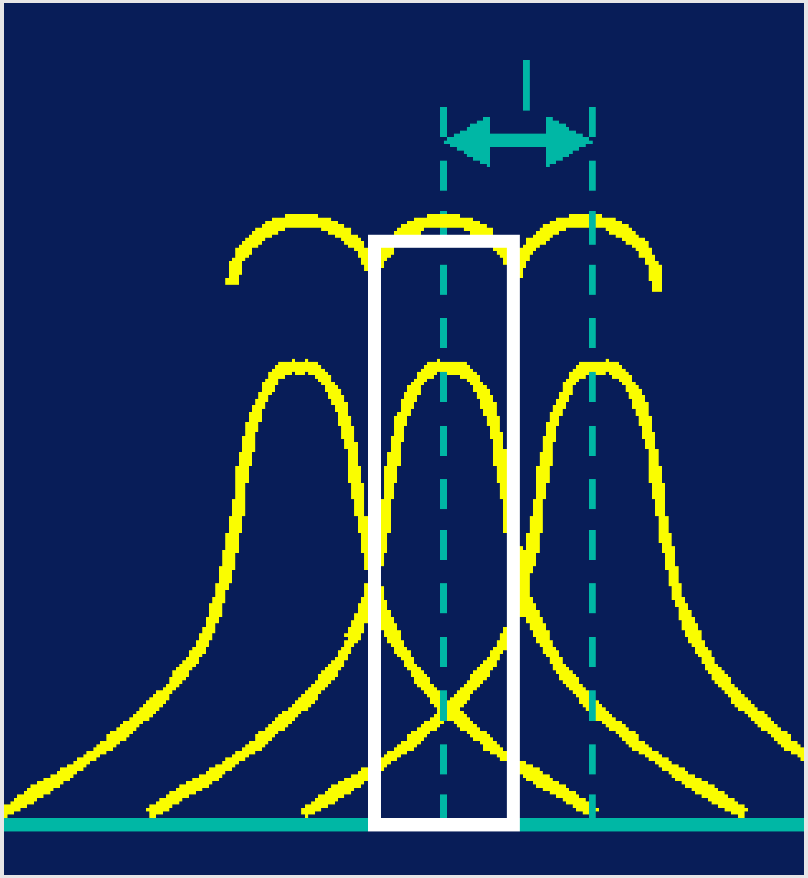
MSAD-
MULTIPLE SCAN AVERAGE DOSE

- Total Dose is the central slice dose plus the scattered dose from adjacent slices

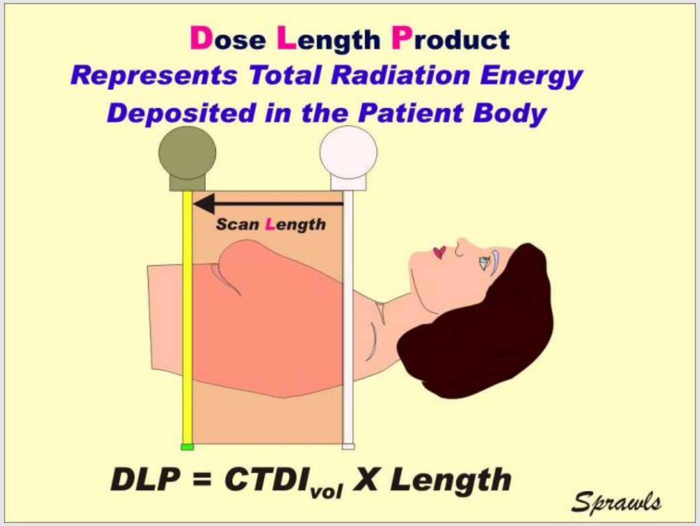
- Uses CTDI to calculate an average dose in the middle of series of CT scans

- Ratio of slice width to slice spacing multiplied by CTDI
  - MSAD = CTDI (ST/TI)

- When there is no overlap or gap between the slices, the MSAD equals the CTDI



Dose Length Product



- DLP is the $CTDI_{vol}$ multiplied by the scan length (slice thickness × number of slices) in centimeters.

- DLP is affected by variations in patient anatomy so $CTDI_{vol}$ is a more useful tool for comparing different protocols

Example of Dose Calculations

- Formula:
  - MSAD = CTDI x (slice thickness / table movement or incrementation)
- Example 1
  - CTDI = 2 slice thickness = 5mm table increment = 4mm
  - 2 x (5/4) so 2 x 1.25 = 2.5 MSAD = 2.5 rads
- Example 2
- CTDI = 2 slice thickness = 2.5mm TI = 3
- 2 x (2.5/3) so 2 x .83 = 1.66 MSAD=1.66 rads
- If table movement is greater than slice thickness, dose DECREASES
- If table movement is less than slice thickness, dose INCREASES

Spiral Scanning

- MSAD is greater than CTDI if:
  - Pitch is less than 1
- MSAD is less than CTDI if:
  - Pitch is greater that 1
- They are equal if pitch is 1

Dose Comparison

- Radiation dose for CT examinations is substantially higher when compared with film or screen radiography

- The higher dose is the price that is paid for the excellent low-contrast resolution seen on CT images

- It is not unusual for the surface dose to be 10 times higher in CT and the average absorbed dose 100 times higher

Dose Comparison (cont'd)

- Some perspective
  - Average annual background radiation for Americans is about 3 mSv
  - Exposure from a chest x-ray is about 0.1 mSv
  - Exposure from a chest, abdomen, or pelvis CT is about 10 mSV

Factors Affecting Dose

- Radiation beam geometry (180 vs 360 degrees)
- Filtration
- Detector efficiency
- Slice width and spacing
- Pitch
- Scan field diameter (smaller SFOV–higher dose)
- Radiographic technique (i.e., mAs and kVp)
- Patient size and body part thickness
- Repeat scans
- Collimation

Patient Dose is Increased With:

- Repeat scans
- Low pitch
- Thin slices (More scatter from adjacent slices)
- Overlapping slices
- Almost anything that improves detail will increase dose

Factors to Reduce Dose:

- Exposure Techniques -Decreased mAs equals decreased dose to the patient, kVp typically kept at 120
- Filtration- as filtration is increased, patient dose decreases unless the radiographic technique is increased
- Scan field Diameter- is the diameter of the actual irradiated field.
  - smaller scan fields give higher dose
  - smaller body parts gives higher dose
- Repeat scans- Radiation is cumulative
- Radiation dose is inversely proportional to pitch
- Patient characteristics *size, shape, density*- Thick body parts or large patients require increased mAs that increases the radiation dose

- CT is one of the procedures producing the highest radiation exposure

- An average of 5 rads (5 cGy) per exam
  - Varies with size of patient
  - Type of exam (head or Abdomen)
  - Type and brand of equipment

- For a head scan the dose is more uniform – skin dose to center
- While for an abdomen the center dose is only about 1/3 of the entry dose

- Dose is nearly uniform throughout the body, while that from radiography is maximum at the skin entrance.

- Dose during CT is higher with thinner or overlapping slices

- Reduction of patient dose is almost always at the expense of image quality

Risk–Benefit

The level of risk associated with a CT examination can be considered acceptable if:

1. **The individual is aware of the risk**
2. **The individual receives some commensurate benefit**
3. **Everything reasonable has been done to reduce the risk**

General Principles—Pediatric CT

1. The patient (or the parent) should be told of the small risk involved
2. The procedure should be restricted to cases in which it is specifically indicated and clinical information cannot be obtained by other means
3. Every effort should be made to decrease the radiation dose by adjusting the kVp and mAs to a suitable level according to the size of the child being scanned. Shielding should be used when possible

Special Considerations for Pediatric CT

- Increased sensitivity
  - Children are much more radiosensitive than adults
    - Have a longer time for latent radiation results
    - More opportunity for future scans
- Higher effective dose
  - Due to small body size so less shielding of organs by other body tissue
- Increasing use
  - As a screening device

Radiation Dose to the Fetus

- **The radiosensitivity of a developing fetus**
  - greatest from conception to 3 months
  - this is the time of organ and neural crest development

- The risk-benefit ratio of performing a CT study of the body on a pregnant women in the first trimester must be carefully weighed

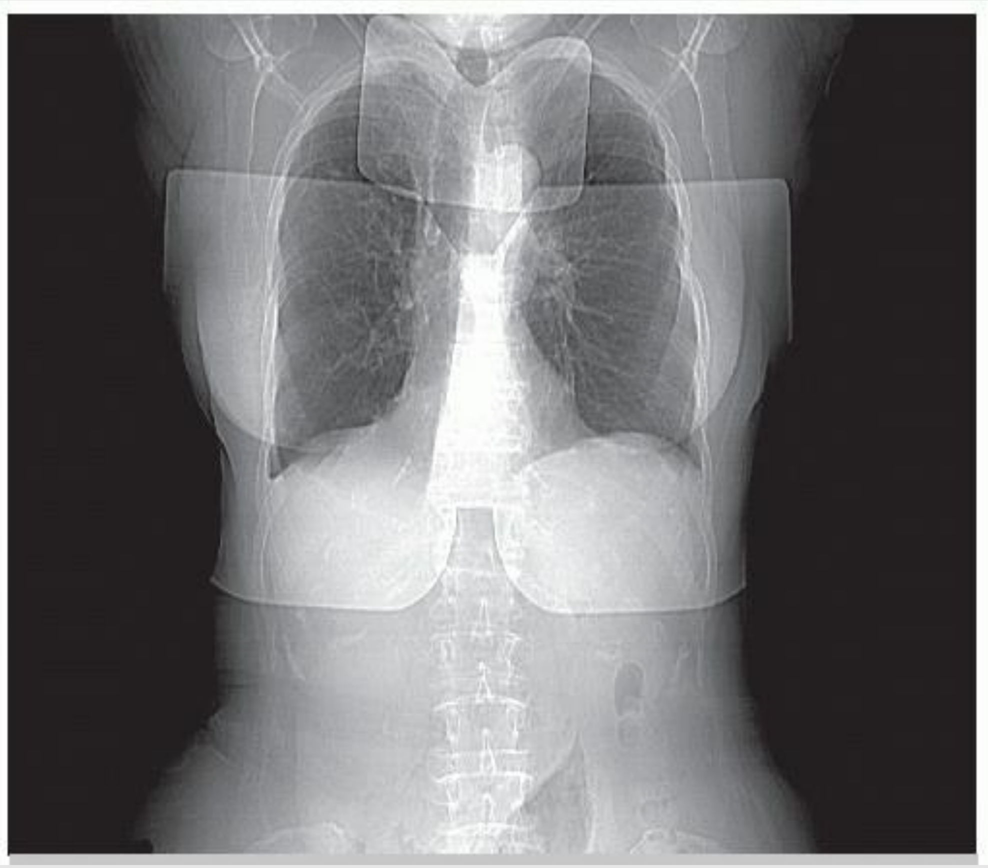
SHIELDING

- Should be provided for all patients who are in their childbearing years, men and women.
- Patient must be completely shielded around the body because of the x-ray tube travel
- Shielding should not cover area of interest or too close to cause artifacts

Thyroid and Breast Shield

- Reduce exposure of entry dose

- Do not reduce the quality of the scan

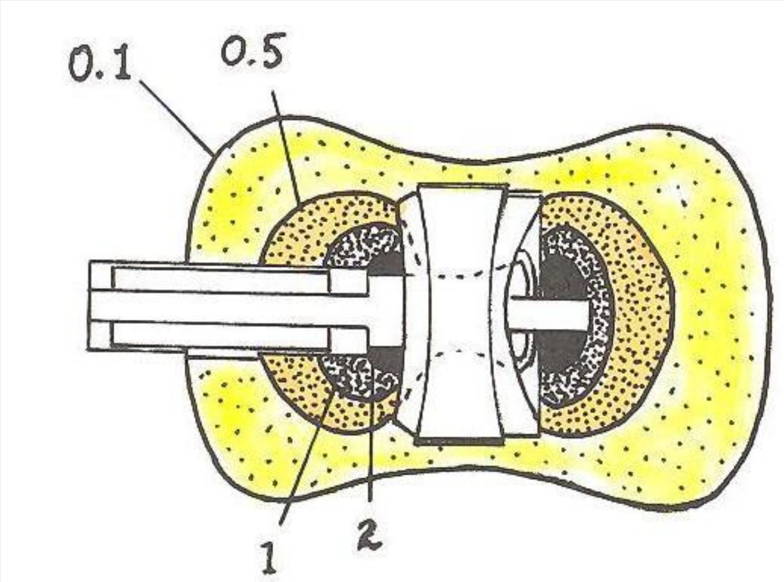


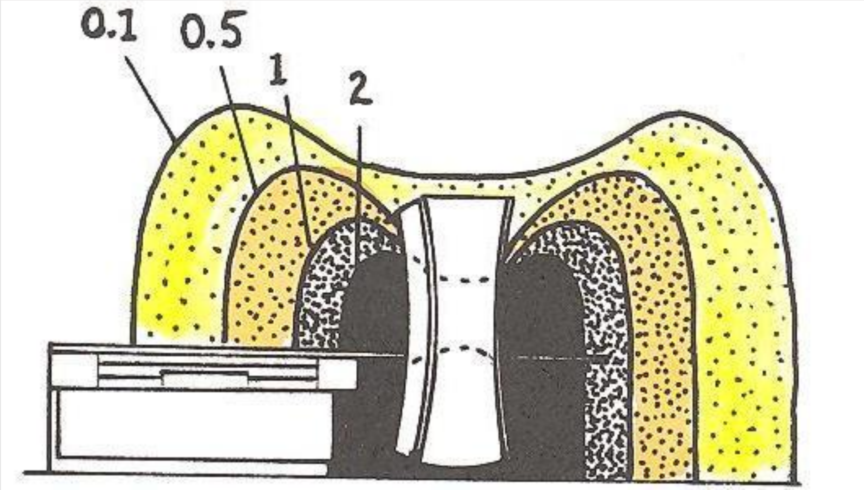
PERSONAL RADIATION EXPOSURE

- Area radiation exposure is figure 8 shaped
- Lowest area radiation exposures are in the plane of the gantry and outside the patient aperture. (Beside gantry not in front or back)
- Highest area radiation exposure is near the patient and is due to scatter radiation produced in the patient
- When a technologist is in the room, protective apparel must be worn and the radiation monitor should be positioned above the collar
- ALWAYS practice AS LOW AS Reasonably Achievable (ALARA) by applying cardinal principles of radiation protection- time, distance, and shielding

Area Radiation Exposure

- Top View
- Side View





Strategies for Reducing Dose

- Adjusting mAs
- Automatic tube Current Modulation(ATMC)
- Avoid Increased kVp (120 is almost always sufficient)
- Use Increased Pitch
- Limit use of Thin slices
- Limit Repeat Scans (Multi Phasic Studies)
- Utilization of Equipment with Newer Reconstruction Methods (Iterative Reconstruction to replace Filtered Back Projection

Strategies for Reducing Dose

- Limit repeat scans
- Verify the CT is clinically indicated
- Customize the CT examination when possible
- Shield patient

Q & A

Question 1

True or False: CT scans have lower radiation dose than Xray.

- **Answer: FALSE**

Question 2

True or False: Children and fetuses are more sensitive to radiation exposure.

- **Answer: TRUE**

Question 3

True or False: The thinner the slice (0.625mm) the less radiation that is being admitted to the patient.

- **Answer: FALSE**

Question 4

True or False: The more mAs that is used, the more patient dose increase.

- **Answer: TRUE**

10 MINUTE BREAK

IMAGE PRODUCTION
Multi-Slice CT

Definition of Computed Tomography

- Originally termed "body section radiography" in the early 1920s, the term was used to described imaging a specific layer or section of the body
- In 1935, the term was refined to *tomography,* derived from the Greek word *tomos* meaning section
- In 1937, *transverse axial tomography* was the term used to refer to the imaging ability of cross-sectional images to be acquired

Historical Development

- CT was developed in 1967 by Godfrey Hounsfield by EMI (Electronic Musical Industries)

Image Reconstruction from Projections

- Theoretically derived in 1917 when mathematician Radon proved two- or three-dimensional objects could be “built up” from several projections from different directions
- In the 1960s, image reconstruction from projections proved useful in medical applications
  - Nuclear medicine in 1963
  - Computed tomography (CT) in 1967

Basic Principle of CT

- Computed tomography (CT) produces sharp, clear cross-sectional images of the human body by reconstructing a large number of projections from different locations

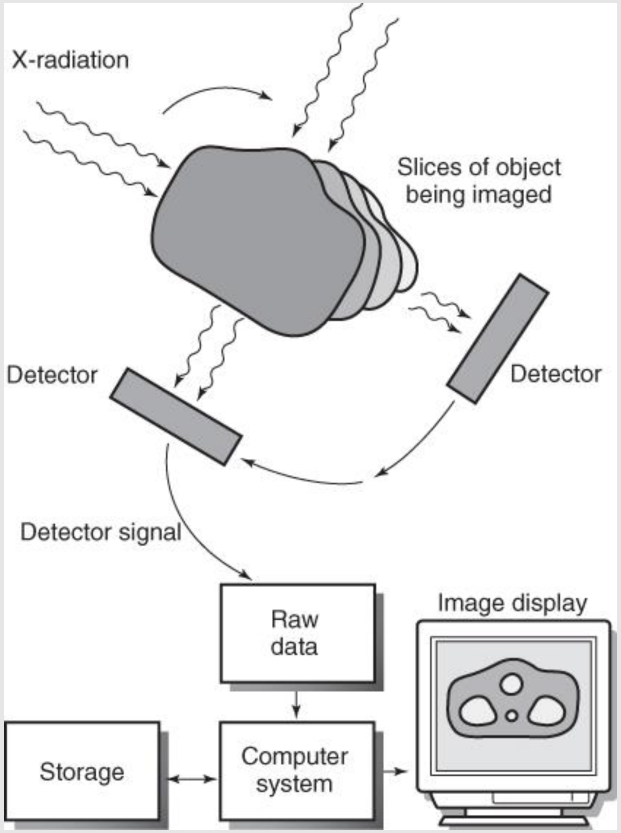


Figure 1-1 Image reconstruction from projections. From many different locations, radiation passes through each slice or cross section of the object being imaged. This radiation is projected onto a detector that sends signals to a computer for processing into an image that reveals the internal structure of the object.

ADVANCED HEALTH EDUCATION CENTER®
EDUCATION ▲ STAFFING ▲ CONSULTING

Clinical Application of CT

- In 1963, Hounsfield applied these reconstruction techniques to produce the world's first clinically useful CT scanner for imaging the brain
- Hounsfield's work revolutionized radiology and transformed the old terminology
  - No longer referred to as *transverse axial tomography*
  - The term *computed tomography (CT)* is now accepted throughout the medical community

Figure 1-2 First-generation model of a CT head scanner. (Courtesy Thorn EMI, London, United Kingdom.)

Formation of CT Images

- The formation of CT images by a CT scanner involves three steps:
  - Data acquisition
  - Image reconstruction
  - Image display, manipulation, storage, recording, and communication

Data Acquisition

- *Data acquisition* refers to the collection of x-ray transmission measurements from the patient
- Special electronic detectors measure the attenuation of the x-ray beam as it passes through the patient

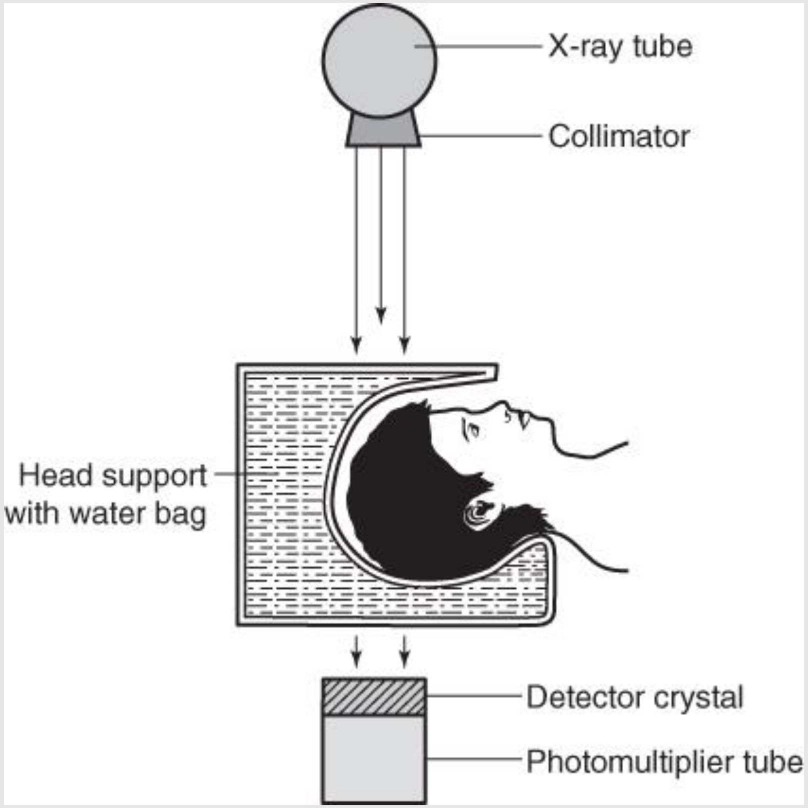


Figure 1-4 Data collection scheme in the first CT brain scanner.

Data Acquisition (Cont.)

- The first CT scanners required the x-ray tube and detectors to move in a straight line across the patient's head
  - Starting from left to right, rotate 1 degree, then move from right to left; repeated for 180 degrees
  - Process termed translate-rotate-stop-rotate or *scanning*
  - This method of data acquisition proved problematic due to the length of exam time
- Newer generation CT scanners resolved the time issue by allowing the technologist to acquire a volume of tissue (*volume scanning*) with continuous rotation of the x-ray tube and detectors (*spiral/helical*)

ADVANCED HEALTH EDUCATION CENTER®
EDUCATION ▲ STAFFING ▲ CONSULTING

Image Reconstruction

- Data collected by the detectors during the data acquisition process are sent to the computer for processing
- Computers are vital to the reconstruction process, as special mathematical techniques known as *image reconstruction algorithms* are applied to the data to produce an image

Image Display

- The reconstructed image can then be displayed for viewing or stored for later reanalysis
- Display occurs on monitors mounted onto control consoles (for the technologist's use) or physician's consoles (for the radiologist's use) and are necessary in the manipulation, storage, and recording of CT images

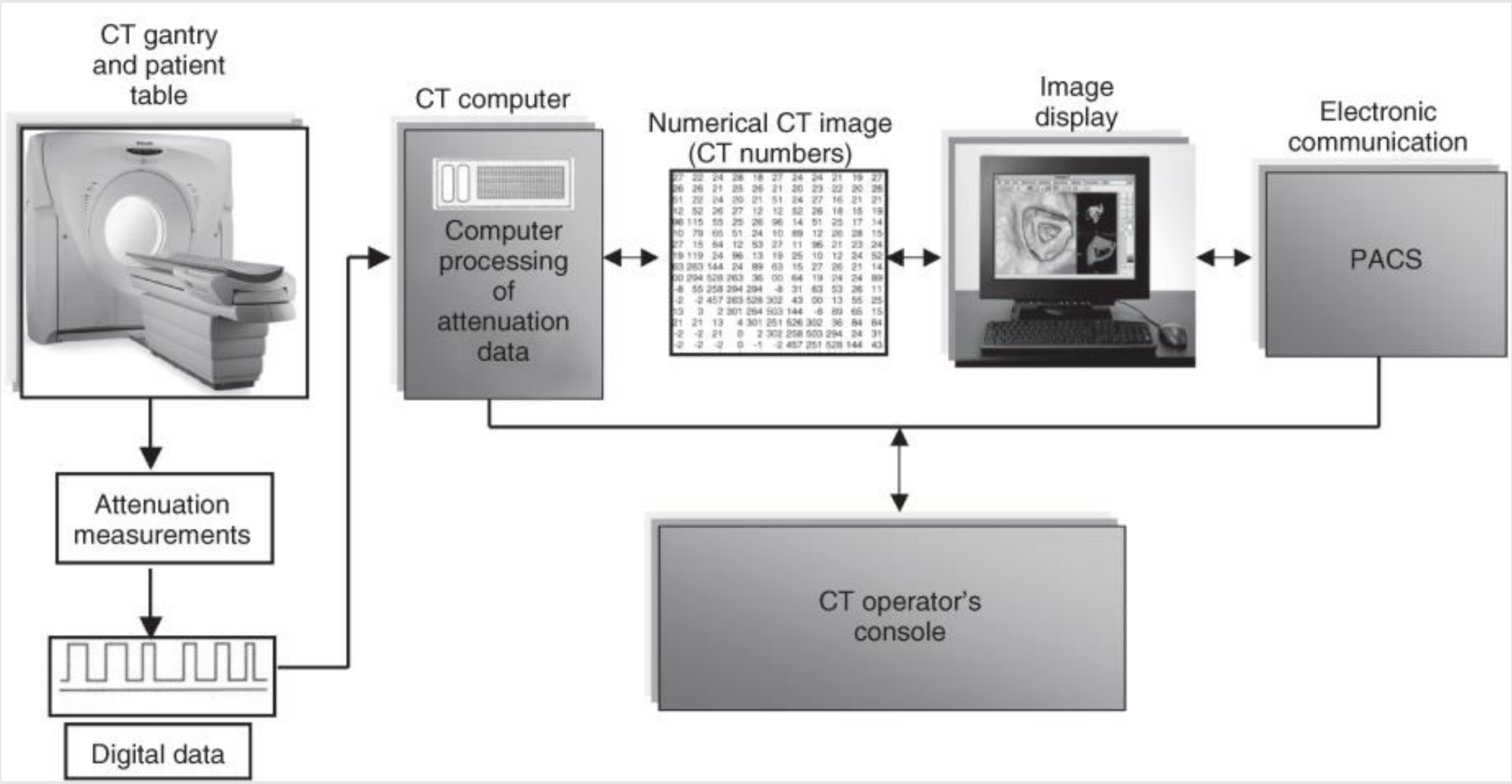
Image Manipulation

- Also known as digital image processing
- Images may be modified to make them more diagnostic and useful for the observer
- Examples include the following:
  - Image reformatting (sagittal or coronal images created from axial acquisitions)
  - Image smoothing
  - Edge enhancement
  - Gray-scale manipulation
  - Three-dimensional (3D) processing

How CT Scanners Work

- Basic steps to familiarize the technologist
  - Turn scanner's power on and perform quality testing
  - Place patient in scanner opening (gantry) using appropriate positioning for protocol
  - Set technical factors at the control console
  - Begin scanning with x-ray tube and detectors inside the gantry rotating around patient
  - Attenuated x-ray beam is measured by detectors that convert the attenuated data into electrical signals
  - Electrical signals are converted into digital data for the computer
  - Computer performs image reconstruction process
  - Digital reconstructed image is converted into electrical signals in order to be viewed by the technologist on a monitor
  - Images are sent to PACS or stored on optical disks

How CT Scanners Work (Cont.)



A CT scanner showing the main components. The data communications component is not shown.

Spiral/Helical CT Scanners: Volume Scanning

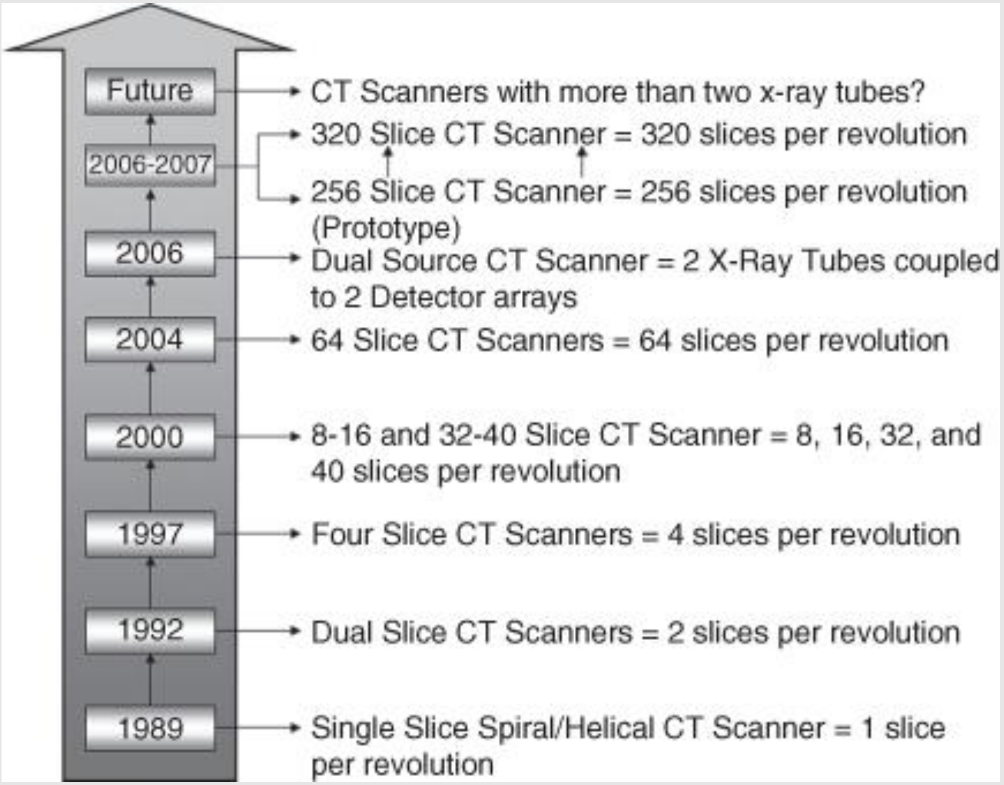
- Technique of CT imaging in which a volume of tissue is scanned by moving the patient continuously through the gantry of the scanner while the x-ray tube and detectors rotate continuously for several rotations
- Continuous motion of the x-ray beam and patient results in a spiral or helical path

High-Speed CT Scanners

- 1975: Dynamic spatial reconstructor (DSR) is installed for dynamic volume scanning
- 1983: U.S. Food and Drug Administration approves electron beam CT (EBCT) scanner
- 1989: First report of practical spiral CT scanner was presented at the Radiological Society of North America (RSNA) meeting in Chicago
- 1998: *Multislice CT (MSCT)* introduced at RSNA meeting

Multislice CT (MSCT) Scanners

- MSCT is based on the use of multidetector technology to scan four or more slices per revolution of the x-ray tube and detectors
- Increasing the number of slices per revolution thus increases the volume coverage and reduces the exam time
- Number of slices per revolution has been increasing at a steady pace in recent years



The evolution of MSCT scanners, including the DSCT scanner.

Other MSCT Improvements

- High-speed imaging
- Large bore gantry apertures
- Improved z-axis resolution
- Dose modulation techniques
- Cone beam image reconstruction algorithms
- Pitch
- Improved *isotropic resolution* of less than 0.4 mm

Dual Source CT Scanner

- *Dual source CT (DSCT)* scanners feature two x-ray tubes and two detector array components
- Used primarily in cardiac imaging
- Provide improved temporal resolution compared to single source CT (SSCT)
- Also known as dual-energy CT because each x-ray tube operates at different energy levels

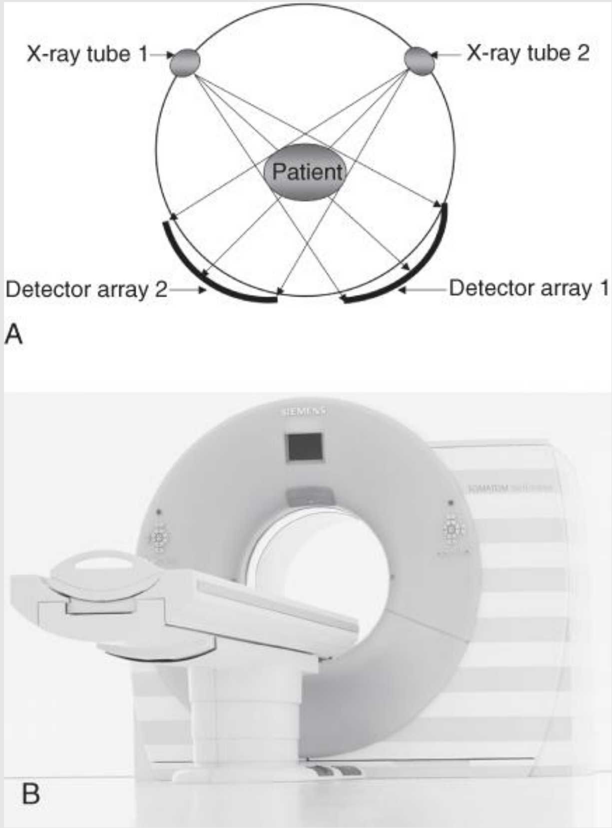


Figure 1-18 The basic concept of the DSCT scanner **(A)** and a full view of the scanner **(B)** introduced by Siemens Medical Solutions. (Courtesy Siemens Medical Solutions.)

ADVANCED HEALTH EDUCATION CENTER®
EDUCATION ▲ STAFFING ▲ CONSULTING

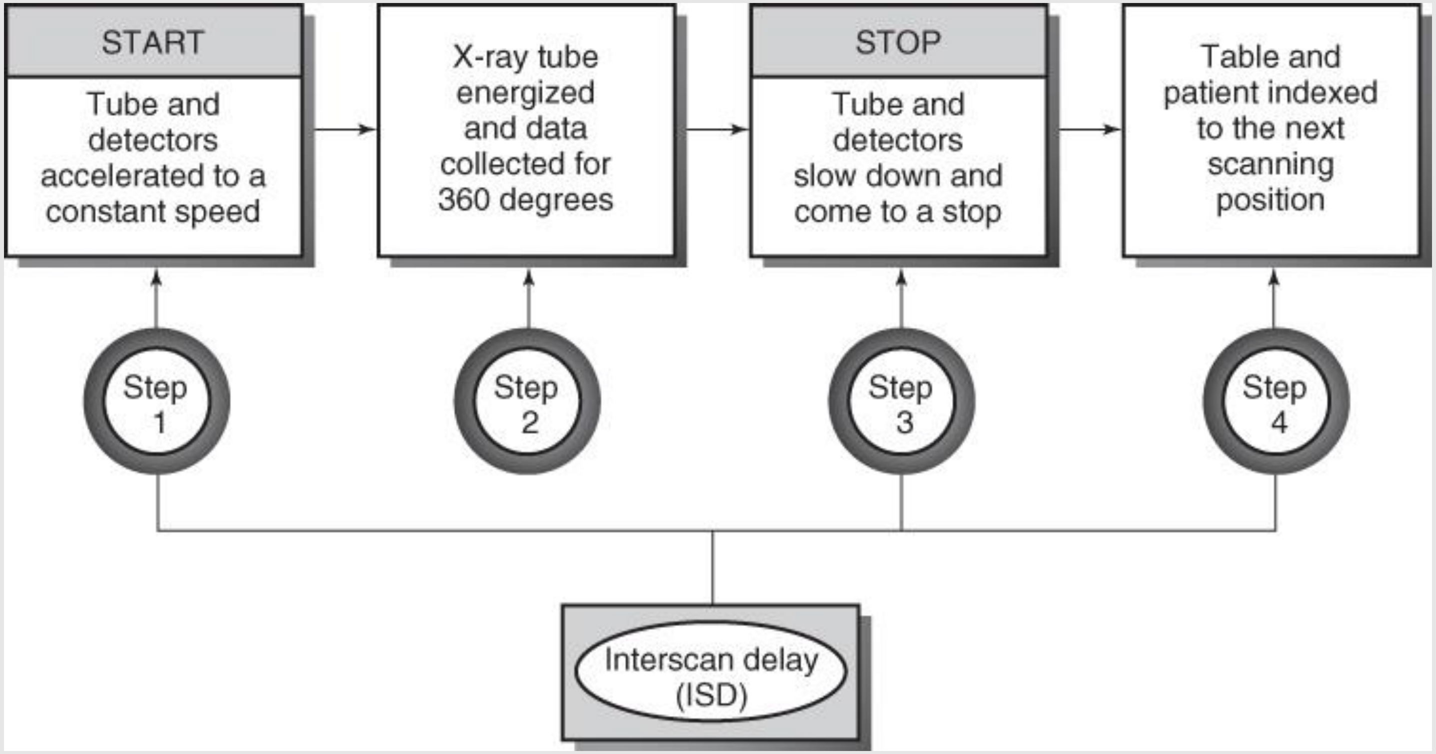
Applications of Volume CT

- CT fluoroscopy
- CT angiography
- 3D imaging
- Virtual reality imaging
- Cardiac CT imaging
- CT simulators in radiation therapy
- PET/CT (positron emission tomography)

Historical Background of SSCT

- *Single-slice spiral/helical CT scanners (SSCT)* replaced conventional slice-by-slice scanners in 1990
- SSCT was invented to do the following:
  - Overcome the problems imposed by conventional CT
  - Provide shorter scan times
  - Improve three-dimensional (3D) imaging

Conventional CT Scanning Sequence



Characteristic four-step process of slice-by-slice sequential CT scanning.

Slice-by-Slice CT Limitations

- Longer examination times because of the *interscan delay*
- Omitted anatomy due to inconsistent patient respiration referred to as *slice-to-slice misregistration*
- Inaccurate generation of 3D or reformatted images producing stairstep artifacts
- Few slices with maximum contrast enhancement

SSCT Data Acquisition Problems

- Several problems can result from data acquisition with spiral/helical beam geometry
  - No defined slice, and thus localization of a particular slice is difficult
  - Data collected in nonplanar geometry
  - Effective slice thickness increases
  - Projection data inconsistencies resulting in streak artifacts
- These problems can be solved through a special postprocessing technique called *interpolation*

Limitations of SSCT

- As pitch increases, image quality decreases and artifacts increase
- Limited volume coverage speed, which is necessary in CT angiography and 3D postprocessing techniques
- Based on a single row of detectors
- Poor geometric efficiency
- Unable to meet the needs of time-critical clinical examinations such as multiphase organ dynamic studies

Multi-slice CT Scanner

- **Multidetector computed tomography:** (MDCT) A form of computed tomography (CT) technology for diagnostic imaging. In MDCT, a two-dimensional array of detector elements replaces the linear array of detector elements used in typical conventional and helical CT scanners. The two-dimensional detector array permits CT scanners to acquire multiple slices or sections simultaneously and greatly increase the speed of CT image acquisition. Image reconstruction in MDCT is more complicated than that in single section CT. Nonetheless, the development of MDCT has resulted in the development of high resolution CT applications such as CT angiography and CT **colonoscopy**.

Evolution of MSCT Technology

- Overall goal is to improve volume coverage speed performance
  - Scanning at faster speeds and higher pitch
  - Covering larger volumes with equal image quality
- Subsecond scanners
- Dual-slice CT scanners
- Multislice CT scanners

Multislice Reconstruction

- Due to the cone-beam geometry of multislice CT, special reconstruction algorithms had to be developed to handle the increased beam divergence and minimize cone-beam artifacts
- Algorithms varying according to the number of detector rows
  - MSCT for up to 4 detector rows
  - MSCT for 16 or more detector rows

Advantages of MSCT

- Increase in speed and volume coverage
- Improved spatial resolution
- Efficient use of the x-ray beam
- Reduction of radiation exposure
- Improved accuracy in needle placement in CT fluoroscopy
- Cardiac CT imaging

Technical Applications

- The volume scanning capability of MSCT has opened new dimensions in CT imaging
  - *Real-time CT fluoroscopy*
  - *3D imaging*
  - *CT angiography*
  - *Virtual reality imaging* or *CT endoscopy*

Clinical Applications

- MSCT advantages in speed of volume acquisition and reduced x-ray tube loading have proven clinically useful when applied to the following:
  - Trauma examinations
  - Pediatric examinations
  - Phase differentiation in contrasted studies
  - 3D postprocessing
  - Functional CT imaging

Slip-Ring Technology

- One major technical factor that contributed to the success of spiral/helical CT scanning
- Purpose of the slip ring
  - Allow continuous rotation of the x-ray tube and detectors
  - Eliminate long, high-tension cables to the x-ray tube used in conventional start-stop CT scanners

Advantages of High Voltage & Low Voltage Scanners

- The major advantage of slip-ring technology is that it facilitates continuous rotation of the x-ray tube so that volume data can be acquired quickly from the patient. As the tube rotates continuously, the patient is translated continuously through the gantry 76aperture. This results in CT scanning in spiral geometry. Other advantages are as follows:
  - 1. Faster scan times and minimal interscan delays
  - 2. Capacity for continuous acquisition protocols
  - 3. Elimination of the start–stop process characteristic of conventional CT scanners
  - 4. Removal of the cable wraparound process

Q & A

Question 1

The formation of CT images by a CT scanner involves three steps:

A) Data acquisition

B) Image reconstruction

C) Image display, manipulation, storage, recording, and communication

D) A,B,&, C

- **Answer: D**

Question 2

True or False: Multi-scanner CT systems have an advantage with because of increase speed, improved spatial resolution, and the capability to reduce radiation exposure.

- **Answer: True**

Question 3

- True or False: Multi-scanner CT systems MSCT advantages in speed of volume acquisition and reduced x-ray tube loading have proven clinically useful when applied to the following:
  - Trauma examinations
  - Pediatric examinations
  - Phase differentiation in contrasted studies
  - 3D postprocessing
  - Functional CT imaging

- **Answer: True**

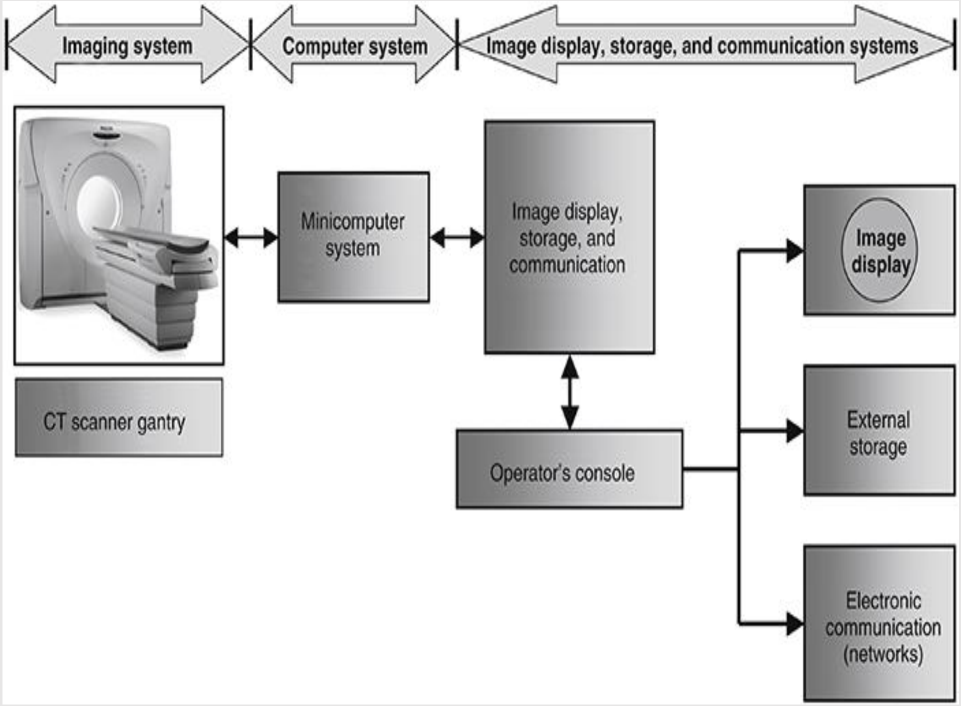
10 MINUTE BREAK

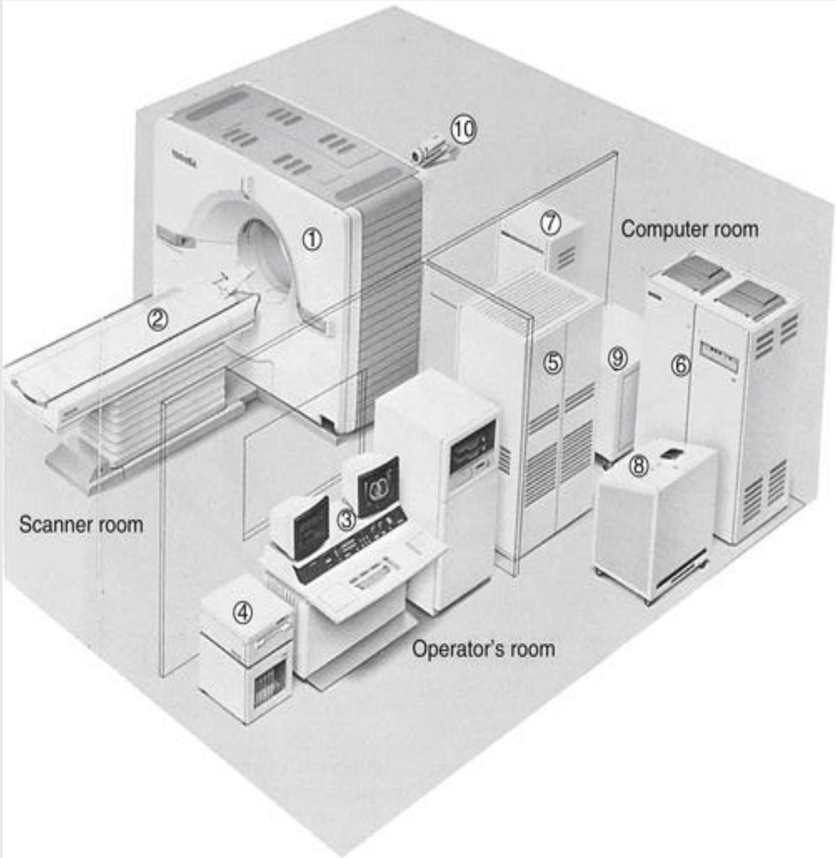
RECORDING & ARCHIVING

Image Evaluation & Archiving

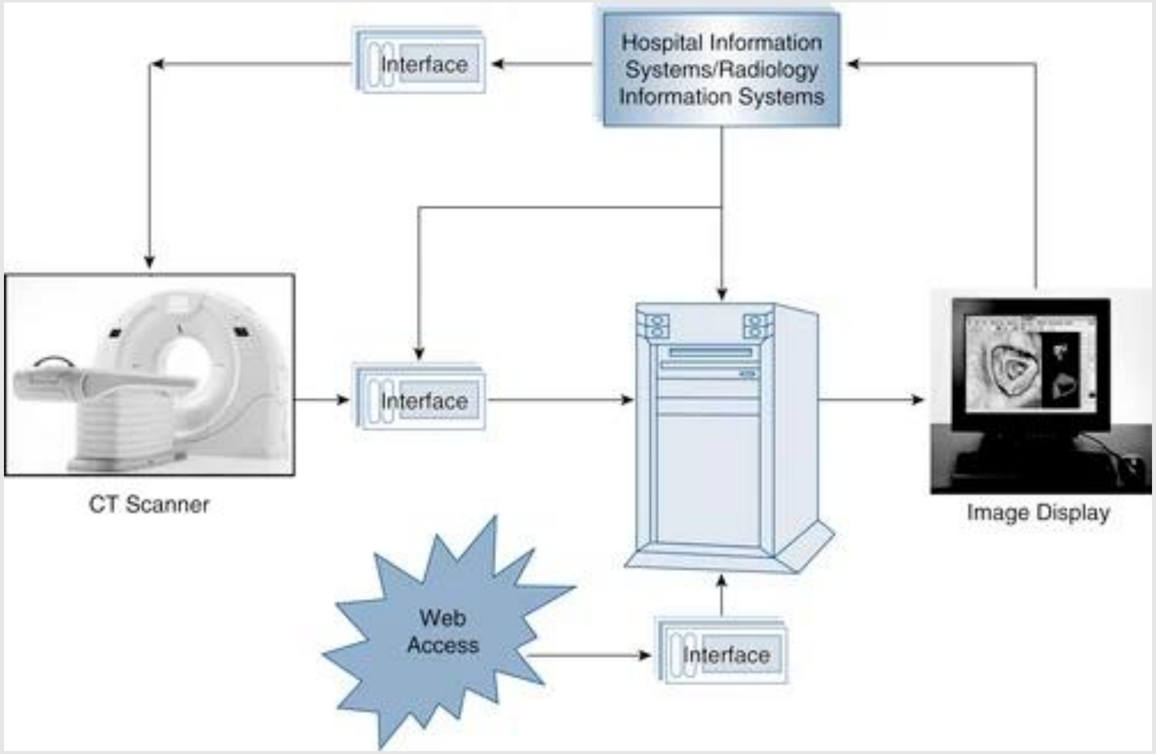
- The Imaging System - in the room
- Computer System – in the computer room
- Display, Recording, & Storage System – in the operator/control

Components of CT Imaging System





Components of CT Imaging System



Film

- Film was similar to film in photographic film.
- Today film in no longer used for imaging display.
- Radiologists now have to make the primary diagnosis from a display monitor.

Technology in the Digital Era

- Healthcare industry continues to implement new technologies
- Clinical decision support (CDS) software
  - Helps improve efficiency of clinical decisions
- Health Information Exchange—allows secure access of information between patients and providers
  - Directed exchange
  - Query-based exchange
  - Consumer-mediated exchange

Informatics

- The collection, classification, storage, retrieval, and dissemination of recorded information

- Radiology professionals use many types of medical information systems
  - Hospital information system (HIS)
  - Clinical information system (CIS)
  - Computerized physician order entry system (CPOE)

Informatics (cont.)

- Generic terms for digital patient records
  - Electronic health record (EHR)
  - Electronic medical record (EMR)

Key Elements of Radiology Informatics

- Radiology information system (RIS)
  - Most often used for scheduling patients, storing reports, patient tracking, protocoling examinations, and billing
  - Intraoperability

- Picture archive and communication system (PACS)
  - Technologies necessary for the storage, retrieval, distribution, and display of images

PACS Fundamentals

- Basic elements of the PACS
  - Networking
  - Digital image format standard
  - Image acquisition
  - Workstations
  - Data storage
    - Previously used:
      - Laser and optical disks
      - Digital Acquisition Tapes (DAT)
    - Currently Used:
      - DVD
      - Compact disc (CD) rom
  - Image distribution

Networking

- A group of two or more computers linked together

- Many types and configuration of computer networks exist
  - Local area networks (LANs)
  - Wide area networks (WANs)
  - Wired networks
  - Wireless networks

Networking (cont.)

- Common in the PACS setting is the client-server network architecture.
- Computers in this model are either servers or clients.
- A server is a computer that facilitates communication between and delivers information to other computers.
- The server acts on requests from other networked computers (clients), rather than from a person inputting directly into it.

Networking (cont.)

- Network bandwidth
  - The amount of data that can be transmitted between two points in the network in a set period of time
- Image data can be compressed to make transmission more efficient
  - Compression schemes can be lossless or lossy

Electronic Standards

- Digital Imaging and Communication in Medicine (DICOM)
  - Universally adopted standard for medical image interchange
- Health Level Seven (HL7)
  - Organization that works to develop universal standards in healthcare data
  - Also refers to the specific standards created by the organization

Image Acquisition

- CT is inherently a digital modality; therefore, the image acquisition from the CT scanner to the PACS should be a direct digital DICOM capture.
- This allow the full spatial resolution and image manipulation capabilities.
- An analog method (called frame grabbing) exists but is inferior to the digital method of image data transfer.

Data Storage

- CT departments generate a tremendous amount of data.
- Archiving is the process of saving image data from the originating modality to an electronic medium.
  - Only image data are stored.

Data Storage (cont.)

- Devices are broadly classified as
  - Online
    - Instantly accessible to the user
  - Near-line
    - Readily, although not immediately, available
  - Off-line storage
    - Data are kept in a less accessible location, requiring manual intervention to use

Storage Devices

- Optical storage devices
  - Compact discs (CD)
  - Digital versatile discs (DVD)
  - Blu-ray disc (BD)

- Tape
  - Magnetic tape

Image Distribution

- PACS must get the correct images to the correct locations in the shortest time possible.
- The Internet is increasing being used for image distribution.
- Any image distribution must incorporate security devices, such as
  - Firewalls, passwords, usernames, secure socket layers, virtual private networks

Q & A

Question 1

Storage Devices include:

A) CD
B) PACS
C) DVD
D) Blue Ray
E) A, B, C, & D

- **Answer: D**

Question 2

True or False: PACS is a network system that allows image storage and viewing.

- **Answer: TRUE**

Question 3

True or False: Film is used all the time in CT.

- **Answer: FALSE**

10 MINUTE BREAK

PATIENT CARE

RT Practice Standards

- “integrates scientific knowledge, technical skills, patient interaction, and care resulting in diagnostic information”

- “A CT technologist recognizes patient conditions, assesses and monitors patient vital signs, and takes appropriate action in emergency situations essential for successful completion of the procedure and to maintain quality patient care.”

- “CT technologists must remain sensitive to the physical and emotional needs of the patient through good communication, patient assessment, patient monitoring, and patient care skills”. asrt.org

Examination Initiation

- CT examinations must be initiated by a clinician with appropriate credentials
  - Before the examination begins
    - Technologist must review the clinician's order and read all clinical data provided.
    - Any discrepancies between the written order, the examination scheduled, or the examination the patient thinks was ordered must be reconciled

Medical History

- Vital aspect of any CT examination. Questions on the CT history form seek to achieve three goals
  - Ensures patient safety
  - Guides the selection of examination protocol
  - Provides diagnostic information for the radiologist
- Technologist must verify the patient's identity before proceeding
  - At least two methods of verification are required

Diagnostic Information

- Many disease or conditions have similar findings on CT images. A medical history can often aid in narrowing down, or pinpointing exactly, the disease or condition from which the patient suffers

- Questions include
  - Past surgeries
  - Significant medical issues
  - Current symptoms

Necessary Information

- Signed consent form
- Specific written order
- Diagnosis pertinent to the procedure
- Allergies-especially contrast
- Laboratory Values
- Medications
  - anticoagulants, sedatives, insulin, blood pressure meds, diuretics, and laxatives

High Risk Patients

- Aneuria
- Chronic heart disease
- Recent myocardial infarctions
- Renal disease
- Respiratory disease
- Previous reaction to contrast
- History of allergies

Pre-medication and Diet

Depends on patient condition and type of procedure

- **Generally**
  - **fasting 4 hours prior to procedure**
  - **anticoagulants withheld if a biopsy is planned**

Anticoagulants

- **Any patient receiving these have increased risks of bleeding**

- **Anticoagulants**-used with history of clot formation

  - **Warfarin (coumadin**)- oral medication,blocks absorption of vitamin K

  - **Heparin** – injected, affects activity of thrombin to prevent clot formation

Antiplatelets and Thromblitic Agents

- **<u>Antiplatelet</u>**-used in patients with acute ischemic event in the heart or brain
  - Acetylsalicylic acid (aspirin)
  - Plavix (Clopidogrel)

- **<u>Thromblitic Agents-</u>** medication used to break a clot
  - Altepase
  - Streptokinase
  - Urokinase

Clotting Value Lab Reports

- **Prothrombin Time (PT)**
  - **Measures Activity of Coagulation in Plasma**
  - **11-14 seconds**
- **Partial Thromboplastin Time (PTT)**
  - **Blood Substance that aids in Conversion of other clotting factors**
  - **25-35 seconds**
- **Platelets**
  - **150,000-400,000 u/L**
- **International Normalized Ratio (INR)**
  - **Evaluates the ability of blood to clot properly**
  - **Results vary with patients treatment**
  - **Normal value = 1**
  - **Higher values in people on anticoagulants = or 2 or 3**
  - **Over 5 increased risk of bleeding**
  - **Under .5 increased risk of clotting**

Critical Kidney Values

- **BUN –**
  - Abnormal Value associated with dehydration and Kidney Disease
  - 7-25 mg/dl
- **Creatinine-**
  - High value associated with renal impairment - does not change as rapidly as BUN
  - .6-1.7 mg/dl

Kidney Values

- Creatinine Clearance
  - a useful measure for estimating the glomerular filtration rate (GFR) of the kidneys.
  - result of this test is an important gauge used in assessing excretory function of the kidneys
  - Cockcroft-Gault formula

$$\text{Creatinine clearance} = \frac{(140 - \text{Age}) \times \text{Mass (in kilograms)}}{72 \times \text{Plasma Creatinine (in mg/dL)}} \times 0.85 \text{ if female}$$

Creatinine Clearance Values

- **Normal > 90**
- Moderate Function 30-60
- Poor Function 15-30
- **Failure <15**
- True test for creatinine clearance is 24 urine lab test

Adverse Effects

- Iodinated CM is one of the most widely used of all medications.
- They are also one of the safest.
- Fatal reactions are extremely rare in both HOCM and LOCM.
  - Estimated at 0.001%

Adverse Effects (cont.)

- Although rare, adverse reactions sometimes occur.
- It is impossible to predict which patient will have an adverse reaction to IV-administered CM.
- Therefore, CT staff must be trained to respond quickly.

Adverse Effects (cont.)

- The term "contrast reaction" is used in a variety of different ways in relation to the effects of iodinated CM.
- In some instances, it describes all undesired effects including the many subjective effects (e.g., heat, metallic taste).
- In other instances, it describes the less common, more serious side effects that may require treatment or even be life threatening.

Adverse Effects (cont.)

- CM reactions can be broadly categorized as either
  - Chemotoxic reactions
    - Result from the physiochemical properties of the CM, the dose, and speed of injection
  - Idiosyncratic reactions
    - All other reactions

- In practice, it can be difficult to characterize some reactions into one group or the other

Idiosyncratic Reactions

- The mechanisms by which idiosyncratic reactions occur are not precisely understood.

- The origin of these reactions is rarely, if ever, “an allergy.”
  - True allergic reactions result in the production of antibodies, which are not found after CM reactions.
  - True allergies result in similar or more severe adverse reactions with reexposure.
    - Research shows this is not true of CM reactions.

Idiosyncratic Reactions (cont.)

- Even though the underlying cause is likely different, symptoms of idiosyncratic reactions resemble allergic (or anaphylactic) reactions and are, therefore, often called **allergic-like** or **anaphylactoid** reactions.

- Even though it is not completely accurate, the term “contrast allergy” remains in common use.

Idiosyncratic Reactions (cont.)

- Acute idiosyncratic reaction are usually classified as
  - Mild
    - Short duration and self-limiting
  - Moderate
    - Not immediately life threatening, although they may progress to be so
  - Severe
    - Potentially or immediately life threatening

Mild Reaction Signs and Symptoms

- Nausea
- Vomiting
- Cough
- Warm feeling
- Headache
- Dizziness
- Shaking
- Itching
- Strange taste in mouth
- Pallor
- Flushing chills
- Sweats
- Urticaria (hives)
- Nasal stuffiness
- Swelling about the eyes and face
- Anxiety

Moderate Reaction Signs and Symptoms

- Tachycardia
- Bradycardia
- Hypertension
- Pronounced cutaneous reaction
- Hypotension
- Dyspnea
- Bronchospasm
- Wheezing
- Laryngeal edema

Contrast-Media Reactions

- Range from mild to severe
- No predictors
- Begin injection with a small amount and wait to check for signs or symptoms
  - Protocol determines how long to wait before proceeding with administration
- Patients at risk for reaction are premedicated
  - Antihistamine and/or corticosteroids

Vasovagal Reactions

Symptoms	Treatment
Diaphoresis	Place patient supine, feet elevated 20 degrees, and head elevated if breathing is a problem. IV fluids and atropine administered for bradycardia
Hypotension	
Bradycardia	

Severe (Anaphylaxis) Reactions

Symptoms	Treatment
Warmth	Maintain airway Call a code Epinephrine usually administered by IV Other drugs administered as needed by code team
Tingling	
Itching palms and soles	
Dysphagia	
Laryngeal and bronchial edema	
Respiratory arrest	
Cardiac arrest	
Seizures	

Severe Reaction Signs and Symptoms

- Laryngeal edema
- Convulsions
- Profound hypotension
- Cardiac arrhythmias
- Unresponsiveness
- Cardiac arrest

Risk Factors for Idiosyncratic Reactions

- Previous CM reaction
- Asthma
- A history of allergy to food, drugs, or other substances
  - Seafood allergy poses no particular risk
    - Seafood allergy results from hypersensitivity to a protein within the seafood and has no association with iodine.

Shock

- Body's pathologic reaction to
  - Illness
  - Trauma
  - Severe physical or emotional stress

- Symptoms
  - Decrease in Blood Pressure
  - Increase in Heart Rate
  - Rapid shallow Respirations
  - Mental Status Change

Types of Shock

- Hypovolemic- loss of blood, plasma, or prolonged loss of fluids
- Cardiogenic -Failure of heart to pump adequately
- Septic – microorganisms in blood
- Anaphylactic -- allergic reaction to food ,drug or chemical

Anaphylactic Shock

- Most common in CT from iodinated contrast

- Release of histamines and contraction of smooth muscles in respiratory tract

- Symptoms of tightness in chest, itching, urticaria, choking and wheezing

- 1st Drug epinephrine (adrenaline)

Neurogenic or Vasovagal

- **Neurogenic-induced by spinal cord injuries, severe pain, neurologic damage or extreme psychological stress.**
- **Vasovagal –stimulation of vagus nerve (10^{th})**
- **Note: for these the heart rate drops (bradycardia) instead of tachycardia**
- **Drug of choice is <u>Atropine</u>**

Preventive Measures

- For patients identified as being at increased risk of adverse reaction to CM, options include
  - Perform examination without CM
  - Use LOCM
  - Pretreatment with steroids

Documenting Adverse Reactions

- At a minimum, elements to be documented include
  - Amount and type of contrast injected
  - Signs and symptoms of the reaction
  - Interventions or medications given during the reaction and the patient's response
  - Final outcome (such as whether the patient was sent home or admitted to the hospital)

CIN Risk Factors

- Creatinine clearance less than 25 mL/min
- History of diabetes mellitus
- History of recent administration of iodinated contrast agent
- Anticipated large volume of CM
- History of congestive heart failure

Methods of Preventing CIN

- Identify patients at high risk.
  - Patients with diabetes mellitus or other risk factors should have a recent SeCr.
- Use LOCM or IOCM.
- Ensure adequate patient hydration.
- Minimize CM volume.
- Allow at least 48 hours between procedures requiring CM.
- Discontinue other nephrotoxic medications before the procedure.

Chemotoxic Reactions

- The types of chemotoxic reactions to CM are variable and the underlying causes multifactorial
  - Contrast media–induced nephropathy
  - Effects on thyroid function
  - Pulmonary effects
  - Pheochromocytoma
  - Central nervous system effects
  - Delayed reactions

Metformin Therapy

- CM can result in CIN. When renal dysfunction occurs in patients taking metformin, the drug can accumulate and result in lactic acidosis.
  - Although the incidence of occurrence is low, when it does occur, lactic acidosis is fatal in about 50% of patients.

- As a precaution for patients with eGFR less than 60, metformin should be temporarily discontinued after CM administration; it can be resumed after 2 days, assuming kidney function is normal.

Diabetic Hypoglycemia Reaction

- Abnormally low level of glucose in the blood
- Caused by an excess of insulin or oral hypoglycemic drug

- Symptoms (progressive)
  - Hunger
  - Nervousness & Irritability
  - Tachycardia
  - Profuse perspiration and clammy skin
  - Slurred speech
  - Seizure
  - Coma

- Check Chart for Diabetes & contact nurse or doctor
- Give some type of sugar

Notes About Diabetic Patients

- Metformin
  - Metformin is the generic form of Glucophage, can be found in other diabetic medications
  - Withheld 48 hours post contrast
  - Binds to iodine and causes blood toxicity
- Must have a creatinine level
  - All ages

Diabetic Ketoacidosis

- **Insufficient Insulin in blood to process glucose**
- **Patient becomes hyperglycemic**
- **Occurs more slowly than hypoglycemia**
- **Symptoms**
  - **Weakness, drowsiness & headache**
  - **"Sweet" odor to breath & orthostatic hypotension**
  - **Warm dry skin, dry mucus membranes & polyuria**
  - **Tachycardia and rapid deep respirations**

Dialysis and CM

- Do not give CM to dialysis patients in whom it is hoped that the dialysis is temporary.
- CM may be given to patients on dialysis with end-stage renal failure.
  - Patients on dialysis who undergo contrast-enhanced CT may continue their routine dialysis schedule.

CM Effect on Thyroid Function

- No effect on patients with normal thyroid function.
- Insignificant effect on patients with **hypo**thyroidism.
- When given to patients with **hyper**thyroidism, CM may precipitate thyroid storm.
  - This is a severe, life-threatening condition resulting when thyroid hormone reaches a dangerously high level.

Pulmonary Effects

- CM may cause
  - Bronchospasm
  - Pulmonary arterial hypertension
  - Pulmonary edema

- Patients at increased risk are those with a history of pulmonary hypertension, bronchial asthma, or heart failure.

- The use of LOCM significantly reduces the risk.

Gastrointestinal CM

- In the GI tract, CM is helpful to distinguish loops of bowel from cyst, abscess, or neoplasm.
  - Oral CM is used for most CT studies of the abdomen and pelvis.
  - Rectal administration of CM is useful for some indications.

Delayed Reactions

- Defined as reactions that occur between 1 hour and 1 week after CM injection.
- Data on delayed reactions are difficult to accurately collect.
- Skin reactions account for the majority of true late reactions.
  - Red spots or bumps, weltlike swelling, hives
- Salivary gland swelling (or iodide "mumps").
- Patient receiving interleukin-2 may reexperience the side effects of that medication after receiving CM.

Health Professional Responsibilities When Administering Contrast Agents

- Administered under the supervision of a licensed physician with proper qualifications
- Patient assessment and history
- Patient comfort and education
- Recognize signs and symptoms of reaction and act appropriately.
- Patient care and surveillance
- Postexam considerations for patient
- Remain calm and reassuring during procedures.

Q & A

Question 1

- True or False : It is important to obtain medical history for any contrast CT study?

- **Answer: True**

Question 2

- Kidney function tests include:

A) BUN

B) Creatinine

C) Glomulerus Filgtration Ratio (GFR)

D) Insulin

E) A, B, & C

- **Answer: E**

Question 3

- True or False: Diabetes is not a required question to ask patients when doing any CT contrast study :

- **Answer: FALSE**

Question 4

- True or False: Anaphylaxis is a common reaction in the CT department.

- **Answer: TRUE**

Question 5

- True or False: Patients that are allergic to contrast iodine will need to be pre-medicated prior to completing the CT contrast study.

- **Answer: TRUE**

Venipuncture

Venipuncture

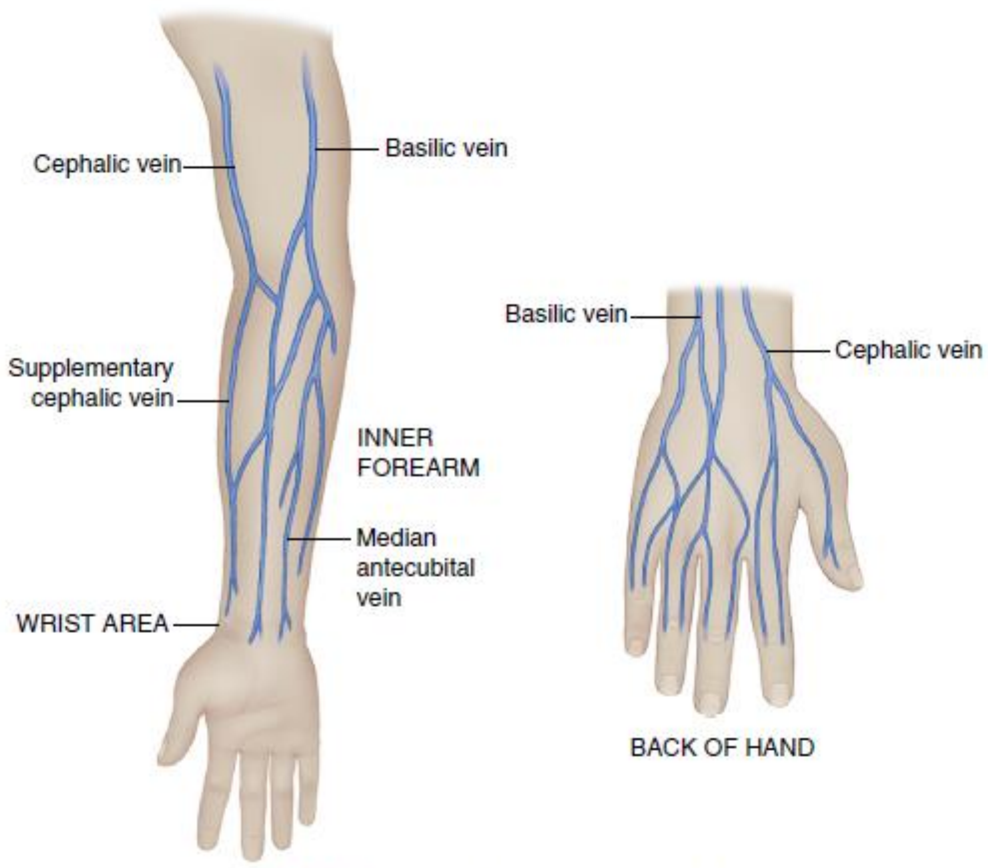


Fig. 22.19 Common Sites of Venipuncture.

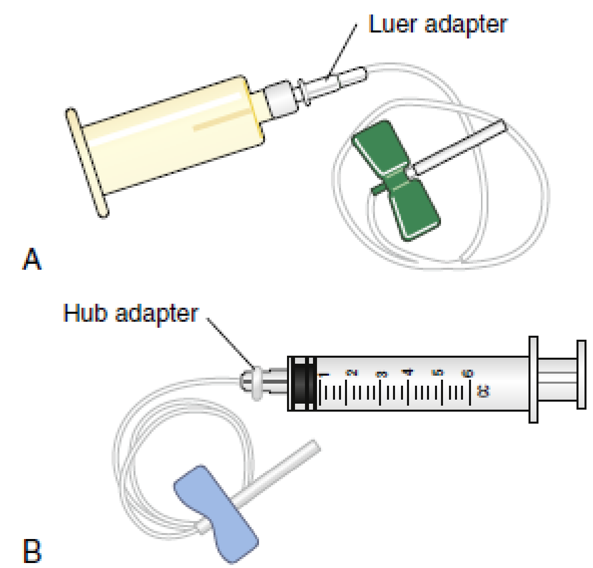
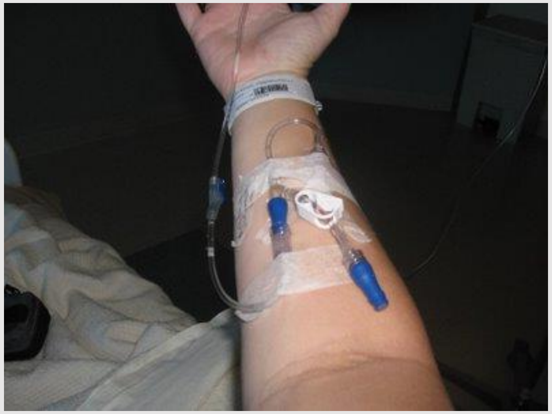


Fig. 22.20 Butterfly Winged Infusion Set.



Extravasation / Infiltration

- Leakage or injection of IV fluids outside of the vessel
- Also called infiltration
- Infiltration refers to diffusion of the fluid into the surrounding tissues
- Extravasation is the presence of fluid outside the vessel
- Painful and often dangerous condition
- Treatment is to apply cold packs to the site
- Can also cause compartment syndrome

Injection Techniques

- Method of injecting iodinated CM will vary according to
  - Vascular access available
  - Type of examination
  - Specific clinical indication

Injection Parameters

- Parameters that may vary
  - Whether the injection is performed by hand or with the use of a mechanical injector
  - Contrast volume and concentration
  - Flow rate at which the contrast will be injected
  - The delay between injection and scanning
  - Whether a saline flush is used

Vascular Access

- Stable IV access is necessary for CM administration.

- Vascular access may consist of
  - Standard indwelling peripheral catheter
  - Central venous access devices (CVAD)
    - Peripherally inserted central catheters (PICC)
    - Nontunneled central venous catheters
    - Tunneled central venous catheters

Starting a Peripheral IV

- Obtain basic consent
- Use aseptic technique
- Use an indwelling catheter set with a flexible plastic cannula whenever a mechanical injector will be used
- Steps involved
  - Assemble supplies
  - Choose site
  - Place the needle
  - Secure site

Removal of Needle

- Remove tape
- Pull needle without applying pressure
- Immediately apply pressure with dry gauze
- Elevate arm
- Check site after one minute
- Apply sterile dressing
- DOCUMENT DOCUMENT DOCUMENT

VENOUS SELECTION

Veins found in the antecubital fossa are:

- generally large

- easy to access

- durable to withstand a bolus injection of contrast medium without extravasation

(leaking of the contrast medium from a blood vessel into the surrounding tissues)

Veins found within the antecubital fossa commonly used during venipuncture include the:

*Median Cubital Vein (most accessed)

*Cephalic Vein

*Basilic Vein

Other common IV access sites include the cephalic vein of the lateral wrist and veins on the posterior hand or lower forearm, such as the cephalic or basilic veins

Supplies Needed

• Sharps container

• Tourniquets

• Alcohol wipes

• Various sizes of butterfly and angio-catheters

• Disposable or prefilled syringes

• IV infusion tubing

• Arm board

• Cotton balls or 2 × 2-inch (5 × 5-cm) gauze

• Tape or securing device (e.g., Tegaderm) If using tape – precut pieces of tape for securing purposes

• Gloves (latex-free recommended)

• Contrast medium

Starting an IV

- Starting an IV :
  - Greet the patient. Check patient ID and explain the procedure.
  - Select the appropriate injection site.
  - Don clean gloves.
  - Cleanse the selected area with the alcohol wipe.
  - Hold the skin taut with your nondominant hand.
  - Insert the needle at the correct angle, and pull back slightly on the plunger.
  - If no blood is present, inject the medication.
  - Withdraw the needle quickly, and wipe the injection site.
  - See to the patient’s comfort.
  - Remove your gloves and perform hand hygiene.
  - Chart the medication.
  - Discard the container and any remaining medication.

Q & A

Question 1

- Infiltration is when contrast media _______.

A) Safely flows into the vein

B) Pools under the skin

C) is ingested by mouth

D) Can be processed by inhalation

- **Answer: B**

Question 2

- True or False: Venipuncture should be done as a sterile procedure?

- **Answer: False**

Question 3

- True or False: It is best to use any superficial vein that is seen.

- **Answer: False**

Question 4

- True or False: It is ok to “fish” for a vein and poke the patient multiple times with the same needle.

- **Answer: False**

Contrast Agents

TWO CLASSIFICATIONS

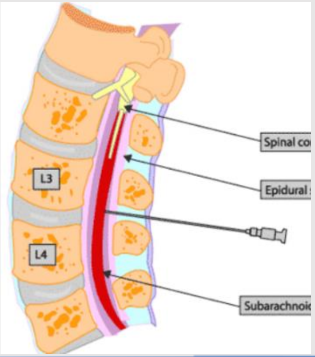
- **Negative -- Air and other Gases**
  - **Absorb less x-rays than surrounding tissue**
  - **Appears dark or black**
  - **Most often used in digestive system**

- **Positive – Barium Sulfate & Iodine**
  - **Absorb more x-rays than surrounding tissue**
  - **Appears light or white**

METHODS OF ADMINISTRATION

- Parenteral
  - Injection into a vessel (Iodine)
- Ingestion
  - UGI & Small Bowel (Barium & Iodine)

- Retrograde
  - Enema (Ex. Barium or Iodine)
  - Cystogram (Iodine)
- Intrathecal
  - Myelogram (Air or Iodine)



Intravascular Contrast Agents

- Iodinated agents are universally used because they are
  - Water soluble
  - Easy to administer intravascularly
  - Safe
- IV agents increase the difference in attenuation between adjacent structures because
  - Different tissues often enhance differently
  - Iodinated CM is handled differently in normal versus abnormal tissue

Element Iodine Atomic # 53

- **Aqueous Iodine Compounds used for many exams**
  - **Oral**
  - **Intrathecal**
  - **Ductal and Joints**
  - **Vascular**
  - **Fistula or Tract Exams**

Excreted by Kidneys

Properties of Iodinated Agents

- **Osmolality**
  - **The number of particles in solution, per unit liquid, as compared with blood**
- **High-osmolality agents (HOCM) may have as much as 7 times the osmolality of blood**
- **Low-osmolality agents (LOCM) have roughly twice the osmolality of blood**
- **Iso-osmolar agents (IOCM) have the same osmolality as blood**

Osmolality/Osmolarity of Contrast

- Osmolality refers to # of particles per kilogram of water (weight)
  - Measured as Milliosmoles/kilogram of water (mOsm/kg)

- Osmolarity refers to # of particles per liter of solution (volume)
  - Measured as Milliosmoles/liter of solution (mOsm/L)

- These terms are used interchangeably to describe <u>Osmotic</u> <u>Activity</u>
  - Refers to the number of particles in the blood or extra-vascular fluid

- Blood ~ 300 mOsm/kg
- Nonionic~ 600 -800 mOsm/kg
- Ionic >1300 mOsm/kg

- Non-Ionic is closer in number to blood so less stress to system and less reactions

Importance of Osmolality

- Osmolality: Primary Factor in Reactions
- Goal – to reduce osmolality
- Contrast molecules have 3 Iodine atoms
  - Ionic molecules disassociate into 2 particles 3:2 ratio
  - Nonionic molecules stay together so 3:1 ratio
- Higher ratio is better
  - Same contrast
  - Less reaction

Ionic Vs Nonionic Aqueous Iodine

- Ionic (High Osmolar)
  - Have iodine
  - Have positive and negative ions
  - Disassociates in solution

- Nonionic (Low Osmolar)
  - Have same amount of iodine
  - Do Not disassociate in Solution

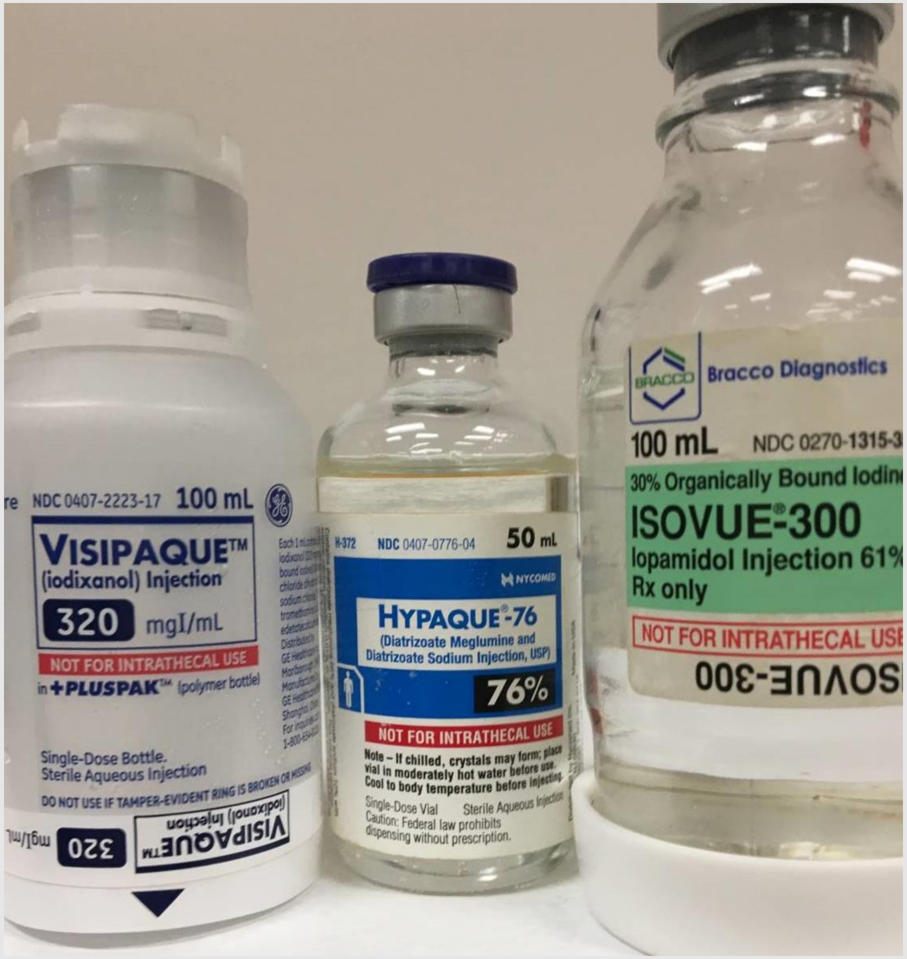
Viscosity of Contrast

- Measurement of resistance to flow
- High viscosity = thick or "syrupy"
- Low viscosity = thin or "watery"
- Inversely proportional to Temperature
- Viscosity determined by particles in solution and attraction between particles

Concentration of Iodine

- Concentration determines opacity
- Higher concentration---- Greater opacity
- Concentration is expressed as weight per volume
  - g/ml or mg/ml

Iodine -- IV


NDC 0407-2223-17
100 mL
VISIPAQUE™
(iodixanol) Injection
320 mgI/mL
NOT FOR INTRATHECAL USE
in +PLUSPAK™ (polymer bottle)
Single-Dose Bottle.
Sterile Aqueous Injection
DO NOT USE IF TAMPER-EVIDENT RING IS BROKEN OR MISSING
NDC 0407-0776-04
50 mL
NYCOMED
HYPAQUE®-76
(Diatrizoate Meglumine and Diatrizoate Sodium Injection, USP)
76%
NOT FOR INTRATHECAL USE
Note – If chilled, crystals may form; place vial in moderately hot water before use. Cool to body temperature before injecting.
Single-Dose Vial
Sterile Aqueous Injection
Caution: Federal law prohibits dispensing without prescription.
Bracco Diagnostics
100 mL
30% Organically Bound Iodine
ISOVUE®-300
Iopamidol Injection 61%
Rx only
NOT FOR INTRATHECAL USE


GE Healthcare
NDC 0407-1412-34
150 mL
OMNIPAQUE™
(iohexol) Injection
240 mgI/mL
in +PLUSPAK™ (polymer bottle)
Single-Dose Bottle.
Sterile Aqueous Solution For Injection or Oral Use.
DO NOT USE IF TAMPER-EVIDENT RING IS BROKEN OR MISSING
NDC 0407-1413-63
100 mL
OMNIPAQUE™
(iohexol) Injection
300 mgI/mL
in +PLUSPAK™ (polymer bottle)
Single-Dose Bottle.
Sterile Aqueous Solution
For Injection or Oral Use
DO NOT USE IF TAMPER-EVIDENT RING IS BROKEN OR MISSING

Iodine -- Oral

MD-Gastroview®
DIATRIZOATE MEGLUMINE AND DIATRIZOATE SODIUM SOLUTION U.S.P.
367 mg/mL Organically Bound Iodine For Gastrointestinal Radiography
Not For Parenteral Use
Rx Only
10-22
P311C
JAN 10
Bracco Diagnostics
120 mL
37% Organically Bound Iodine
GASTROGRAFIN
Diatrizoate Meglumine and Diatrizoate Sodium Solution USP
Rx only
DO NOT INJECT

Negative Contrast

CO2 Machine for CT Colonoscopy for Stomach

Crystals

Gastrointestinal CM

- In the GI tract, CM is helpful to distinguish loops of bowel from cyst, abscess, or neoplasm.
  - Oral CM is used for most CT studies of the abdomen and pelvis.
  - Rectal administration of CM is useful for some indications.

Gastrointestinal CM (cont.)

- The most common definition classifies GI agents as positive or negative depending on the density of the material relative to the wall of the GI tract.
  - By this definition, water is considered a negative agent.

- Less commonly, oral CM is classified in accordance to its HU.
  - Positive agents have positive HU values.
  - Negative agents have negative HU values.
  - Water is considered a neutral agent.

Barium

NDC 32909-945-03
VoLumen
BARIUM SULFATE SUSPENSION (0.1% w/v, 0.1% w/w)
CAT. NO. 9450
Net Contents: 450 mL
CT STUDIES
Bracco Diagnostics
450 mL
NDC 32909-723-01
READI-CAT 2
(BARIUM SULFATE) ORAL SUSPENSION (2% w/v)
For Oral Use Only
Rx only
COMPUTED TOMOGRAPHY STUDIES

NDC 32909-115-00
VARIBAR NECTAR
TARGET VISCOSITY 300 CPS
BARIUM SULFATE SUSPENSION (40% w/v, 30% w/w)
Net Contents: 240 mL
NDC 32909-764-01
E-Z-HD
BARIUM SULFATE FOR SUSPENSION (98% w/w)
CAT. NO. 764
Net Contents: 340 g
DOUBLE CONTRAST UPPER GI STUDIES
NDC 32909-105-10
VARIBAR THIN LIQUID
BARIUM SULFATE FOR SUSPENSION (40% w/v After Reconstitution)
Apple Flavor
CAT. NO. D105
Net Contents: 148 g (Equivalent to 120 g barium sulfate)

Barium Sulfate Solutions

- The most commonly used are positive agents that contain a 1% to 3% barium sulfate suspension.

- In general, the higher the dose, the better the bowel opacification.
  - For most examinations, a minimum of 500 mL of dilute barium sulfate is given 45 minutes to 2 hours before scanning.
  - An additional 200 mL is given just before scanning to fill the stomach and small bowel.

Barium Sulfate Solutions (cont.)

- Low HU oral barium sulfate suspension (VoLumen) resembles water on CT images.
  - Just 0.1% barium sulfate solution
  - Measures from 15 to 30 HU on an image
- Advantages of low HU oral contrast
  - Improved bowel distention (compared with water)
  - Faster transit than standard CT barium solutions
  - More effective visualization of both the bowel wall and the mucosa

Barium Sulfate Solutions (cont.)

- Contraindicated when perforation of the gastrointestinal tract is suspected.
- Barium leaking into the peritoneal cavity can result in inflammation referred to as barium peritonitis.
- Fewer complications from aspiration appear to occur with barium sulfate compared with high-osmolality iodinated agents (e.g., Hypaque).

Iodinated Agents for Oral Administration

- Both HOCM and LOCM are positive agents that can be diluted and administered orally.
- Dosages are similar to those used with barium sulfate.
- HOCM is used for most situations because it is less expensive and provides equivalent gastrointestinal opacification.
- LOCM has advantages in selective cases.

Indication

- In medicine, a condition which makes a particular treatment or procedure advisable.
- Contrast media is used to distinguish different densities for enhancement.

Contraindication

- Contraindication - a condition that serves as a reason not to take a certain medical treatment due to the harm that it would cause the patient.
  - Contraindication is the opposite of indication, which is a reason to use a certain treatment. Absolute contraindications are contraindications for which there are no reasonable circumstances for undertaking a course of action.

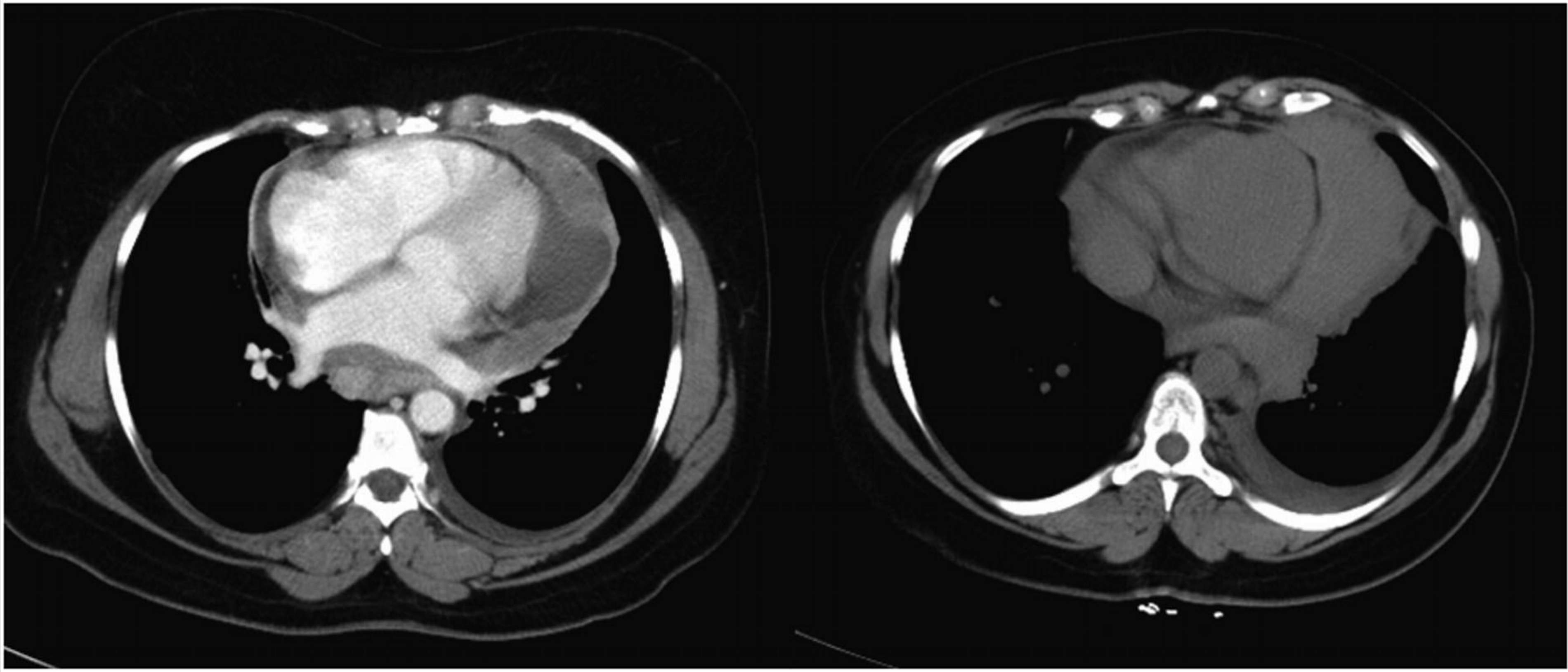
Reasons for Contraindication:

- Hypersensitivity to iodine
- Perforation
- Post Surgery

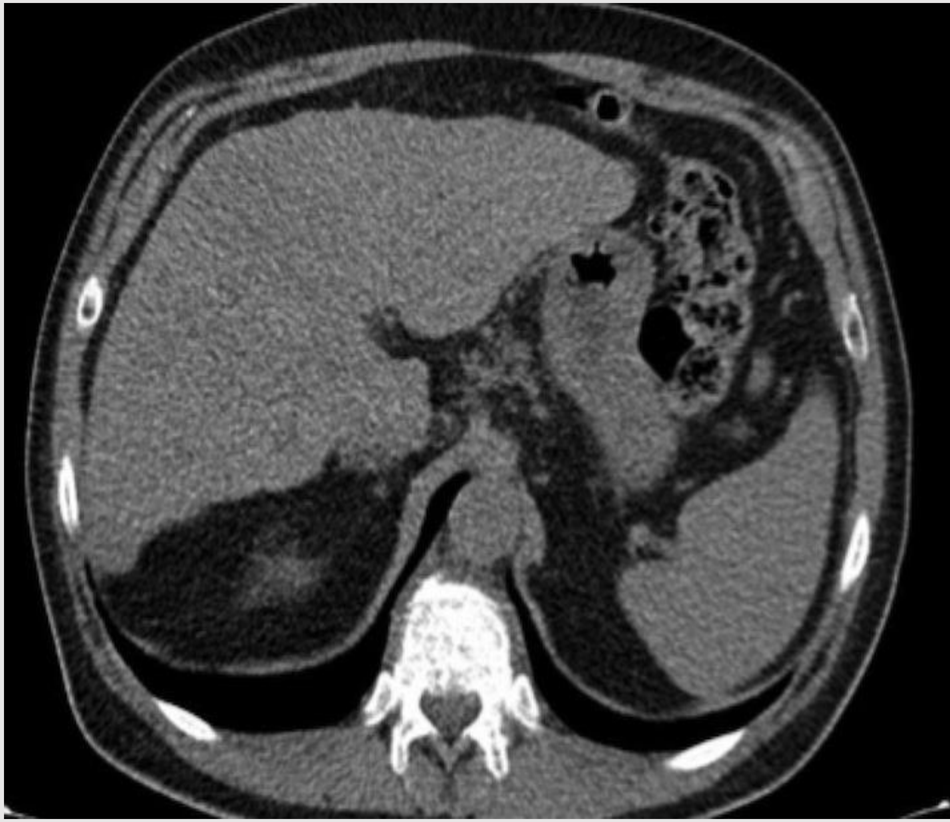
Documenting CM Administration

- Documentation of contrast administration is a legal necessity and should include
  - The name of the agent
  - The dose (volume and concentration)
  - The flow rate(s)
  - The injection site / route givem
  - Any adverse effects and their treatment

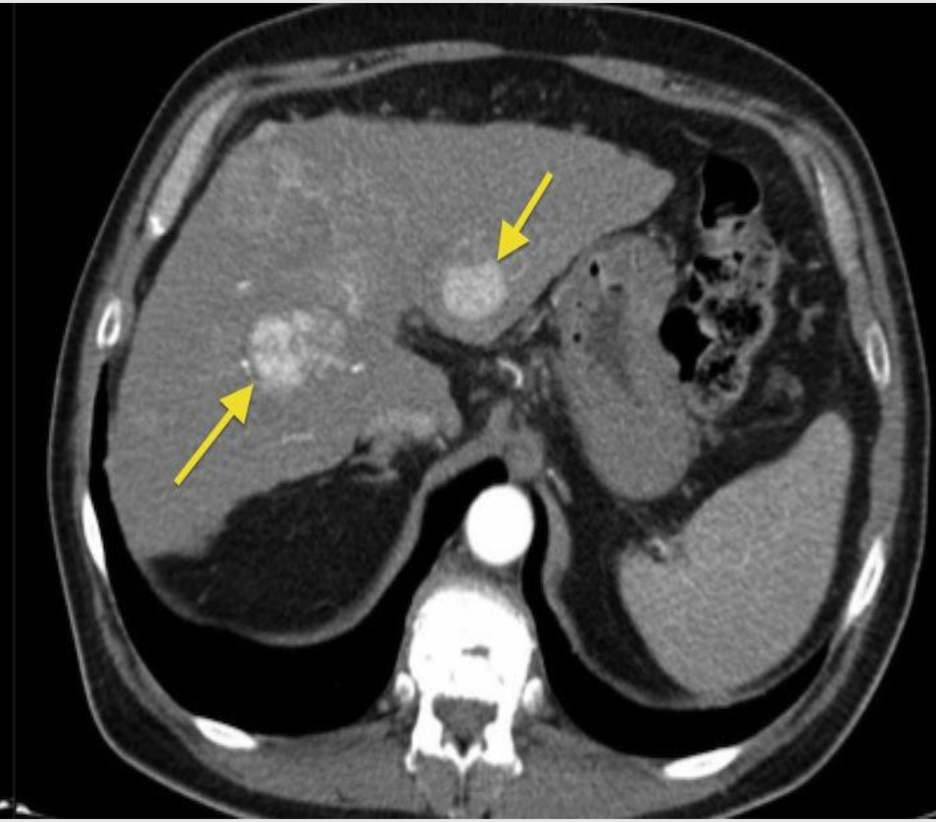
IV Contrast　　No IV Contrast



No IV Contrast

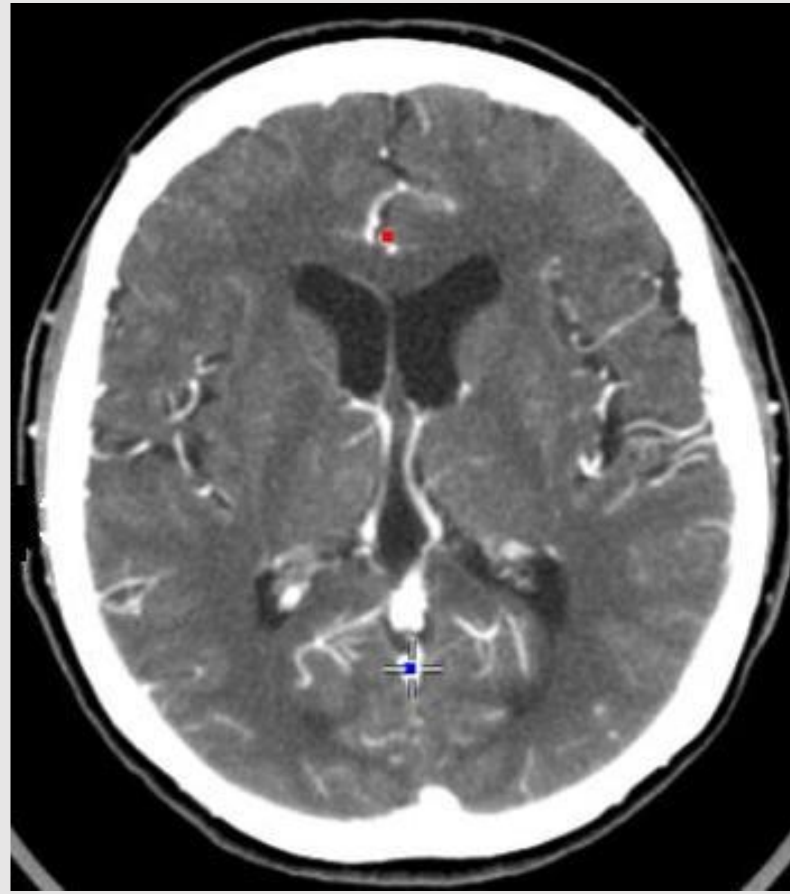


IV Contrast



No IV Contrast

IV Contrast



Q & A

Question 1

- IV and barium contrast appear __________ on a CT scan.

A) White

B) Black

- **Answer: White**

Question 2

- IV contrast is excreted through the _______.

A) GI Track

B) Rectally

C) Kidneys

D) Sweating

- **Answer: C**

Question 3

- True or False: Non-ionic contrast is more tolerable for patients that are sensitive to iodine.

- **Answer: True**

Question 4

- True or False: A patient that has a suspected bowel perforation can take barium sulfate.

- **Answer: FALSE**

10 MINUTE BREAK

IMAGING PROCEDURES

Head, Spine, & Musculoskeletal

Head

Types of Brain / Face Scans

Brain

- Brain / Head
- Skull Base / Posterior Fossa
- Brain Perfussion
- CTA Circle of Willis / Carotid
- Cranial Venogram

Facial

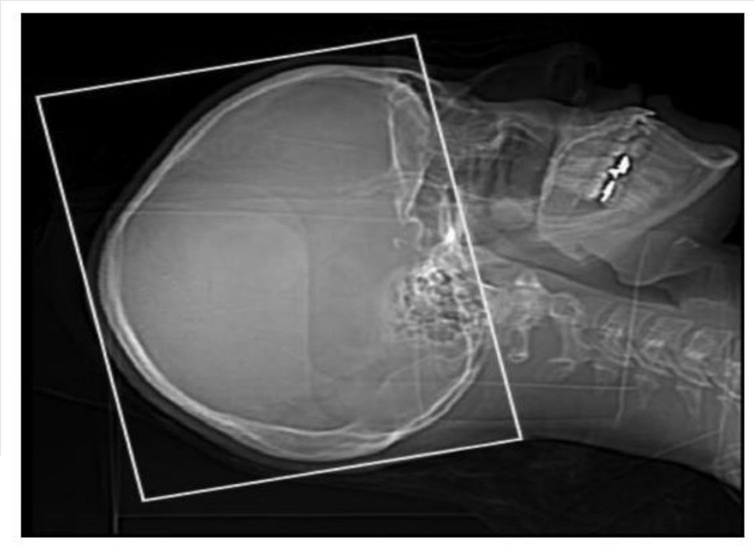
- Maxillofacial
- Orbits
- Temporal Bones
- Sinus
- Sella Turcica

Indications for Head/Facial Imaging

- Trauma
  - Soft tissue and bone
- Inflammatory
  - Abcess
  - Sinusitus
- Congenital
  - AVM
  - Hydrocephalis
  - Cleft palate / lip
- Cerebral Bleeding
  - Stroke
  - TIA
- Endocrine
  - pituitary
- Tumors / Mass / Cancer
  - Primary and metastasis
  - Glioblastomas
  - Meningioma
- Neurological Dysfunction
  - seizures
- CTA
  - Vascularity
  - Stenosis

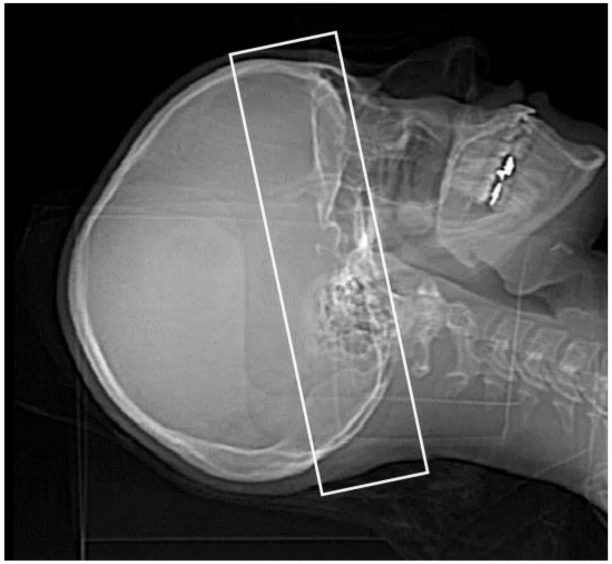
Brain CT Scan Protocol

- **Positioning Landmark**:
  - Glabella
  - Vertex
  - Lips
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Top of the vertex to the base of the skull
- **Parameter Selection:**
  - DFOV: 20-25 cm
  - SFOV: Head
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-350
  - Helical / Axial
  - Slice thickness: 1.25mm, 2.5mm, 3mm
  - Window W: 100 – 160 ww
  - Window L: 30 - 40 wl
- **Reformats**:
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning



Skull Base (Posterior Fossa) Protocol

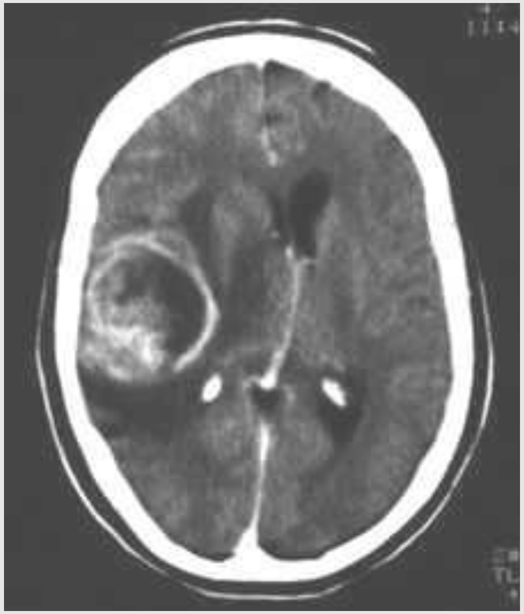
- **Positioning Landmark**:
  - Glabella
  - Vertex
  - Lips
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Top of the vertex to the base of the skull
- **Parameter Selection:**
  - DFOV: 20-25 cm
  - SFOV: Head
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-350
  - Helical / Axial
  - Slice thickness: 1.25mm, 2.5mm, 3mm
  - Standard Window W: 100 – 160 ww
  - Window L: 30 - 40 wl
  - Bone Window W – 4000 ww
  - Bone Window L – 400 wl
- **Reformats**:
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning



Brain CT Scan Protocol Continued

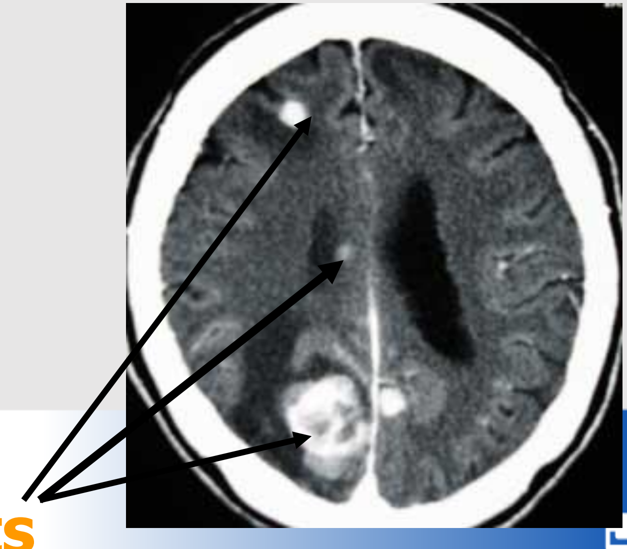
- **Common Pathology:**
  - Intracranial Hemorrhage
  - Early infarction
  - Dementia
  - Hydrocephalus
  - Pain
  - Headaches
  - Trauma
  - Mass
  - Lessions
  - AVM
  - Metastasis
  - Aneurysm
  - Seizures

Abnormalities Demonstrated



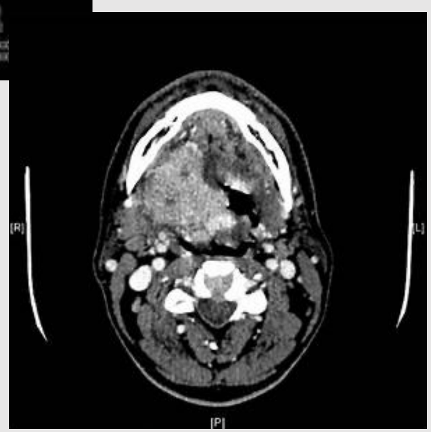
- Cerebral Glioblastomas
  - most common primary tumor of brain
  - appear as a mixture of low density and enhancing areas with mass effect
  - Prognosis is very poor

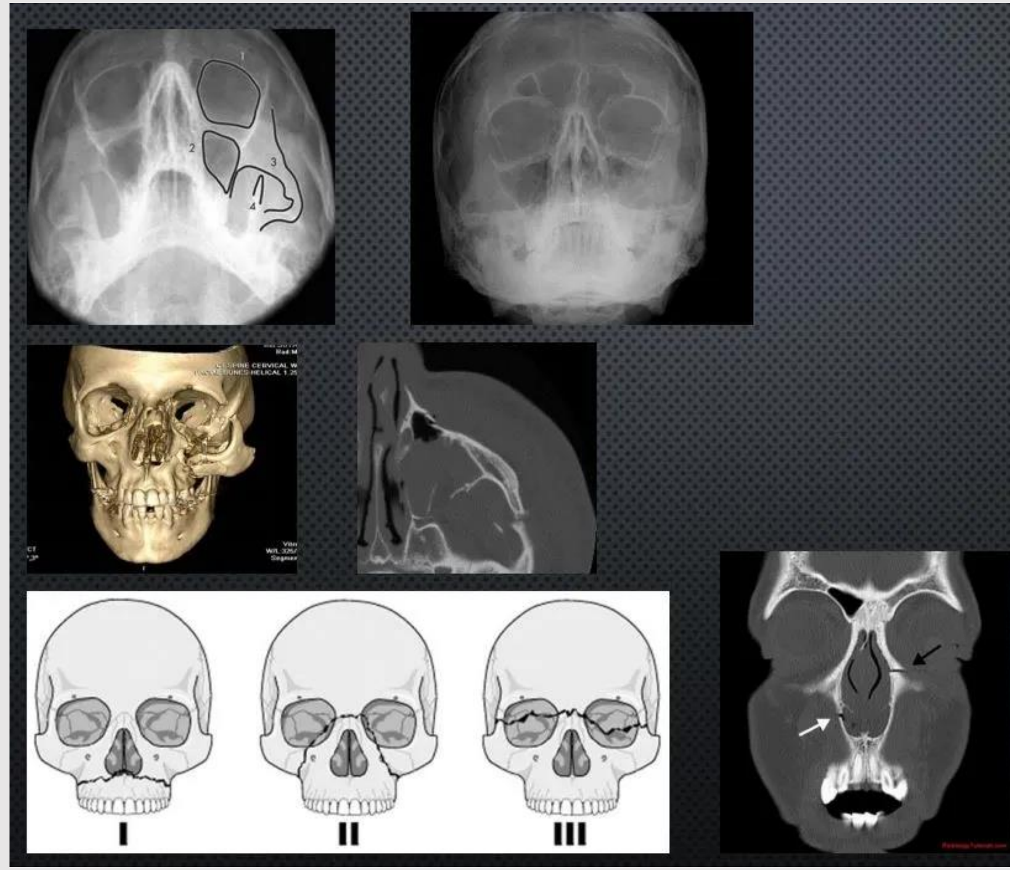
- Metastatic Disease:
  - multiple lesions from a primary tumor - usually breast or lung
  - Usually seen as multiple enhancing lesions with adjacent edema



Facial CT Abnormalities

- Fractures
- Tumors / Mass
- Infection



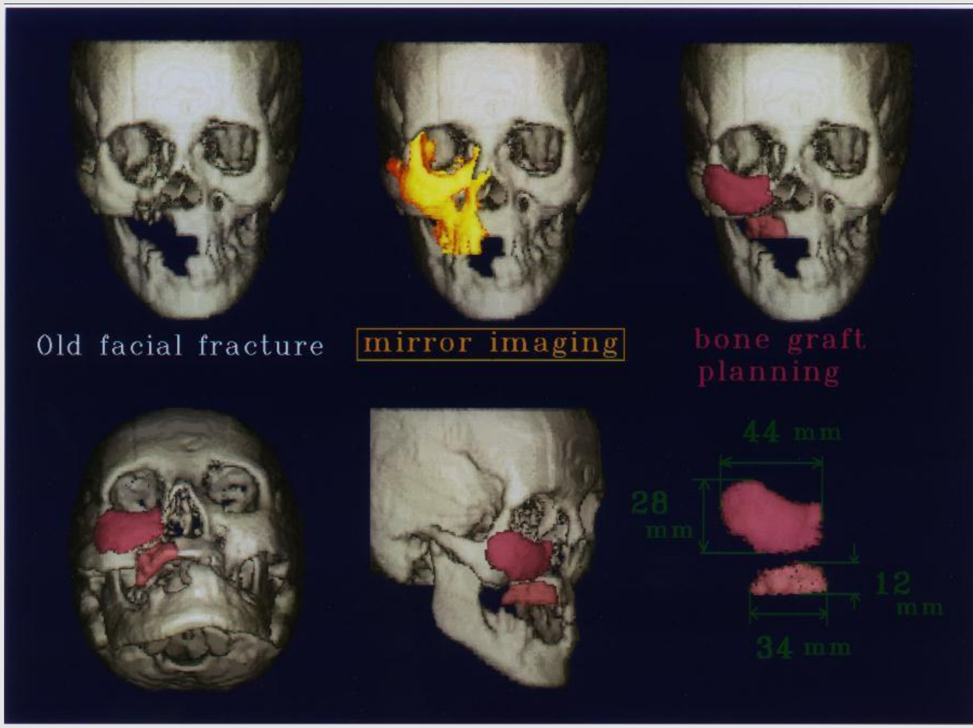


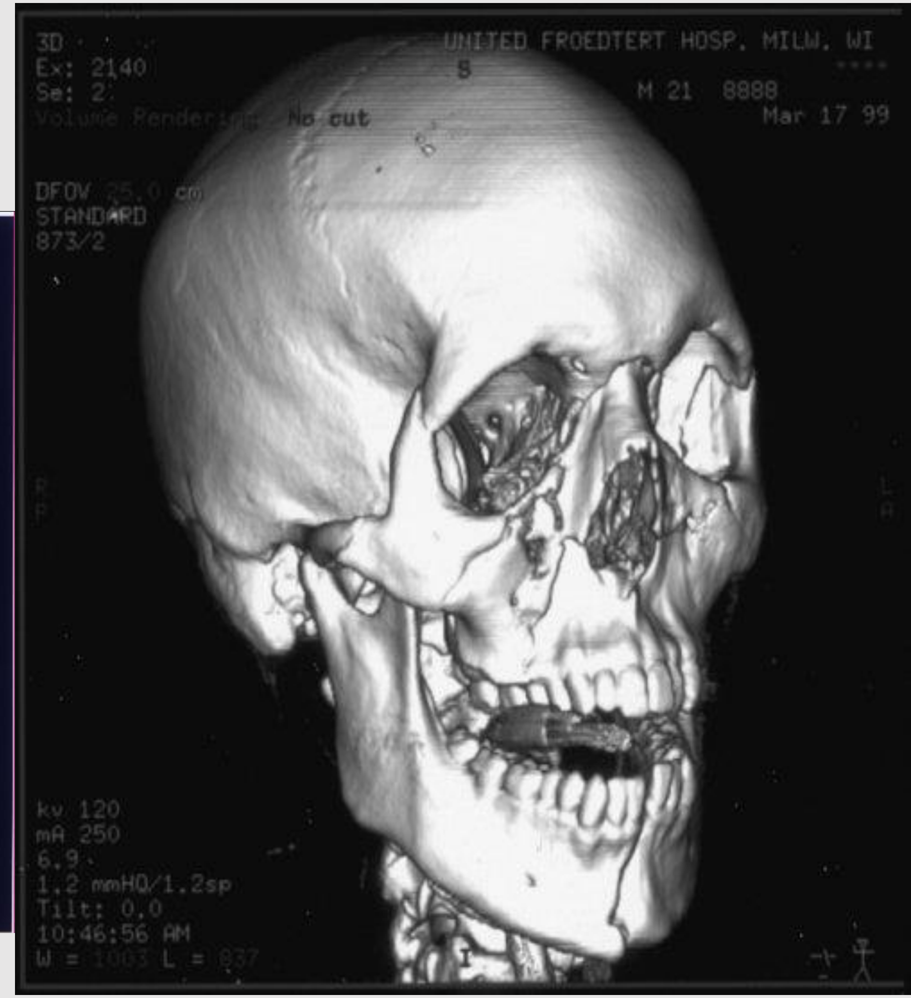
Special Protocols

- CTA Angiogram
- CTV Venogram
- Circle of Willis
- Perfussion

Special Procedures

- 3D Rendering of Skull / Face





ADVANCED HEALTH EDUCATION CENTER®

EDUCATION ▲ STAFFING ▲ CONSULTING

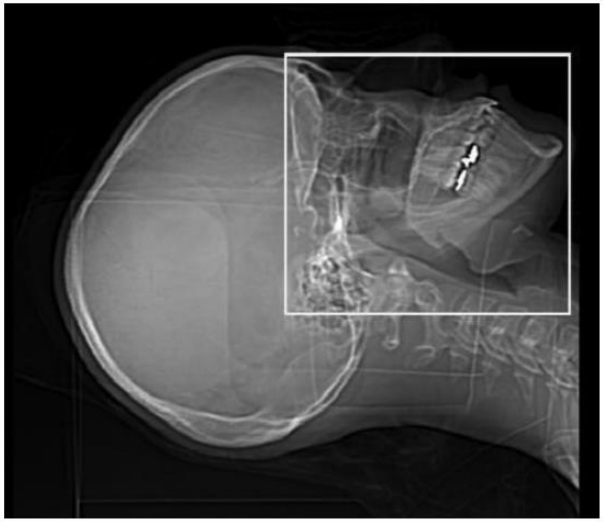
Exam / Patient Preparation

- **Little is needed**
  - **Remove metallic object**
  - **Fasting not required but recommended for contrast injections**
  - **Empty Bladder**
  - **Contrast Injection requires a through history**
  - **Place in a comfortable position**
  - **Close eyes for laser light positioning**

- **If IV contrast is needed:**
  - 18G IV needed for CTA/ Venogram
  - 22G IV needed for routine contrast

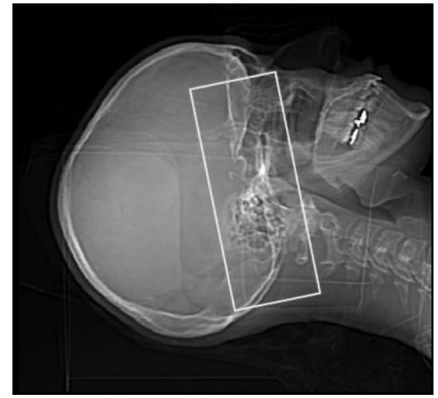
Facial / Sinus CT Scan Protocol

- **Positioning Landmark**:
  - Glabella
  - Vertex
  - Lips
  - Orbits
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Top of the frontal sinus to mandible
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Head
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-350
  - Helical
  - Slice thickness: 1.25mm, 2.5mm, 3mm
  - Standard Window W: 100 – 160 ww
  - Window L: 30 - 40 wl
  - Bone Window W – 4000 ww
  - Bone Window L – 400 wl
- **Reformats**:
  - Coronal
  - Sagittal
  - Axial



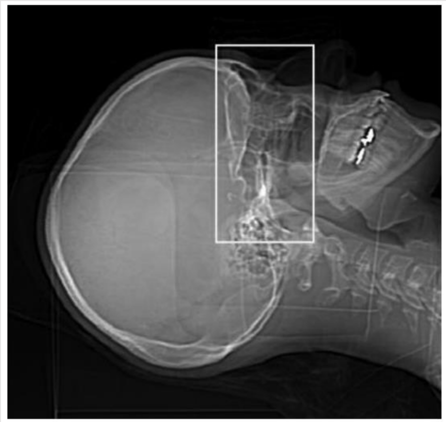
Facial / Sinus CT Scan Protocol

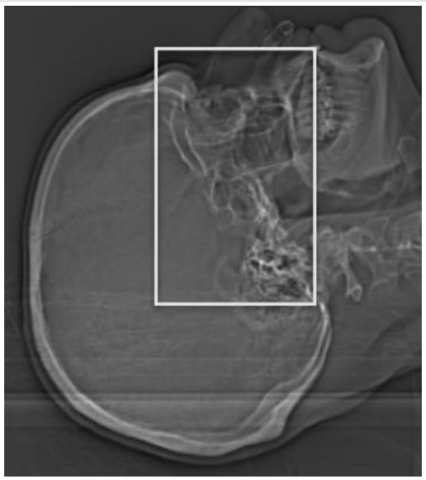
- **Temporal bones**
  - **Thin slices 1-2 mm**
  - **Bone algorithm**
  - **Axial and coronal images**
- **Orbits**
  - **Thin slices 3 mm**
  - **Axial reformatted into coronals and sag.**
- **Paranasal sinuses**
  - **Thin slices 3 mm**
  - **Coronal plane is best**
  - **Bone or soft tissue algorithms used**



Temporal Bones

Orbits





Sinuses

Q & A

Question 1

True or False CT Brain / Head scans are better visualizes with helical scans?

- **Answer: False**

Question 2

Scanning a CT Brain without contrast CT requires:

A) Top of the vertex to the base of the skull

B) Top of vertex to the mandible

C) Top of the TMJ to the Mandible

- **Answer: A**

Spine (C-T-L)

Types of Spine Scans

- Cervical Spine
- Thoracic Spine
- Lumbar Spine

Indications for Spine Imaging

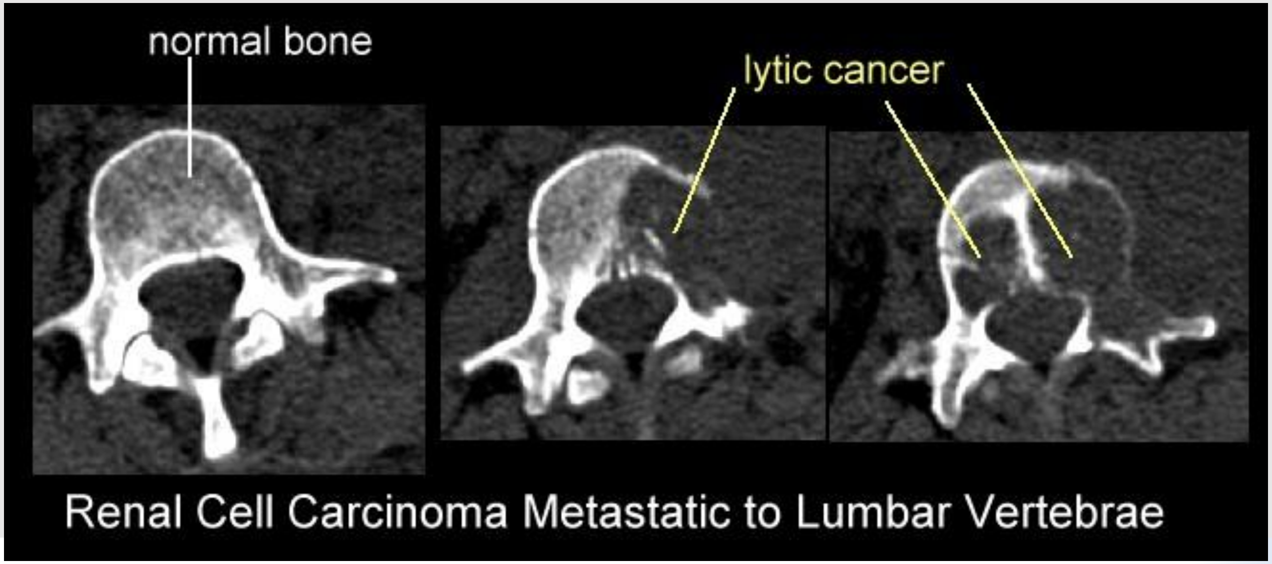
- Trauma
  - Soft tissue and bone
  - Injury
- Inflammatory
  - Abcess
  - Infection
- Congenital
  - Spinal Bifida
- Tumors / Mass / Cancer
  - Primary and metastasis
- Neurological Dysfunction
  - Herniated Disc
  - Disclocation
  - Fistulas
  - Stenosis
- Contrast
  - Post Myelogram

Common Pathology of C/T/L Spine

- Trauma
- Bone Degenerative
- Herniated Discs
- Stenosis
- Bone Metastatic
- Scoliosis
- Stenosis
- Spina Bifida
- Tumors
- Cuada Equina Syndrome

Common Pathology of C/T/L Spine

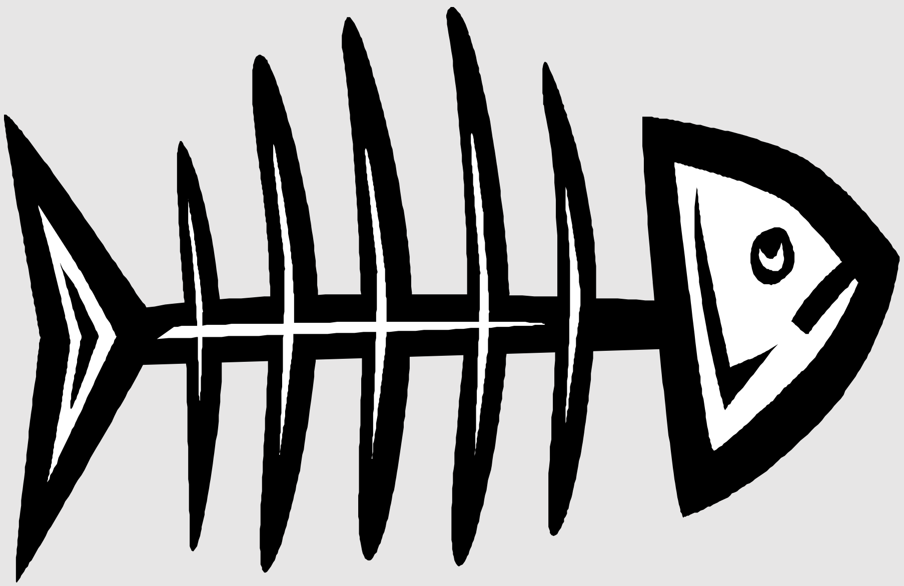
- Bone
- Soft Tissue
- Trauma
- Tumors
- Quantitative Studies

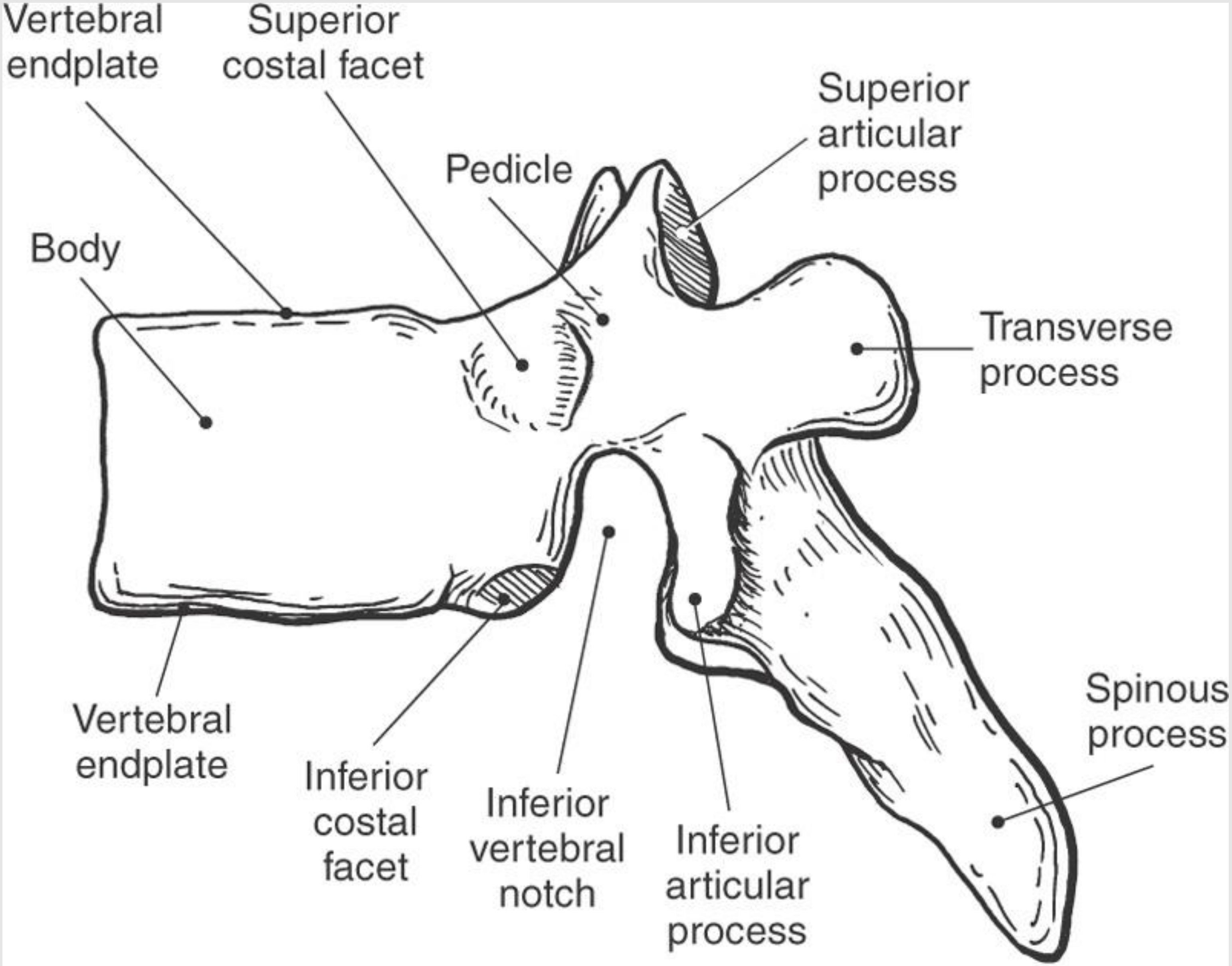


Renal Cell Carcinoma Metastatic to Lumbar Vertebrae

VERTEBRAE

- **Cervical 7**
- **Thoracic 12**
- **Lumbar 5**
- **Sacrum 5**
- **Coccyx 3 To 4**

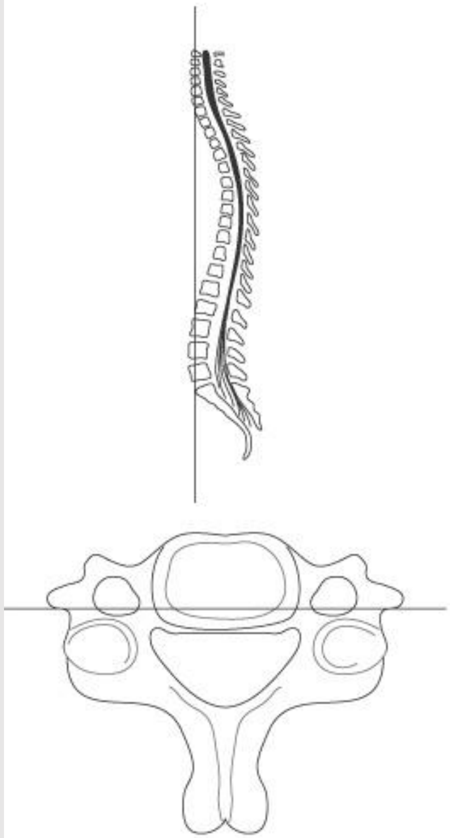


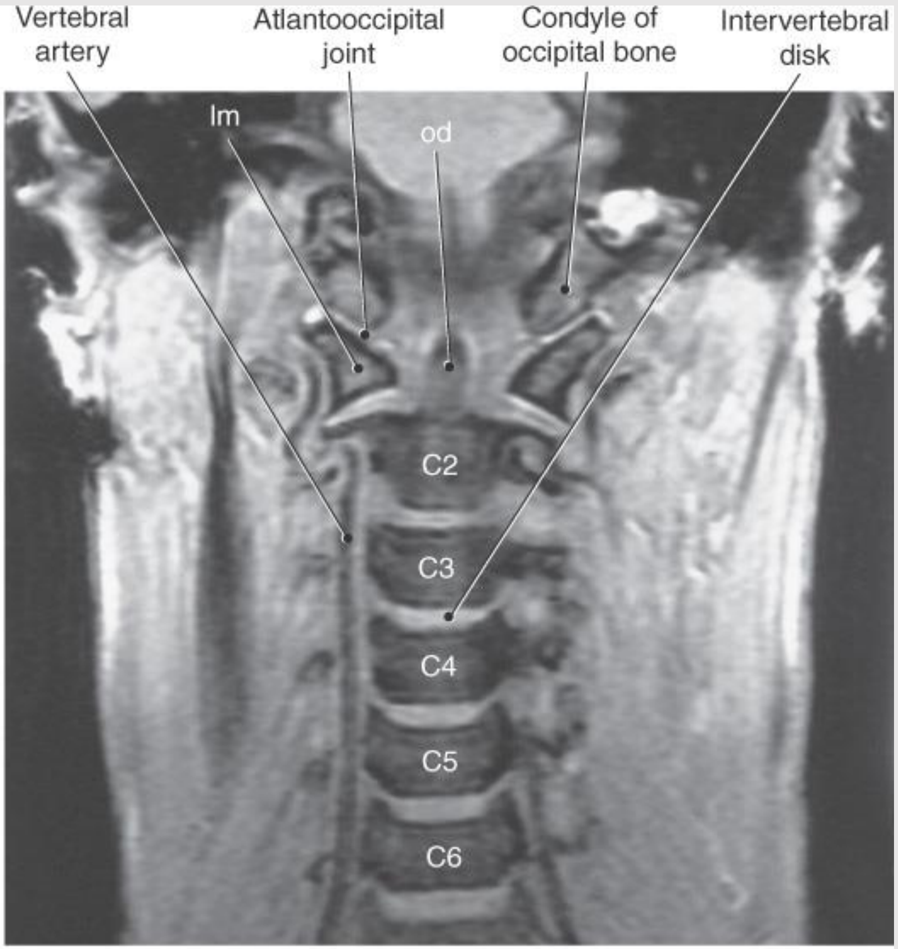

Vertebral endplate
Superior costal facet
Superior articular process
Pedicle
Body
Transverse process
Spinous process
Vertebral endplate
Inferior costal facet
Inferior vertebral notch
Inferior articular process

CERVICAL

- 7 Vertebrae
- Unique To Cervical
  - Transverse Process Has Foramen Called Transverse Foramen
  - Number 1 and 2 have special names and features
  - Spinous Process Is Bifid in 3-6
  - C-7 has long spinous process (vertebra prominens

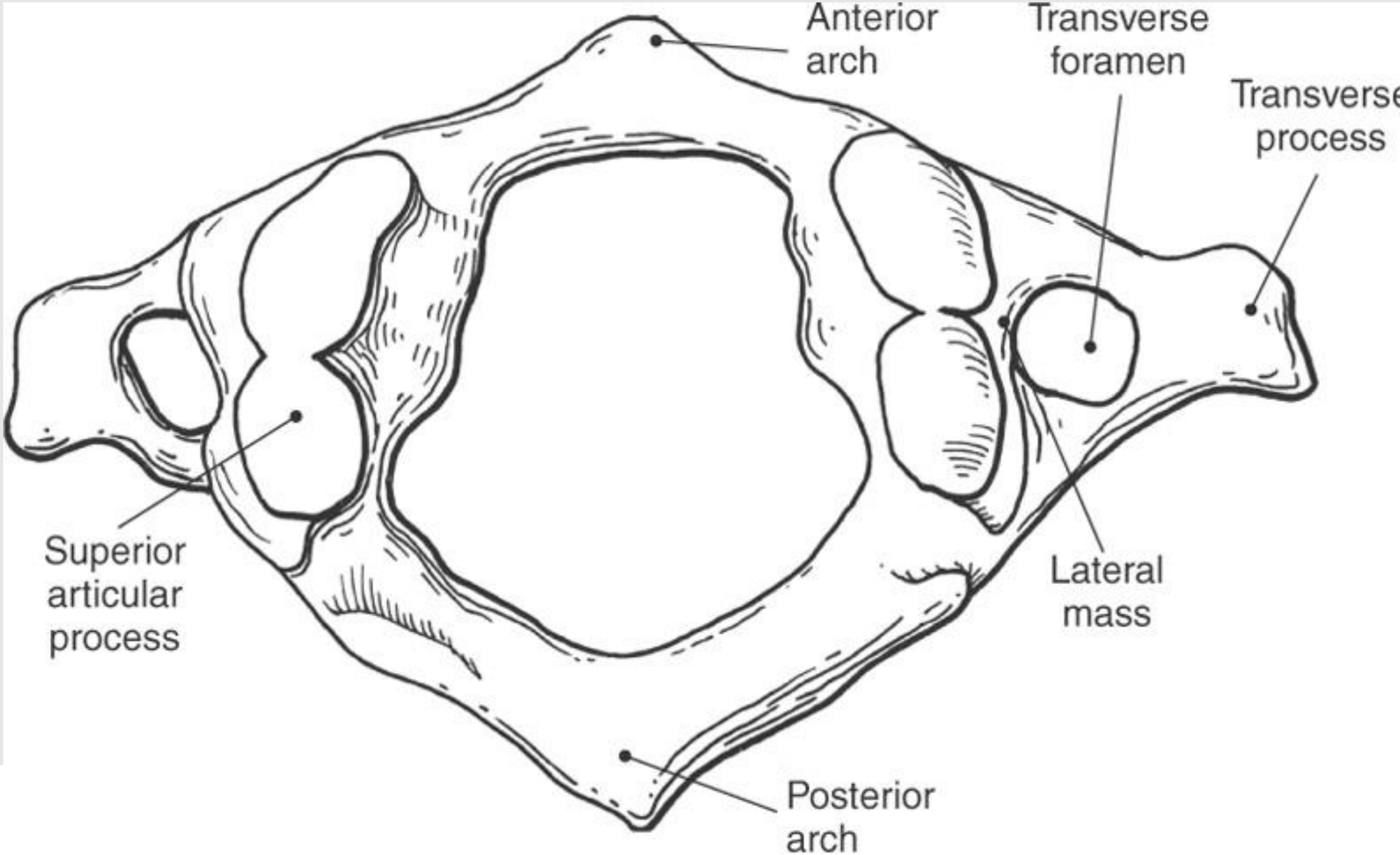
Cervical Spine



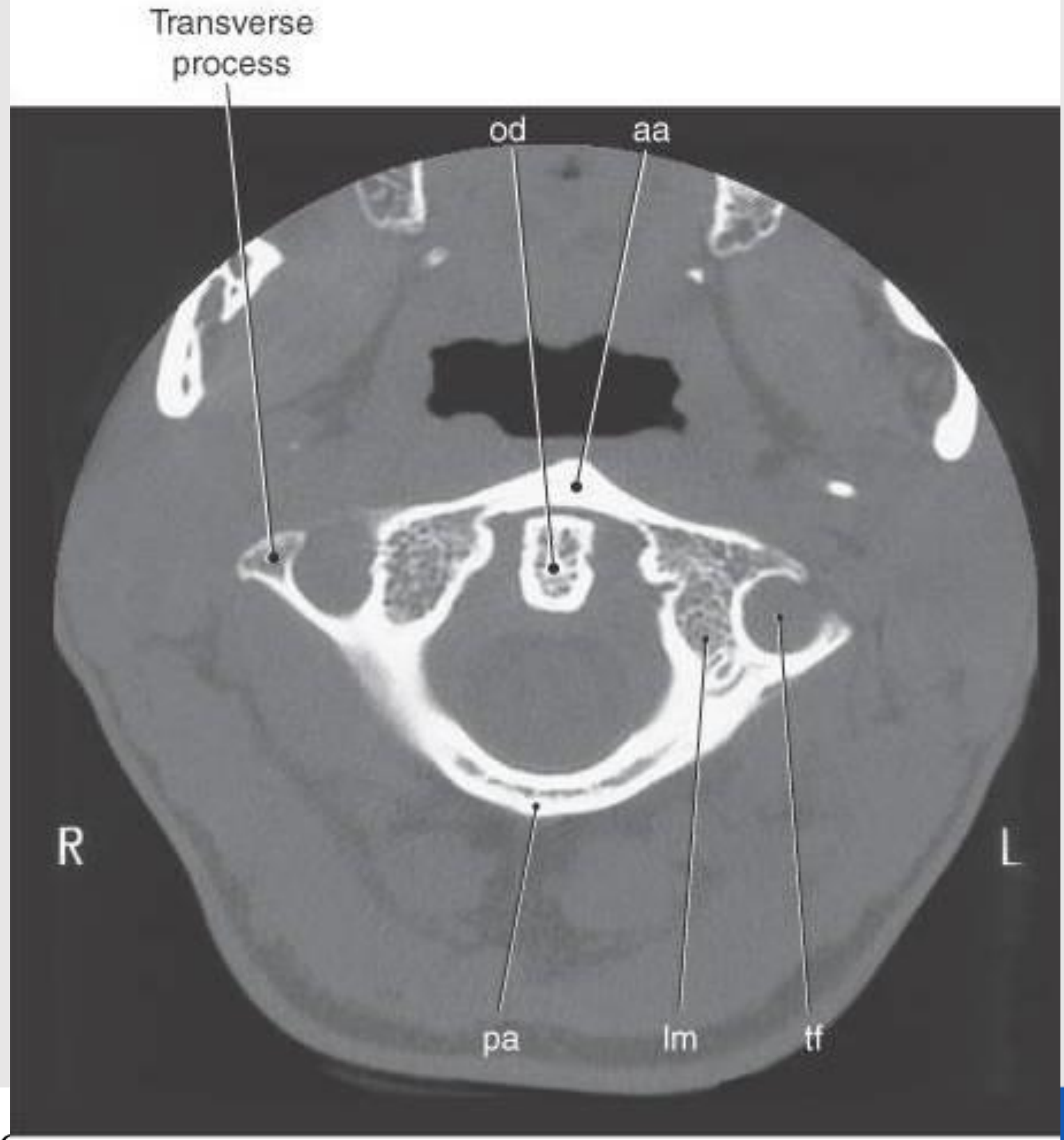


KEY: **lm,** Lateral mass; **od,** odontoid process.

First Cervical (Atlas)

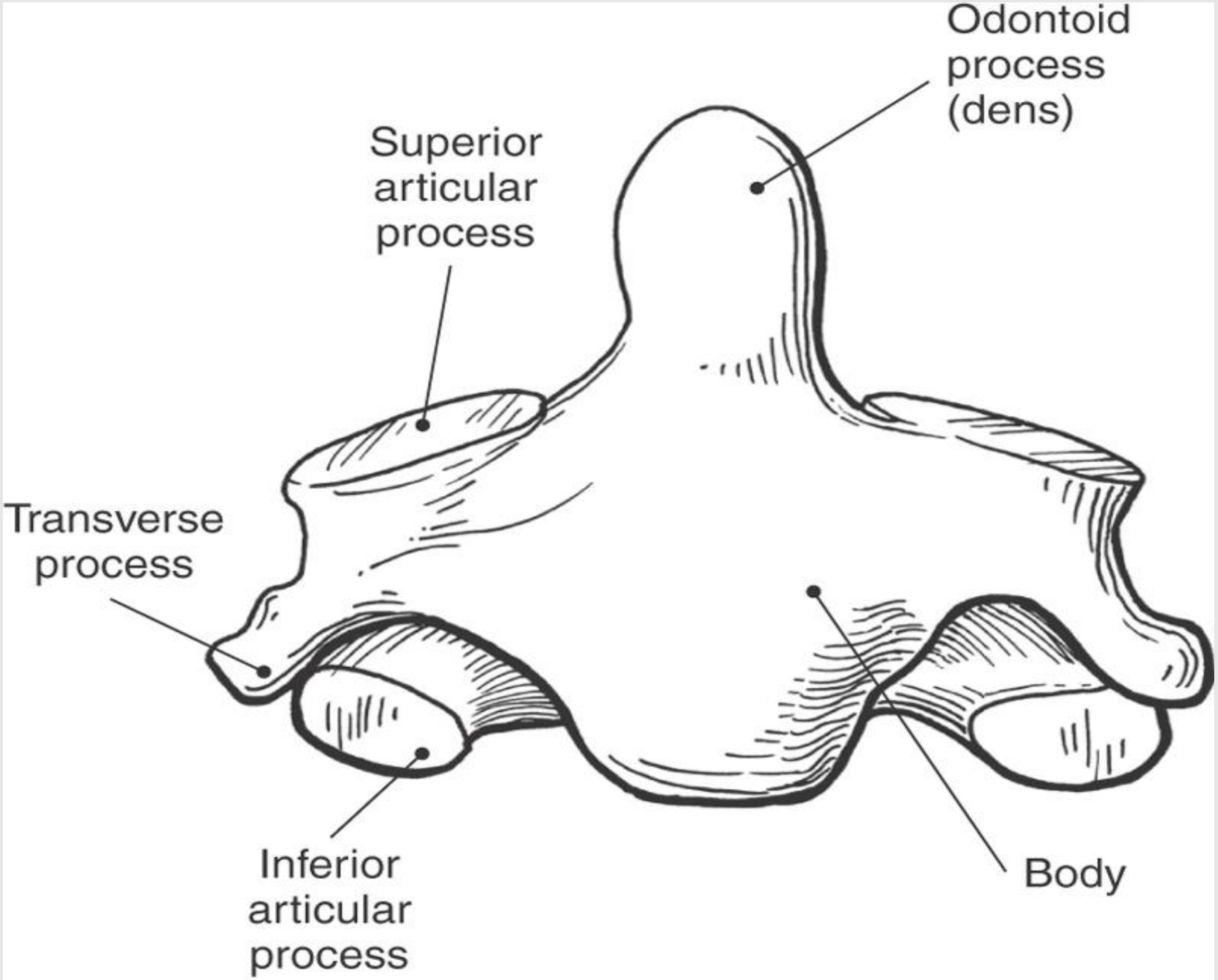


C E R V I C A L 1

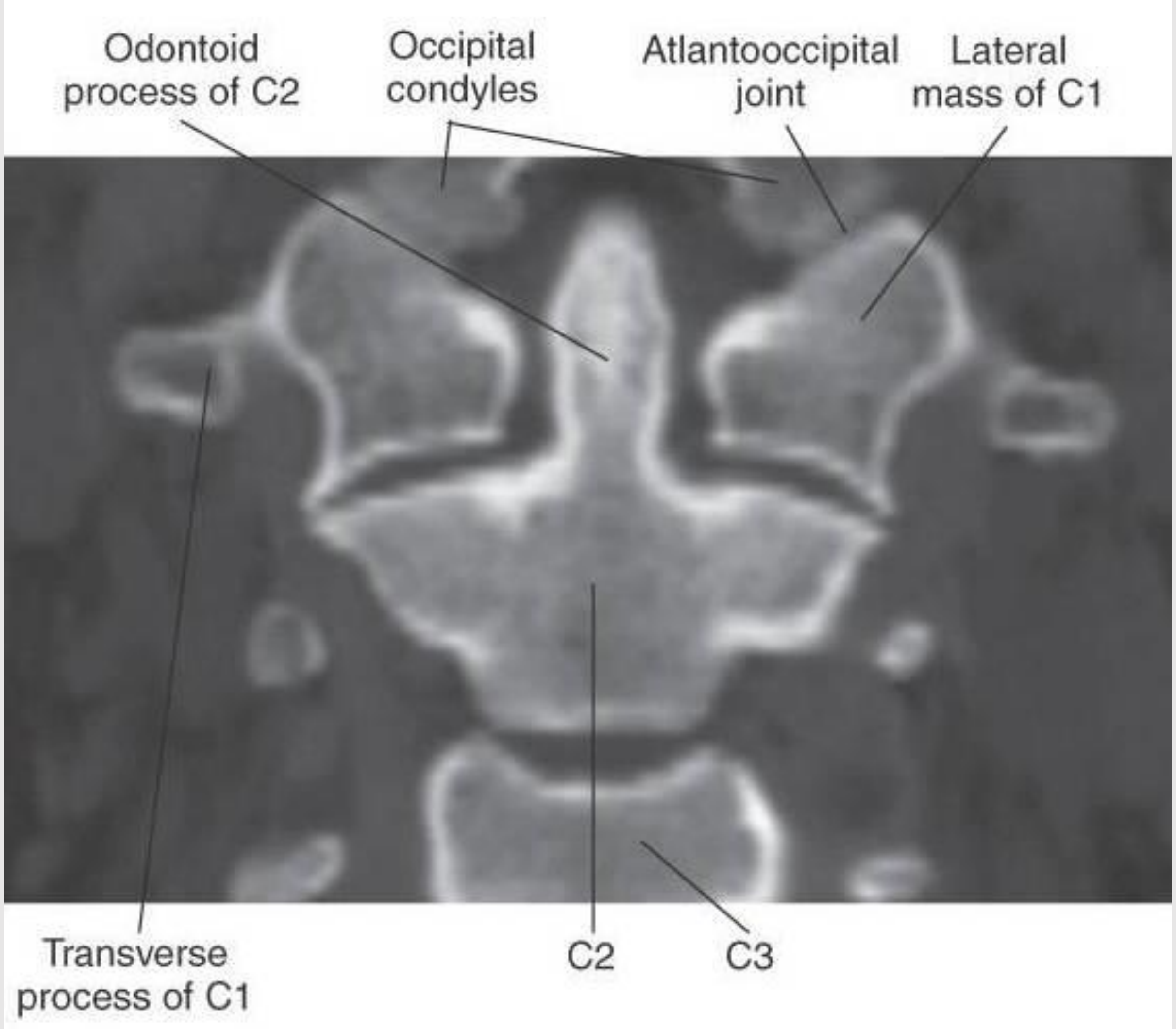


***KEY:* od,** Odontoid process; **aa,** anterior arch; **pa,** posterior arch; **lm,** lateral mass; **tf,** transverse foramen.

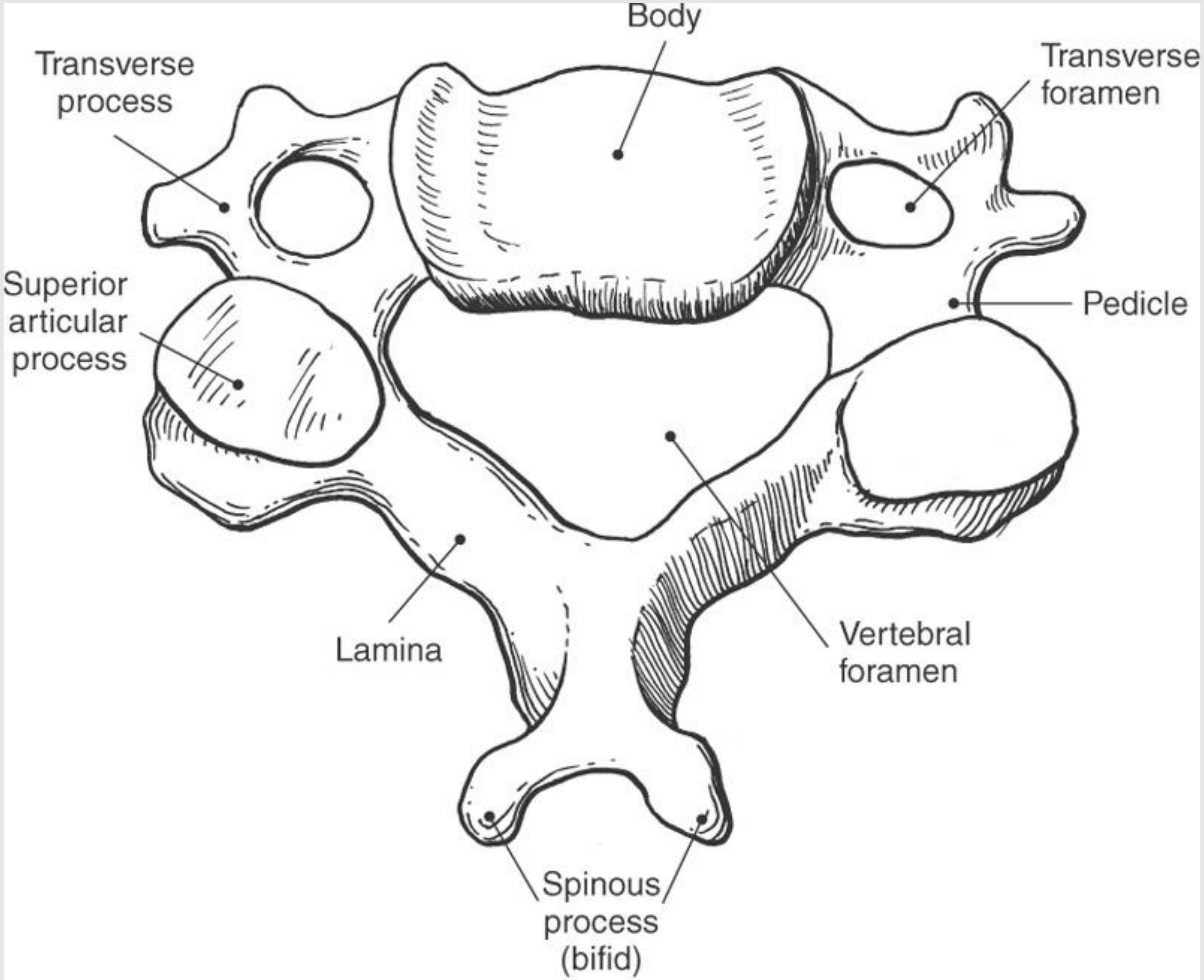
Cervical 2 Axis



Coronal of C-2



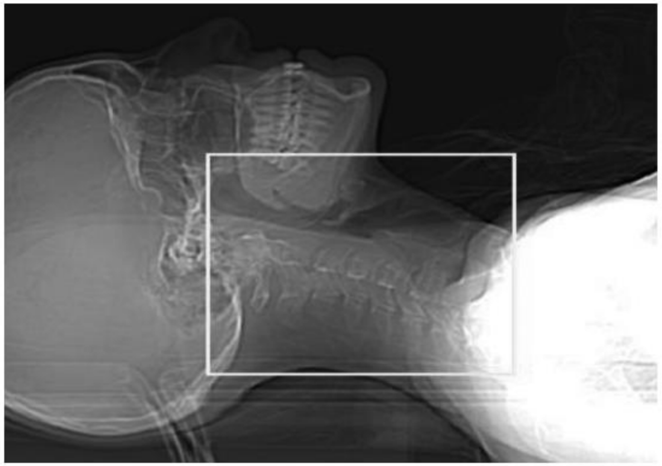
Cervical 3-6



Body
Transverse process
Transverse foramen
Superior articular process
Pedicle
Lamina
Vertebral foramen
Spinous process (bifid)

Cervical Spine CT Scan Protocol

- **Positioning Landmark**:
  - EAM
  - 1" below Jugular notch (T1-T2)
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Top of the EAM to 1-2" below Jugular notch (T1-T2)
- **Parameter Selection:**
  - DFOV: 14-25 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-350
  - Helical
  - Slice thickness: 1.25mm, 2.5mm, 3mm
  - Standard Window W: 350 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial



Exam / Patient Preparation

- **Little is needed**
  - **Remove metallic object**
  - **Fasting not required but recommended for contrast injections**
  - **Empty Bladder**
  - **Contrast Injection requires a through history**
  - **Place in a comfortable position**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

- Intrathecal Contrast
  - Enhance visualization of disk disease and outlines the cord and cauda equina
  - Cranial cisterns

Q & A

Question 1

C-Spine CT Scan requires anatomy from:

A) Top of the EAM to Mid Carina

B) Top of Vertex to Carina

C) Top of Vertex to the top of kidneys

- **Answer: A**

Question 2

True or False: C-Spine CT Scan requires helical thin slices

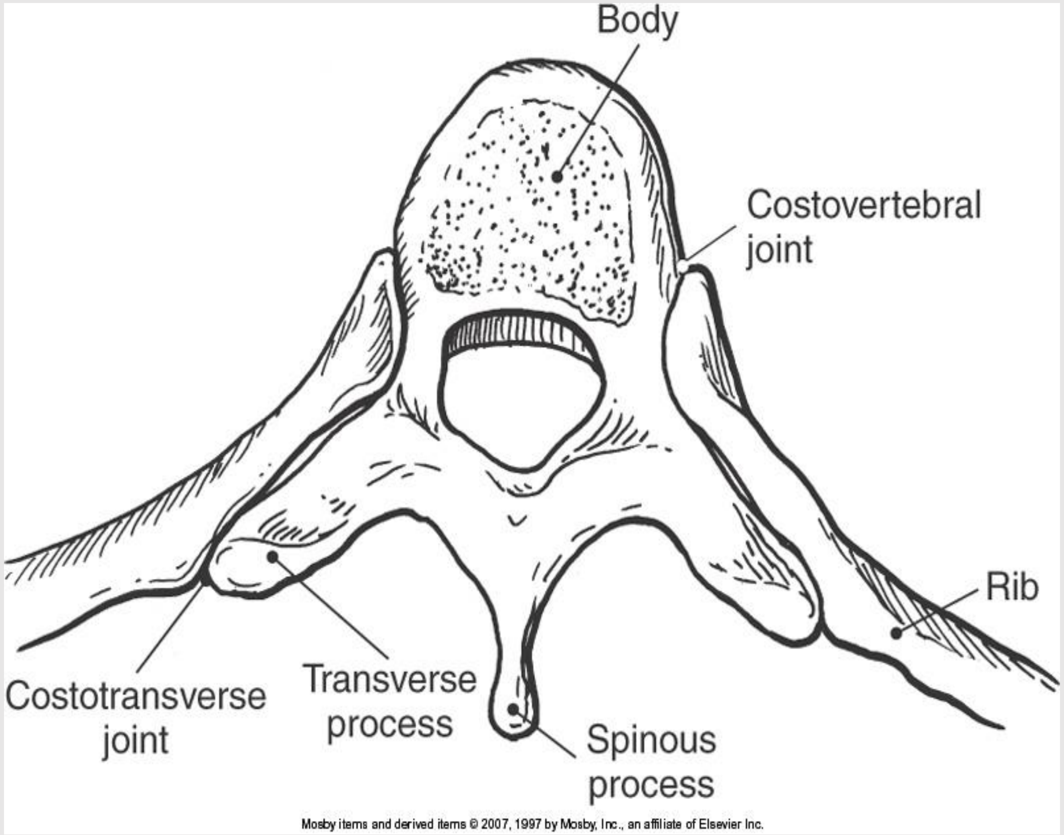
- **Answer: True**

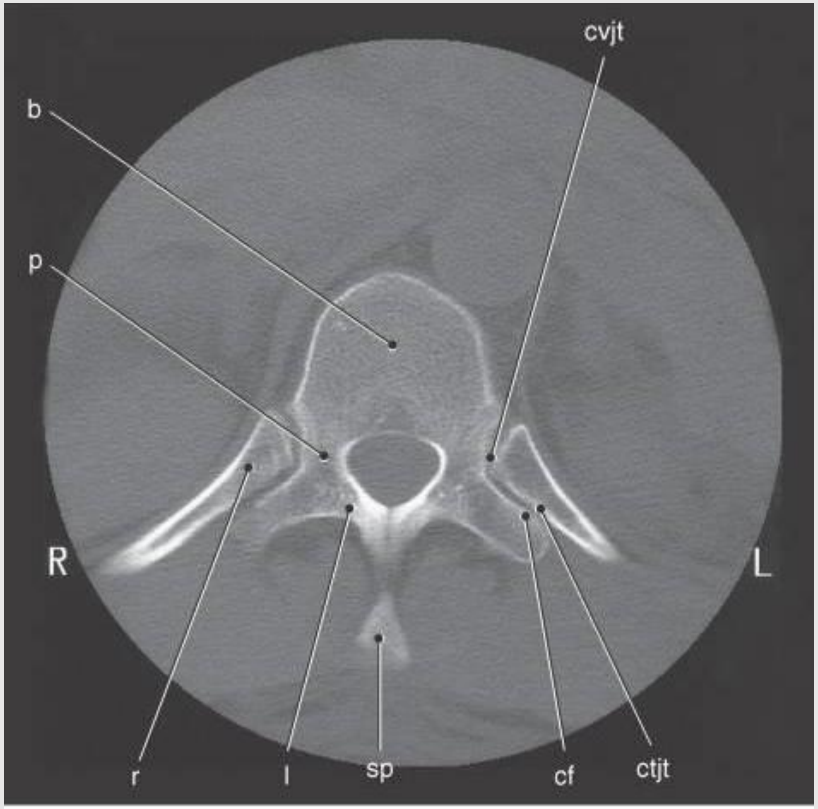
T-spine CT Scan

THORACIC

- 12 Vertebrae
- Ribs Connect To The Vertebra
- First 10 Are True Ribs
- Last 2 Are False Ribs Or Hanging Ribs

Thoracic Vertebrae

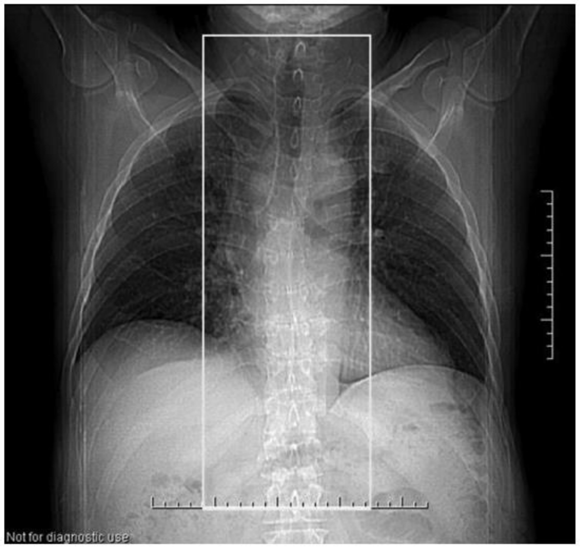




KEY: **cvjt,** Costovertebral joint; **b,** body; **p,** pedicle; **r,** rib; **l,** lamina; **sp,** spinous process; **cf,** costal facet; **ctjt,** costotransverse joint.

Thoracic Spine CT Scan Protocol

- **Positioning Landmark**:
  - Mid neck
  - Top Iliac Crest
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - C-6 to L1
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 1.25mm, 2.5mm, 3mm
  - Standard Window W: 350 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial



Common Pathology

- Scoliosis
- Metastatic Bone
- Herniated Disc

Exam / Patient Preparation

- **Little is needed**
  - **Remove metallic object**
  - **Fasting not required but recommended for contrast injections**
  - **Empty Bladder**
  - **Contrast Injection requires a through history**
  - **Place in a comfortable position**
  - **Close eyes for laser light positioning**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

- IV Contrast Demonstrates
  - Vessels as apposed to lymph nodes
  - Choroid plexus dura mater & meningiomas
  - Scar tissue from recurrent disk herniation
  - Intracerebral tumors that break the blood brain barrier (glioblastomas)
  - Walls of abscesses

- Intrathecal Contrast
  - Enhance visualization of disk disease and outlines the cord and cauda equina
  - Cranial cisterns

Q & A

Question 1

Scanning a T-spine CT requires:

A) Top of C-7 to L-1

B) Top of C-7 to S-1

C) Top of C-7 to L-5

- **Answer: A**

Question 2

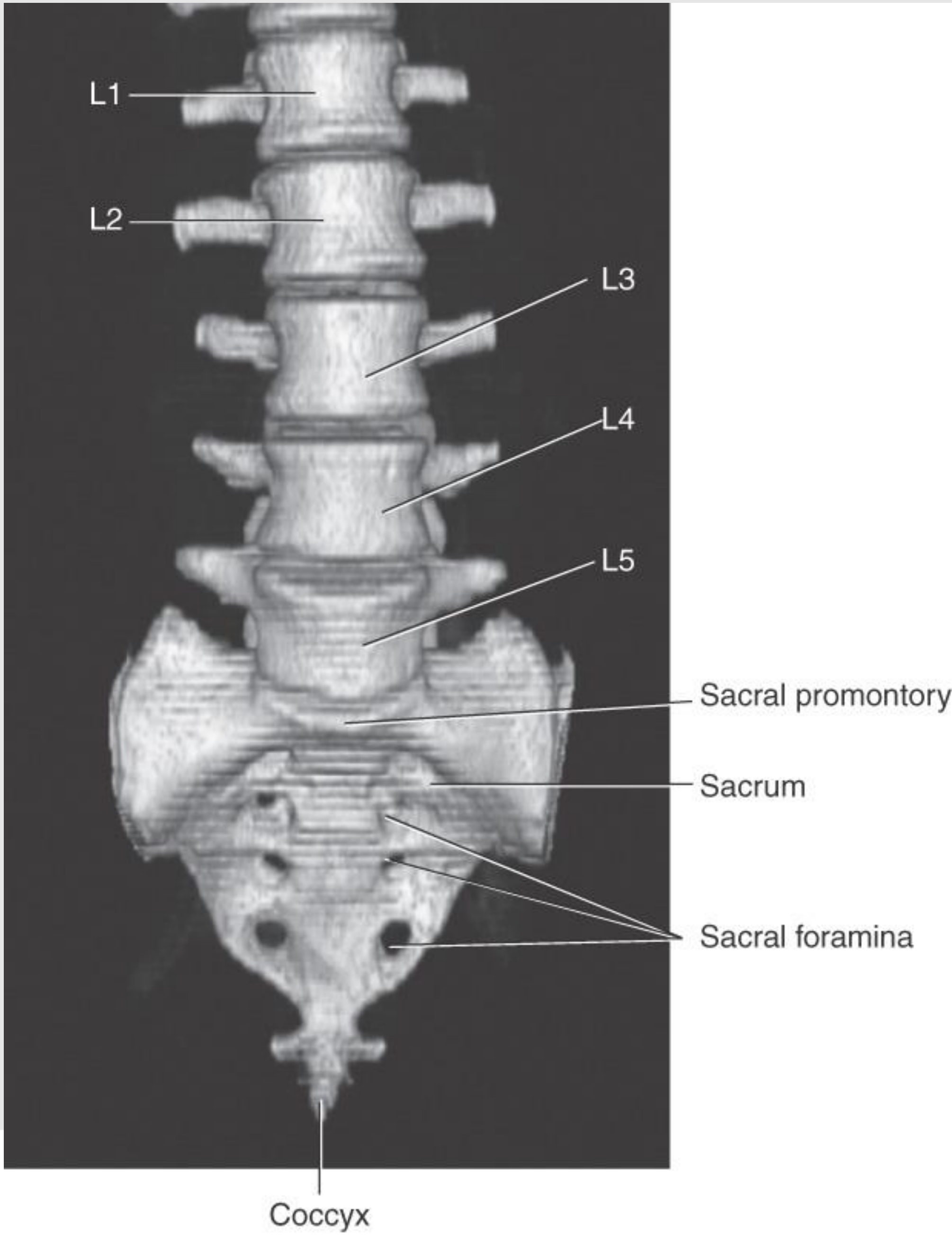
True or False: To better visualize the spine, reconstruction images should include algorithms of bone and soft tissue windows.

- **Answer: True**

L-Spine CT Scan

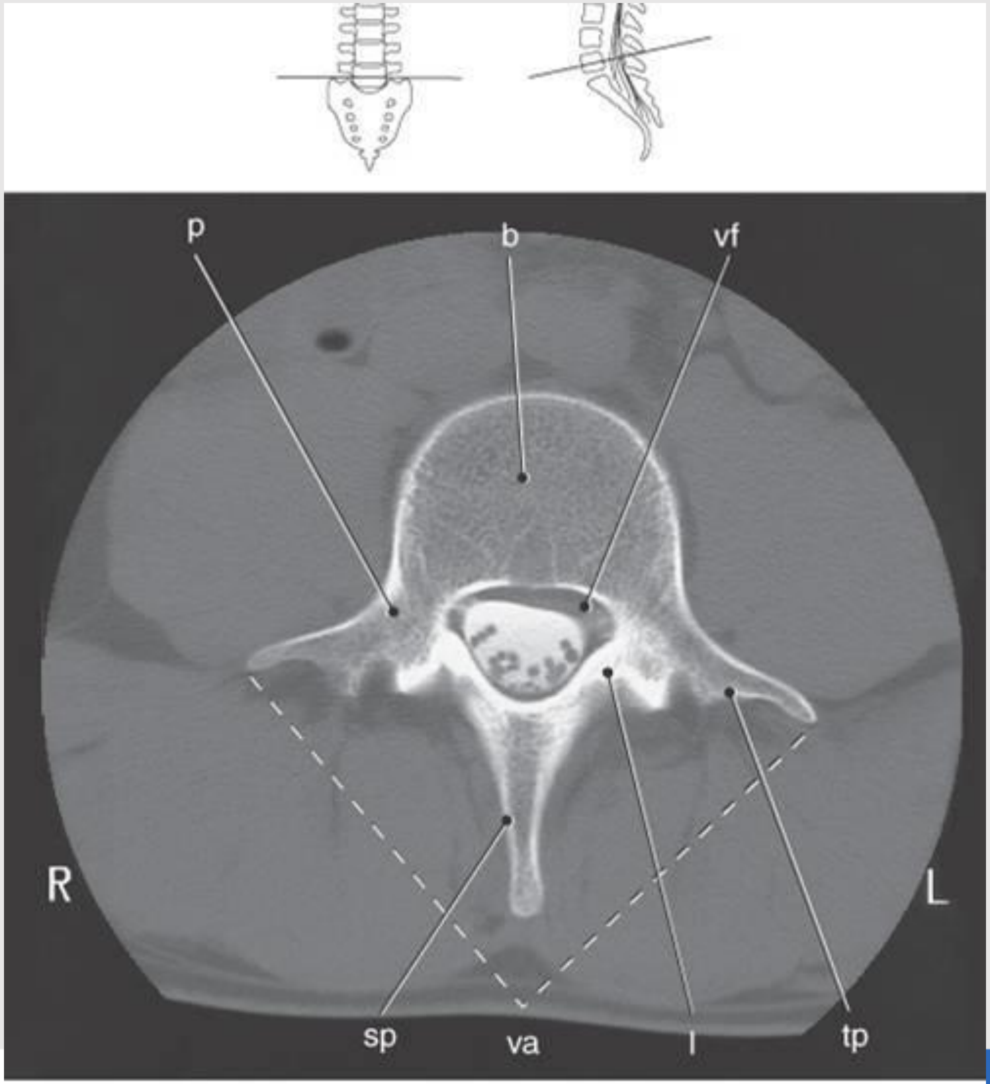
LUMBAR

- Five Vertebrae
- Have larger Spinous Processes
- L5 -- Largest



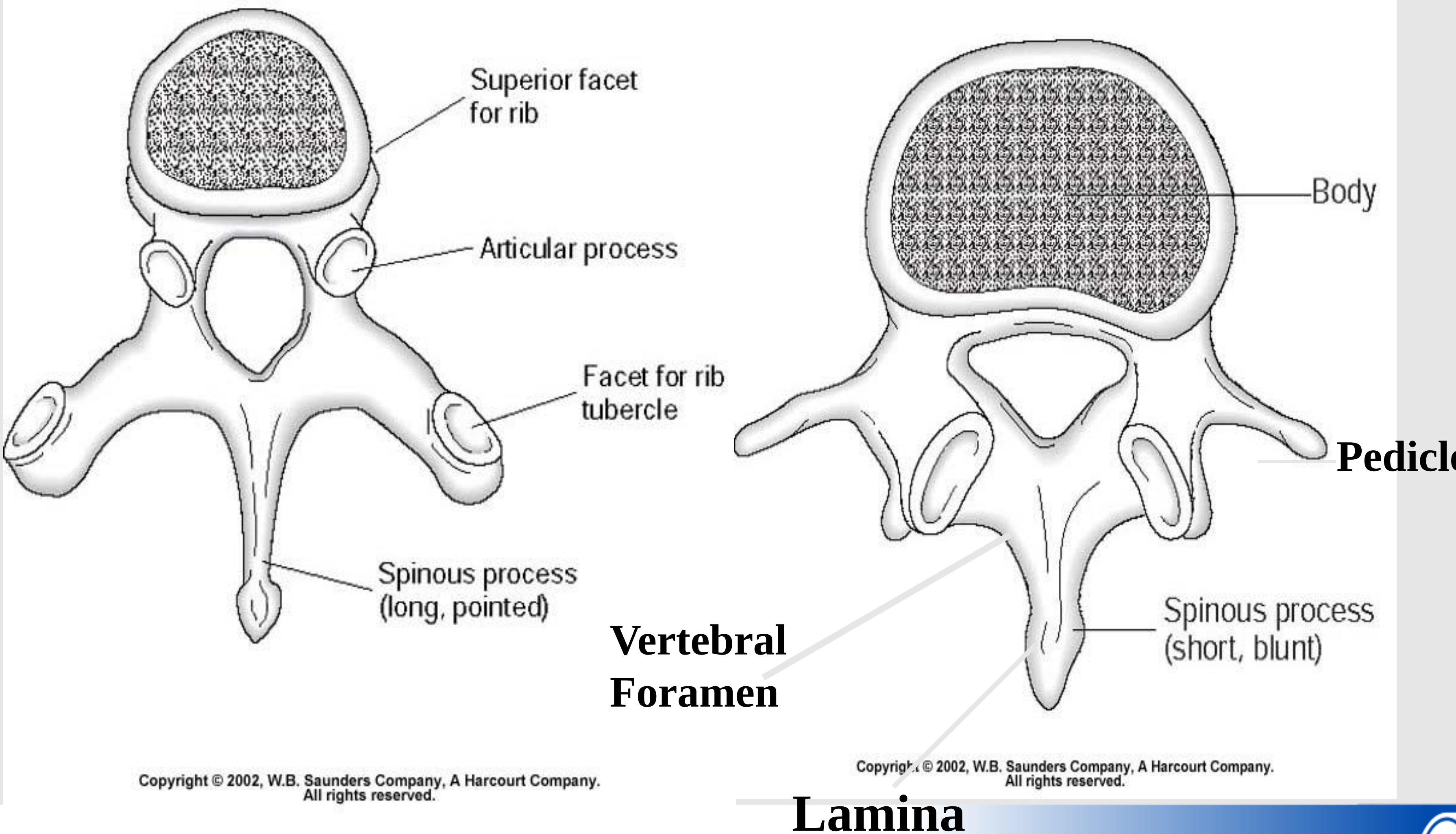
Lumbar Vertebrae

- Which vertebrae?
- What modality?
- What Contrast?
- Name Parts



KEY: **p,** Pedicle; **b,** body; **vf,** vertebral foramen or canal; **sp,** spinous process; **va,** vertebral arch; **l,** lamina; **tp,** transverse process.

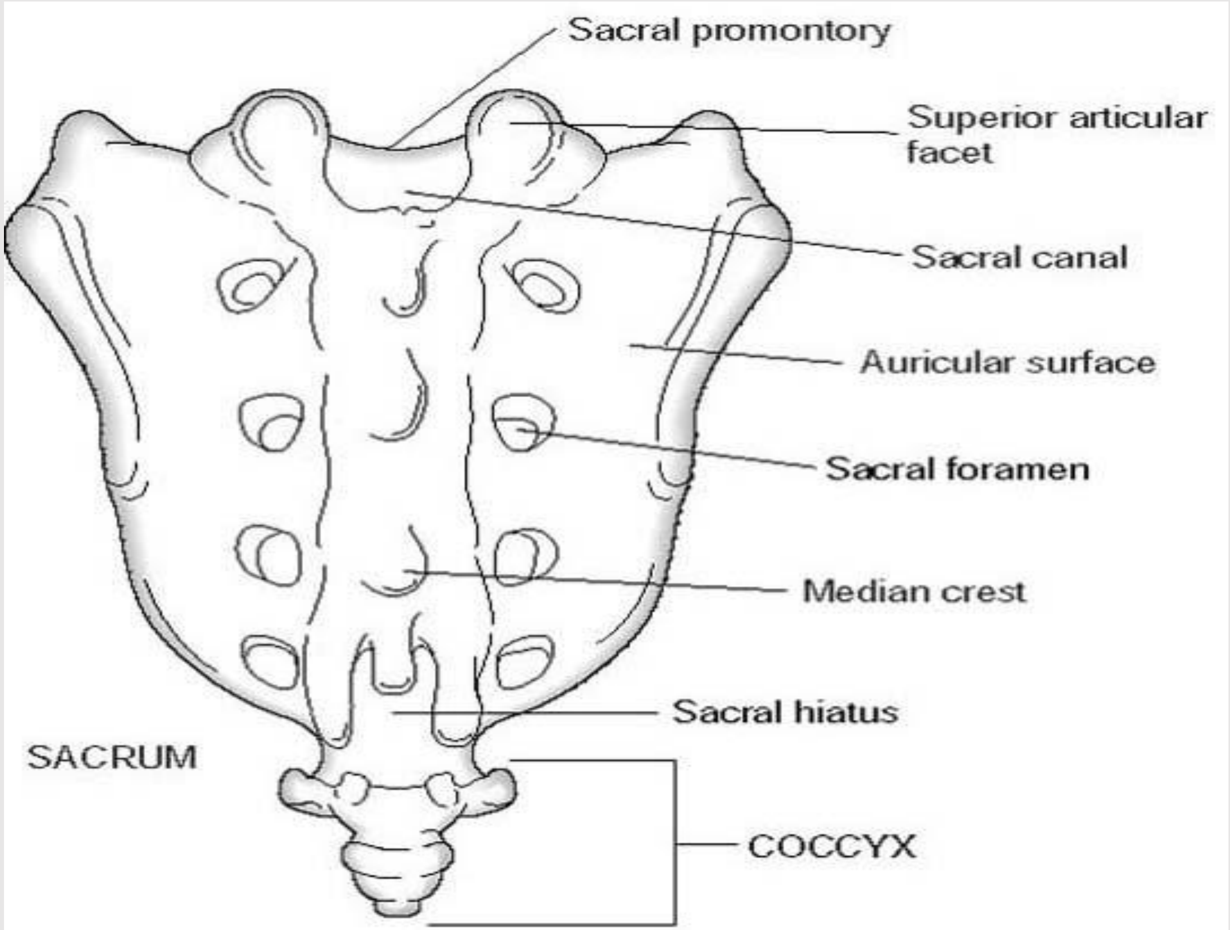
Vertebrae
Thoracic Lumbar



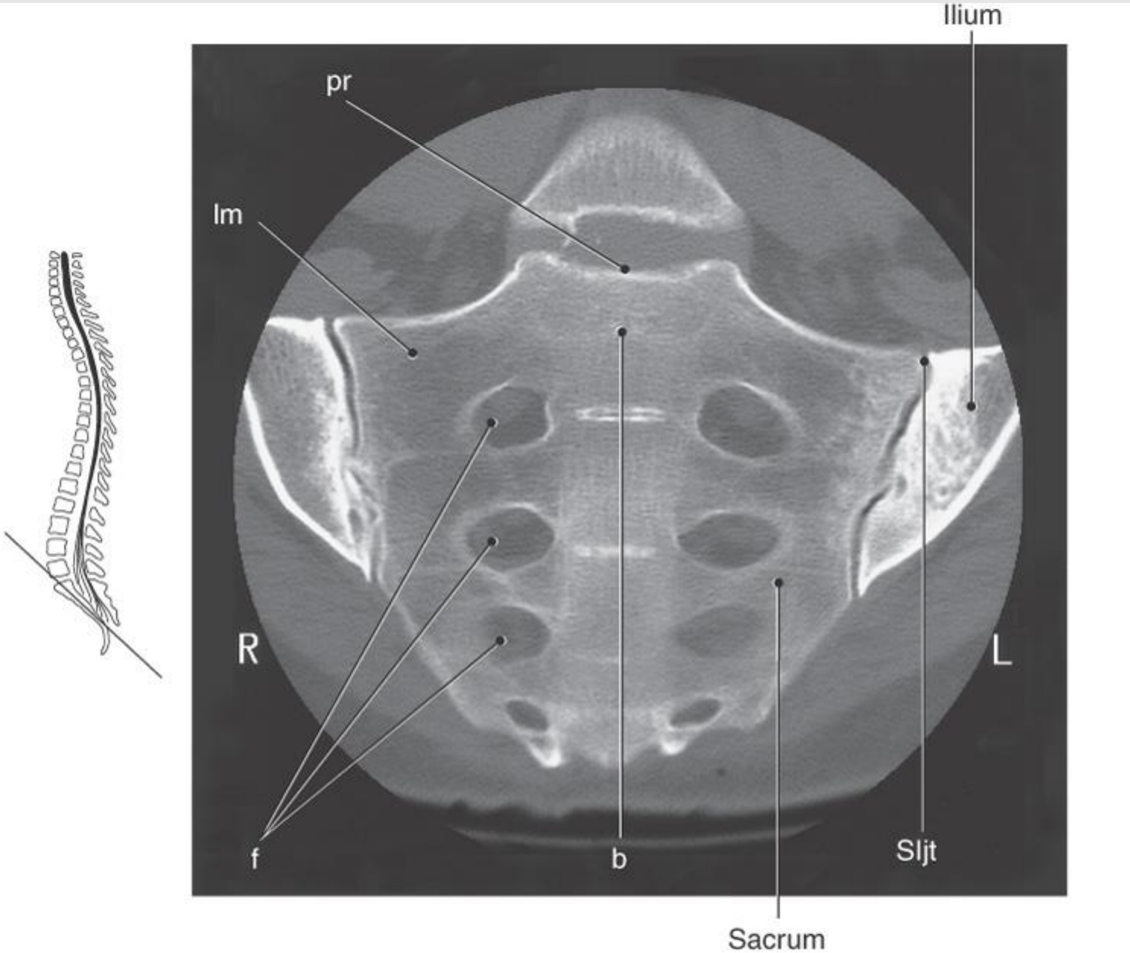
SACRUM

- Five Vertebrae Fused
- The Transverse Processes Fused - Ala
- Lateral Masses Have Five Pairs Of Sacral Foramen
- First Segment Has A Prominence – Sacral Promontory

Sacrum and Coccyx

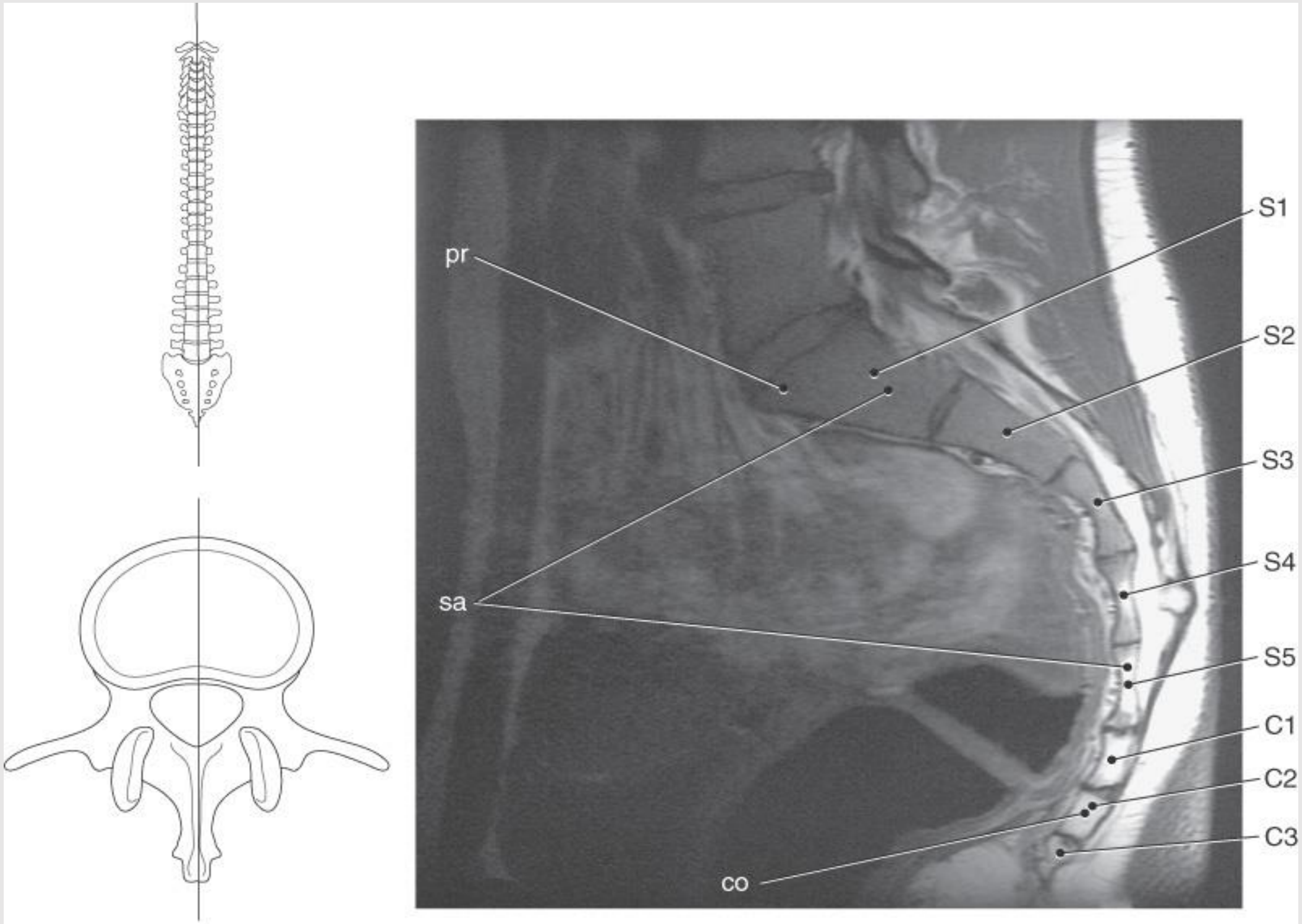


L-5 and Sacrum



***KEY:* pr,** Sacral promontory; **lm,** lateral mass; **f,** sacral foramina; **b,** body of S1; **SIjt,** sacroiliac joint.

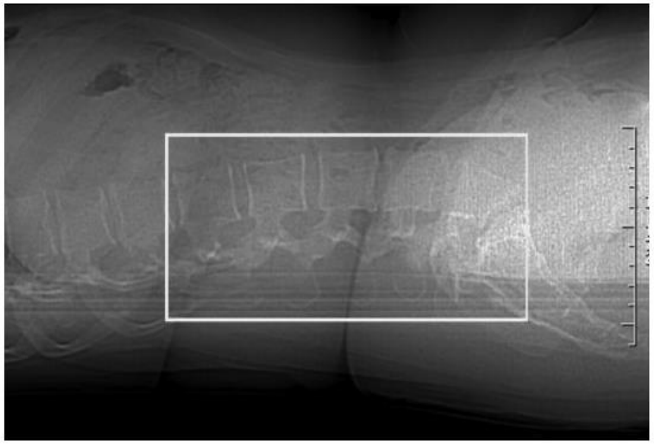
Sagittal of Sacrum



KEY: **pr,** Sacral promontory; **sa,** sacrum; **co,** coccyx.

Lumbar Spine CT Scan Protocol

- **Positioning Landmark**:
  - Xiphoid Tip
  - Pubic Symphysis
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - T11 to Sacrum/ Coccyx
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 1.25mm, 2.5mm, 3mm
  - Standard Window W: 350 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial



Special Protocols C/T/L Spine

- 3D Rendering
- S Curve CT

Special Procedures C/T/L Spine

- Myelogram

Exam / Patient Preparation

- **Little is needed**
  - **Remove metallic object**
  - **Fasting not required but recommended for contrast injections**
  - **Empty Bladder**
  - **Contrast Injection requires a through history**
  - **Place in a comfortable position**
  - **Close eyes for laser light positioning**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

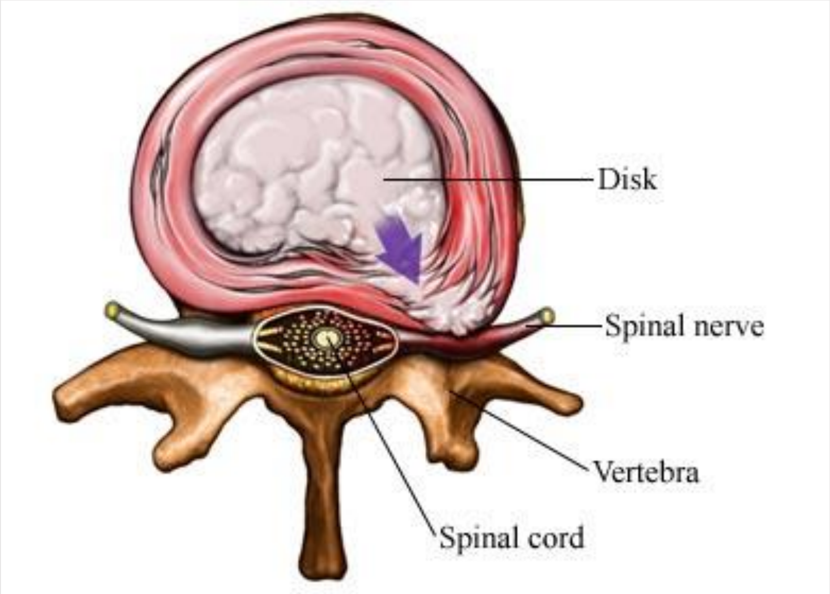
- IV Contrast Demonstrates
  - Vessels as apposed to lymph nodes
  - Choroid plexus dura mater & meningiomas
  - Scar tissue from recurrent disk herniation
  - Intracerebral tumors that break the blood brain barrier (glioblastomas)
  - Walls of abscesses

- Intrathecal Contrast
  - Enhance visualization of disk disease and outlines the cord and cauda equina
  - Cranial cisterns

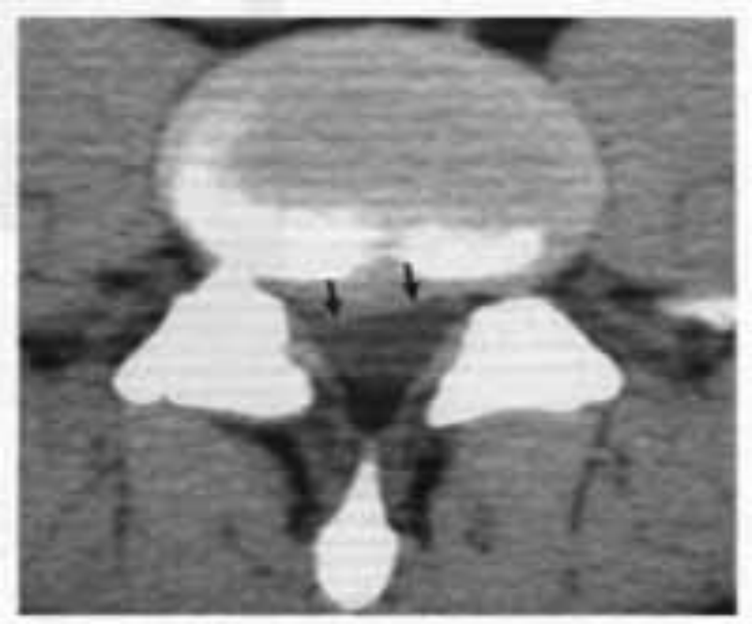
Notes on Spinal Imaging

- Spine is done in the axial/transverse plane
  - Angulation is can done on the axial plane
  - Thin slices (3mm or less) parallel to the disk space
- Most often used to determine traumatic fractures; MRI used more often for spinal cord injuries
- CT differentiates the disk from the adjacent ligamentum flavum, thecal sac, intraspinal fat, and bone.
- Nerve roots are identified as they exit the intervertebral foramina.
- IV contrast enhancement shows epidural veins

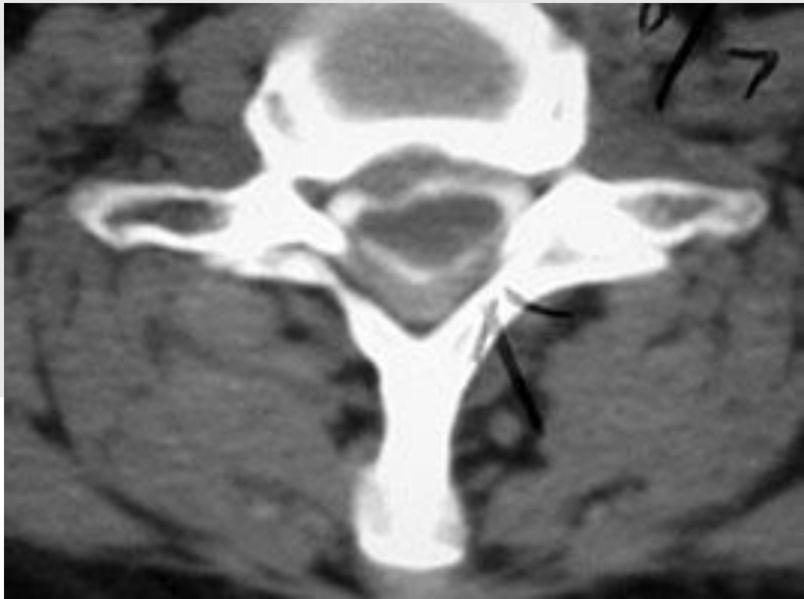
Disk Herniation



Lumbar



Cervical



Examples of Spinal Fractures

Figure 1

Figure 2

Multiplanar and Three-Dimensional Reformats

Q & A

Question 1

L-Spine CT image should include :

A) T-12 to L-5

B) T-12 to S1

C) T-12 to Pubic Symphysis

- **Answer: B**

Question 2

True or False: C/T/L Spine image can be obtained with contrast injection.

- **Answer: True**

Musculoskeletal

Types of Musculoskeletal

Upper Extremity

- Shoulder
- Humerus
- Elbow
- Forearm
- Wrist
- Hand

Lower Extremity

- Pelvis
- Hip
- Femur
- Knee
- Tibia / Fibula
- Ankle
- Foot

Indications for Musculoskeletal Imaging

- Trauma
  - Soft tissue and bone
  - Pain
- Inflammatory
  - Abcess
  - Celulitis
- Congenital
  - Osteogenisis imperfecta
  - Dysplasia
  - Cerebral Palsy
- Tumors / Cancer
  - Primary and metastasis
  - Sarcoma
- CTA
  - Vacularity

Upper Ext / Lower Ext CT Scan Protocol

- **Positioning Landmark**:
  - Dependent on the extremity and the extent of patient mobility
  - Always include above and below the joint space.
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Above and below ordered extremity
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 350-500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial

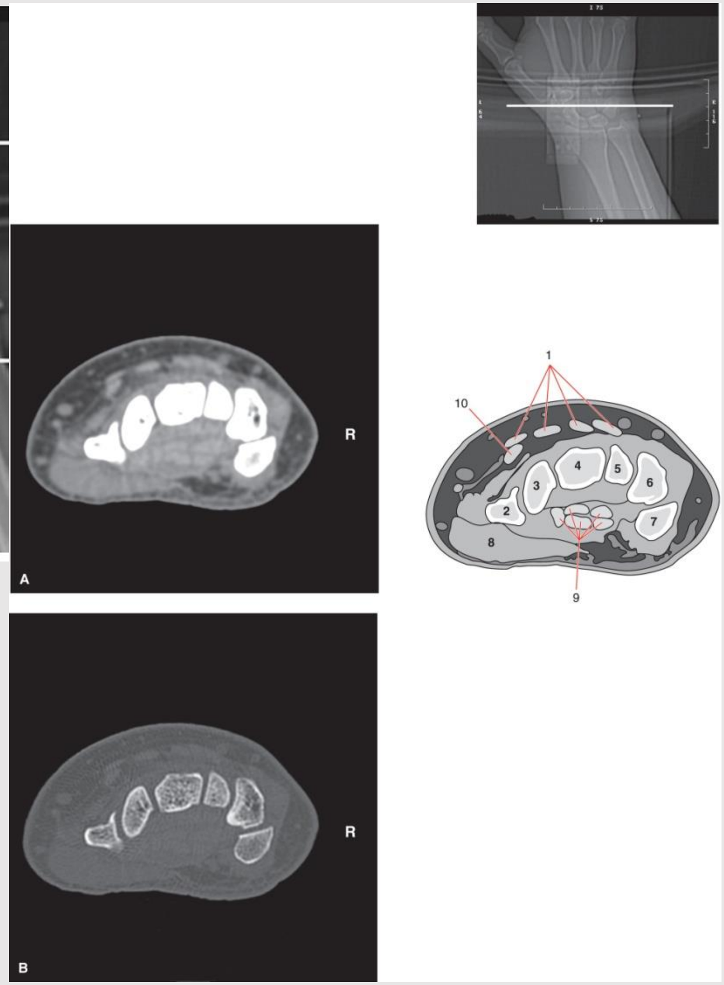
Shoulder Upper Ext CT Scan Protocol

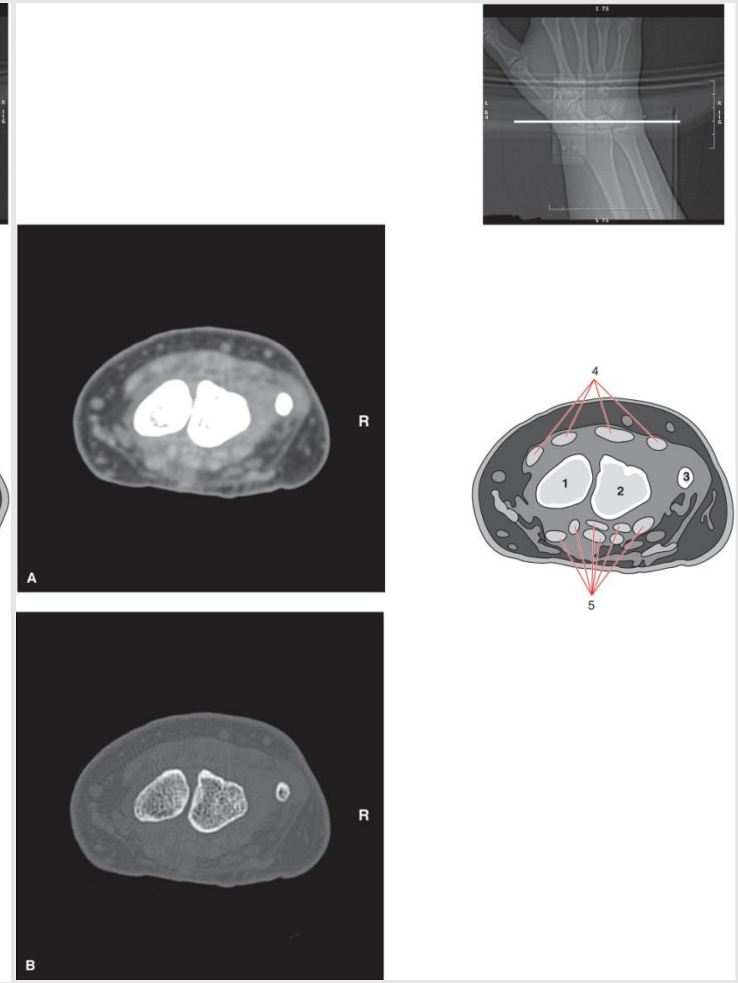
- **Positioning Landmark**:
  - 1-2" Above Jugular notch
  - Inferior Scapula Border
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - 1-2" Above Acromialclavicular Joint to the inferior border of scapula
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625mm, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
- Axial
- **Angiography:**
  - MIP
  - 3D planning

Wrist Upper Ext CT Scan Protocol

- **Positioning Landmark**:
  - Metacarpal
  - Mid forearm
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Proximal to distal radioulnar joint to the proximal metacarpals
- **Parameter Selection:**
  - DFOV: 10-16 cm
  - SFOV: Small/ Med Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625mm, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning

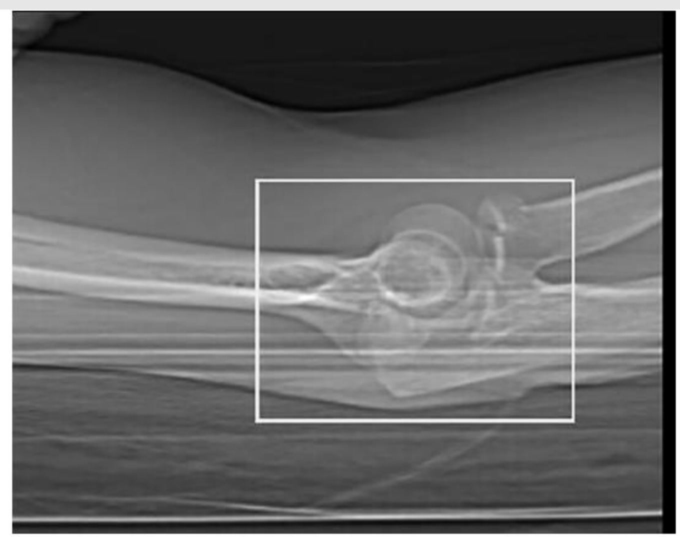
Wrist





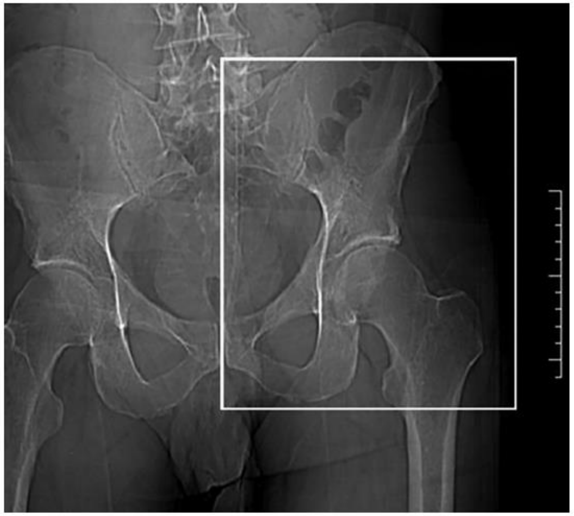
Elbow Upper Ext CT Scan Protocol

- **Positioning Landmark**:
  - Mid Forearm
  - Mid Humerus
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Scan from mid humerus to mid forearm
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Small/Med Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625mm, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning



Hip Lower Ext CT Scan Protocol

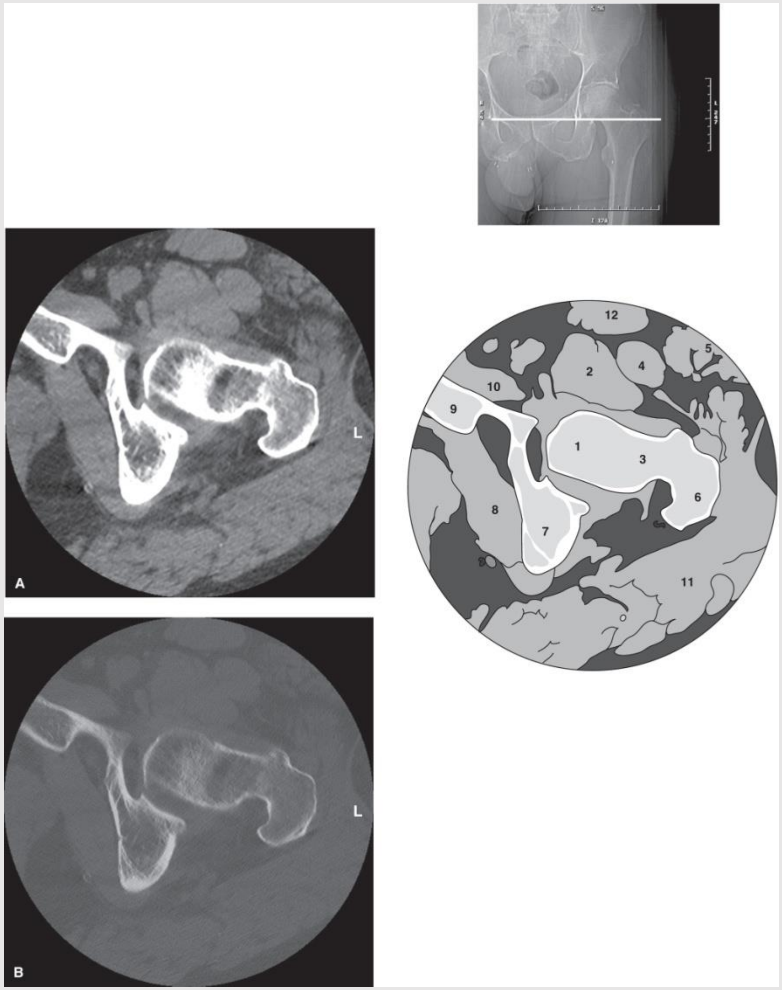
- **Positioning Landmark**:
  - Top of Iliac Crest
  - Mid Femur
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Scan just above sacroiliac joints to mid femur or through entire pathology
- **Parameter Selection:**
  - DFOV: 16-30 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625mm, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning

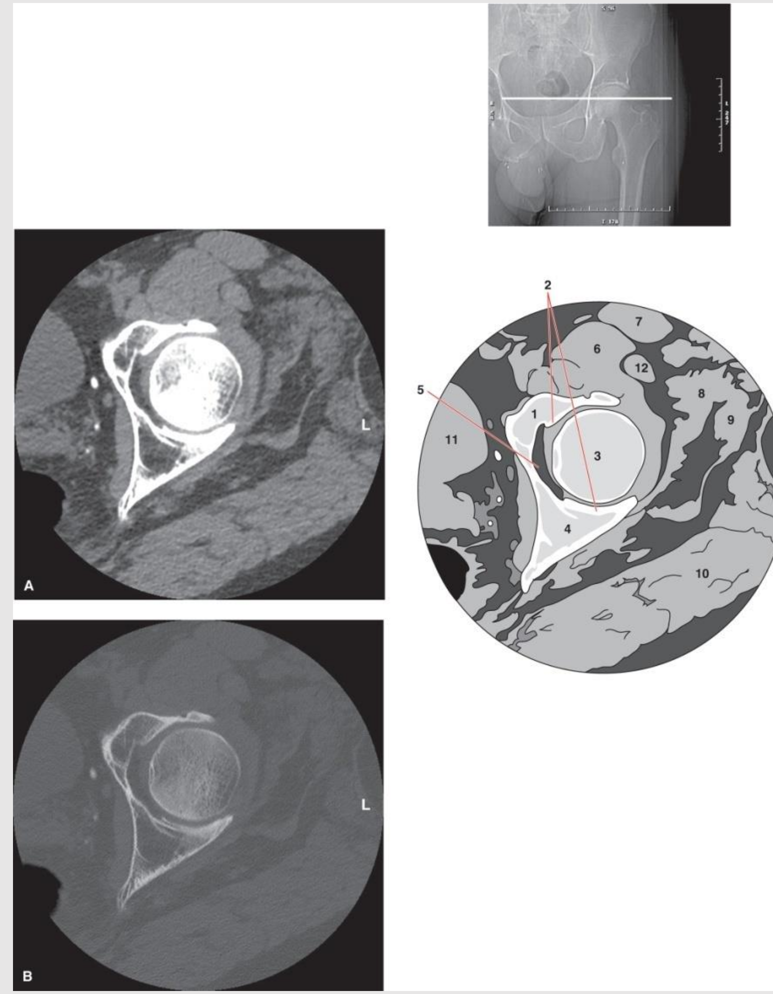


ADVANCED HEALTH EDUCATION CENTER®

EDUCATION ▲ STAFFING ▲ CONSULTING

Hip (cont.)

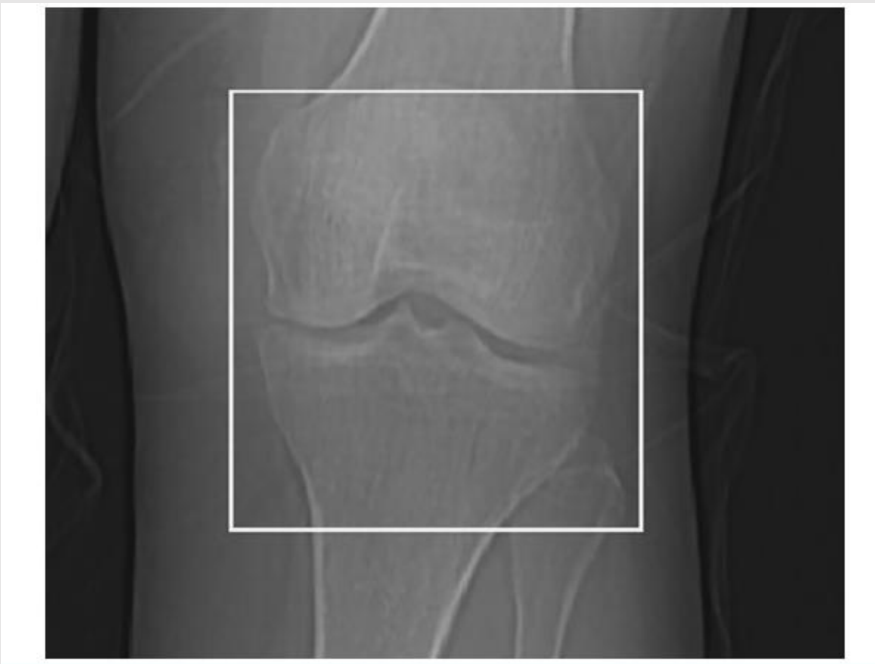


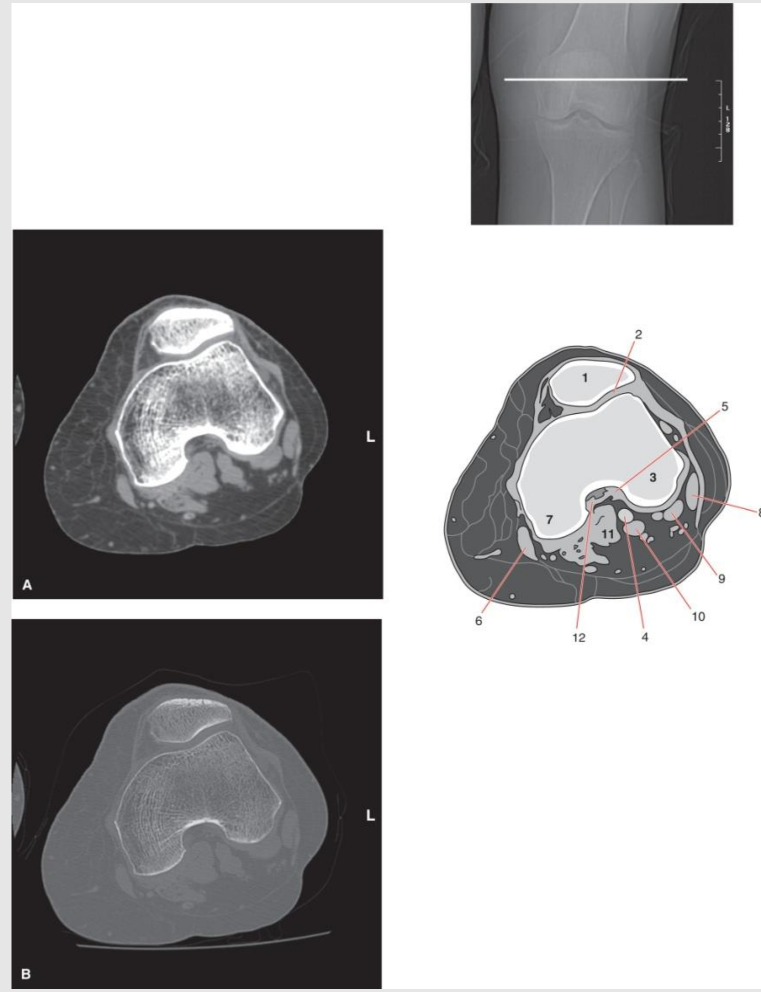


Knee Lower Ext CT Scan Protocol

- **Positioning Landmark**:
  - Lower Distal Femur
  - Mid Tibia/Fibula
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Scan from lower 1/3 femur to mid tibia/fibula or through entire pathology
- **Parameter Selection:**
  - DFOV: 16-30 cm
  - SFOV: Small/Med/Large Body
  - Algorithm: Standard / Bone +
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625mm, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning

Knee





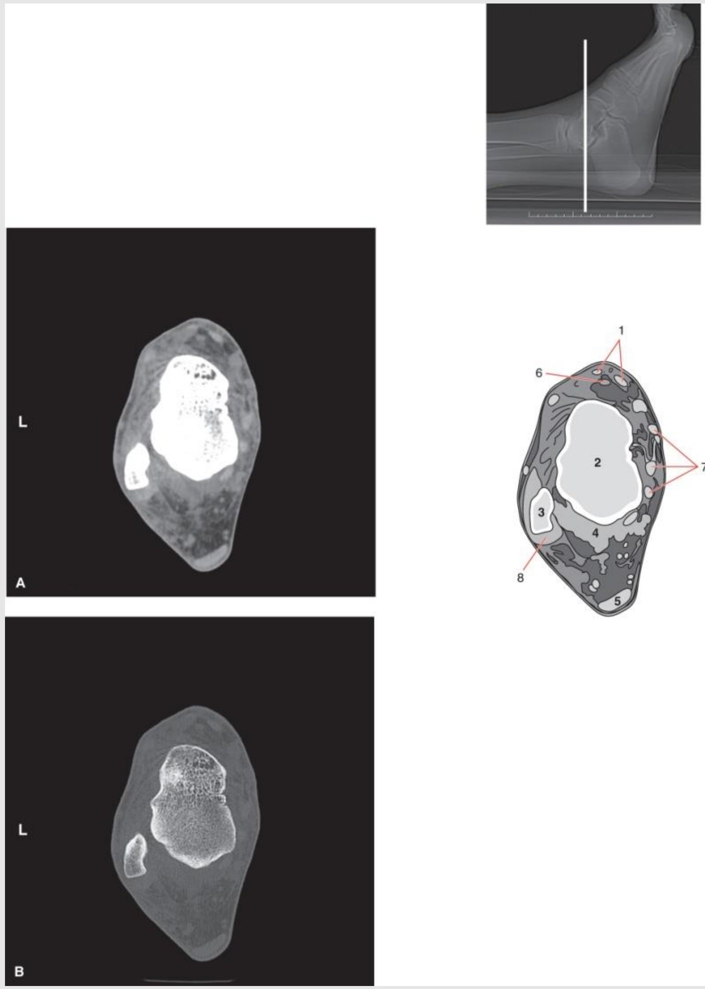
Ankle Lower Ext CT Scan Protocol

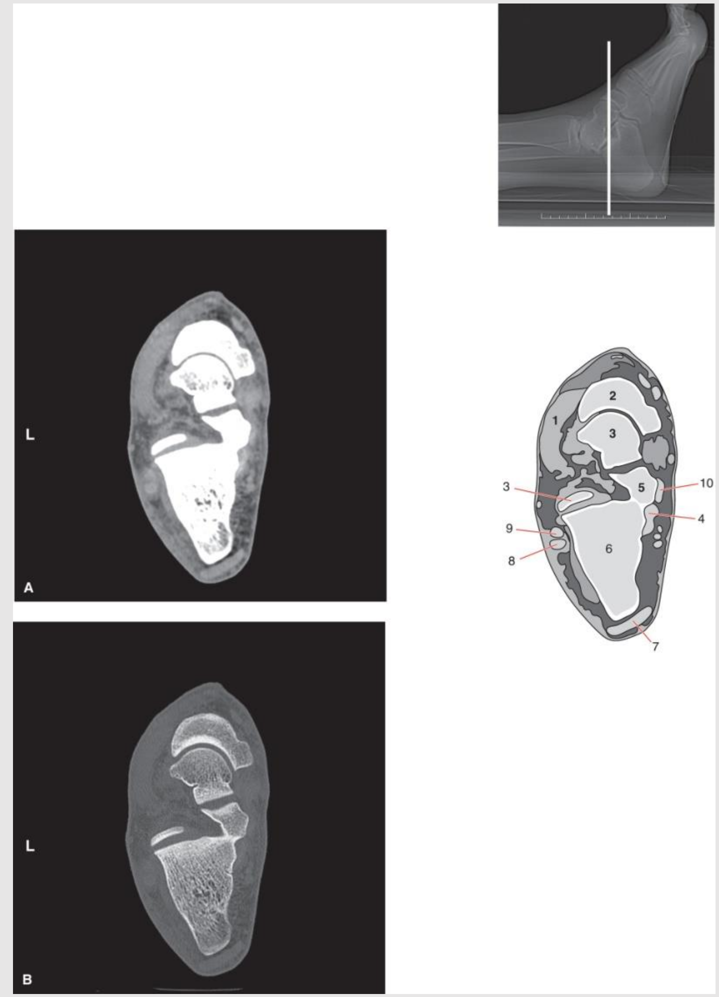
- **Positioning Landmark**:
  - Lower Distal Tibia/Fibula
  - Calcaneus
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Scan from lower 1/3 tib/fib to entire calcaneus
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Small/Med Body
  - Algorithm: Standard / Bone +
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625mm, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning

ADVANCED HEALTH EDUCATION CENTER®

EDUCATION ▲ STAFFING ▲ CONSULTING

Ankle/Foot





Common Pathology

- Achondroplasia
- Osteogenesis imperfecta
- Osteopetrosis
- Osteopenia
- Osteoporosis
- Osteomalacia and rickets
- Paget's disease
- Osteomyelitis
- Aseptic necrosis
- Bone fractures
- Osteosarcoma
- Ankylosing spondylitis

Special Protocols

- 3D Rendering
- Metal Artifact Reduction
- CTA / CTV Runoff
- CTA / Upper Ext Runoff

Special Procedures

- Red Bone Marrow
- Biopsy
- Drain
- Radiation Planning

Exam / Patient Preparation

- **Little is needed**
  - **Remove metallic object**
  - **Fasting not required but recommended for contrast injections**
  - **Empty Bladder**
  - **Contrast Injection requires a through history**
  - **Place in a comfortable position**
  - **Close eyes for laser light positioning**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

- IV Contrast Demonstrates
  - Arteries & Veins
  - Tumor enhancement
  - Intracerebral tumors that break the blood brain barrier (glioblastomas)
  - Walls of abscesses

General Notes

- Thin slices improve spatial resolution

- Reconstruction Algorithm
  - Standard for soft tissue
  - Bone for bone
  - Detail for edge enhancement

- Field of view (FOV)
  - Large enough to cover entire anatomic area

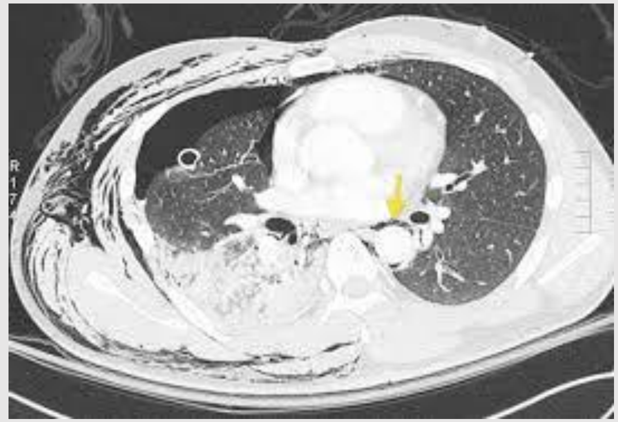
- Display Field of View (DFOV)
  - Can be same as FOV or smaller
  - Smaller DFOV better resolution because smaller pixel size

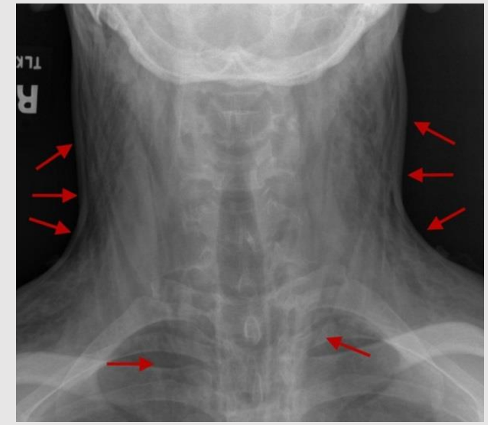
10 MINUTE BREAK

NECK & CHEST

Parts of the Chest

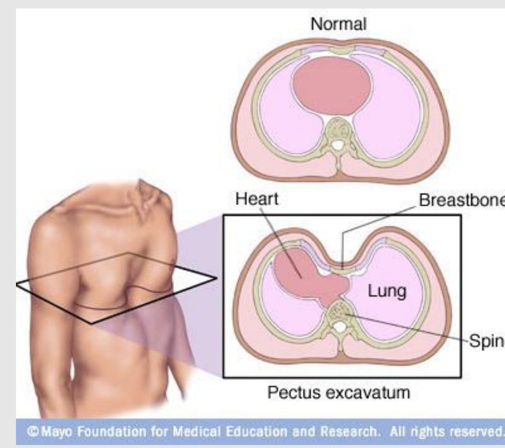
- **Soft Tissue**
  - **Breast Shadows**
  - **Nipples**
  - **Implants**
  - **Subcutaneous emphysema**





- **Bony Structures**
  - **Sternum Deformities (pectus excavatum)**
  - **Ribs (calcifications and fractures)**
  - **Spine (abnormalities & technique)??**

- **Mediastinum**
  - **Air**
  - **Lymphnodes**
  - **Tumors**
  - **Thymus**
  - **Heart and Great Vessels**



Neck

Neck CT Scans

Airway

- Soft Tissue Neck

Vascular

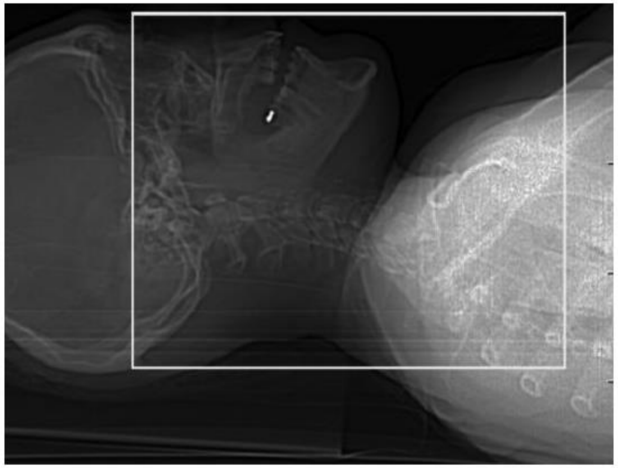
- Parathyroid
- CTA Neck

Indications for Neck Imaging

- Trauma
  - Soft tissue and bone
  - Pain
  - Foreign Body
  - Stenosis
- Inflammatory
  - Abcess
  - Celulitis
- Tumors / Cancer
  - Primary and metastasis
  - Sarcoma
- CTA
  - Vacularity

Airway CT Scan Protocol

- **Positioning Landmark**:
  - EAM
  - Carina
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Top of the EAM to the Carina
- **Parameter Selection:**
  - DFOV: 16-25 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Bone
- **Scan Technique:**
  - kVp 120-140
  - mAs: 150-500
  - Helical
  - Slice thickness: 0.625, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 350-500 ww
  - Standard Window L: 50 wl
  - Bone Window W: 2000 ww
  - Bone Window L: 500 wl
- **Reformats**:
  - Done in Standard / Bone
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning



Common Pathology

- Lymphoma
- Obstruction
- Stenosis
- Repair
- Tracheostomy

Special Protocols

- Parathyroid
- CTA Neck

Special Procedures

- Drain
- Biopsy

Exam / Patient Preparation

- **Little is needed**
  - **Remove metallic object**
  - **Fasting not required but recommended for contrast injections**
  - **Empty Bladder**
  - **Contrast Injection requires a through history**
  - **Place in a comfortable position**
  - **Close eyes for laser light positioning**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

- IV Contrast Demonstrates
  - Vessels as apposed to lymph nodes
  - Choroid plexus dura mater & meningiomas
  - Scar tissue from recurrent disk herniation
  - Intracerebral tumors that break the blood brain barrier (glioblastomas)
  - Walls of abscesses

Chest / Thoracic Cavity

Chest CT Scans

Chest

- Routine
- Low Dose Lung Nodule
- High Resolution CT (ILD)

Vascular

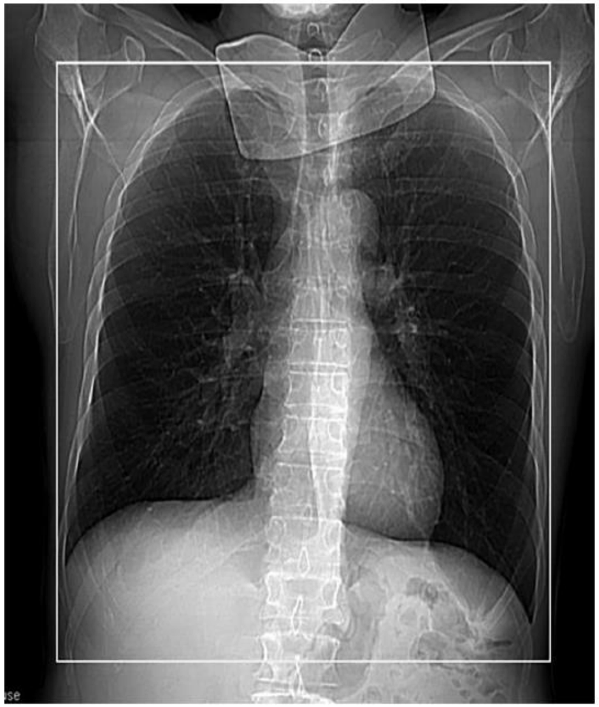
- PE (Pulmonary Embolism)
- CTA Chest
- CTA Heart
- CTA Coronary
- CTA Pulmonary Veins

Indications for Chest / Thoracic Imaging

- Trauma
  - Soft tissue and bone abnormality
  - Pain
  - Foreign Body
  - Stenosis
- Inflammatory
  - Abcess
  - Infection
  - Pneumonia
- Congenital
  - Heart anomalies
- Tumors / Cancer
  - Primary and metastasis
  - Sarcoma
- Disease Anomalies
  - Emphysema
  - Lung Nodule
  - Asbestos
  - Interstitial Lung Disease
  - Bronchitis
  - Cough
  - Sarcoid
  - Scleroderma
  - Cystic Fibrosis
  - COPD
  - Asthma
  - Lung Volume
- CTA
  - Vacularity
  - Embolism
  - Aortic Anyuerism
  - Cardiac

Chest CT Scan Protocol

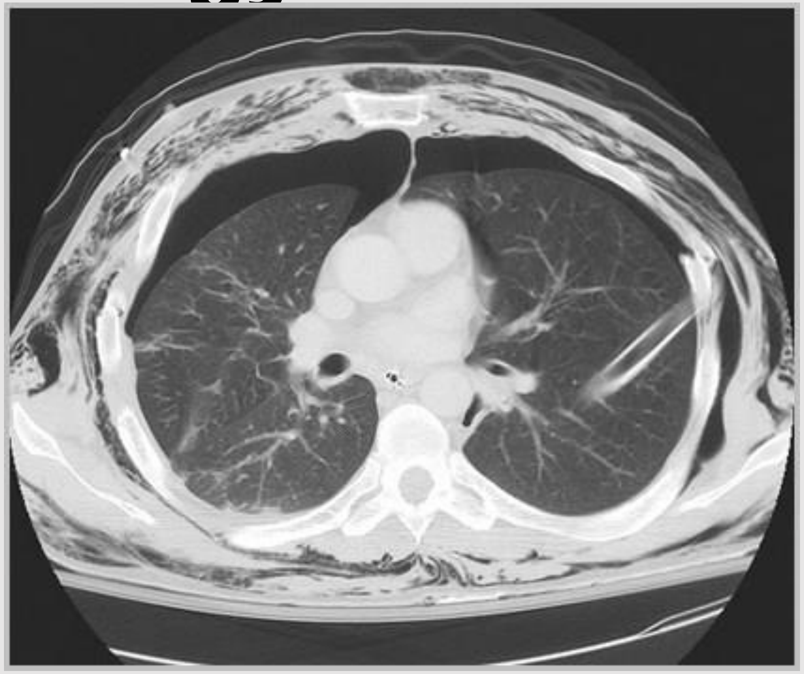
- **Positioning Landmark**:
  - 1-2" Above Jugular Notch
  - Top of Kidneys
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - 1-2" Above Jugular Notch to the top of the Adrenals/ Kidneys
- **Parameter Selection:**
  - DFOV: 20-35 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard / Lung
- **Scan Technique:**
  - kVp 120-140
  - mAs: 80-250
  - Helical
  - Slice thickness: 0.625, 1.25mm, 2.5mm, 3mm
  - Standard Window W: 350-500 ww
  - Standard Window L: 50 wl
  - Lung Window W: 1500-2000 ww
  - Bone Window L: -500 - -700wl
- **Reformats**:
  - Done in Standard / Lung
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning

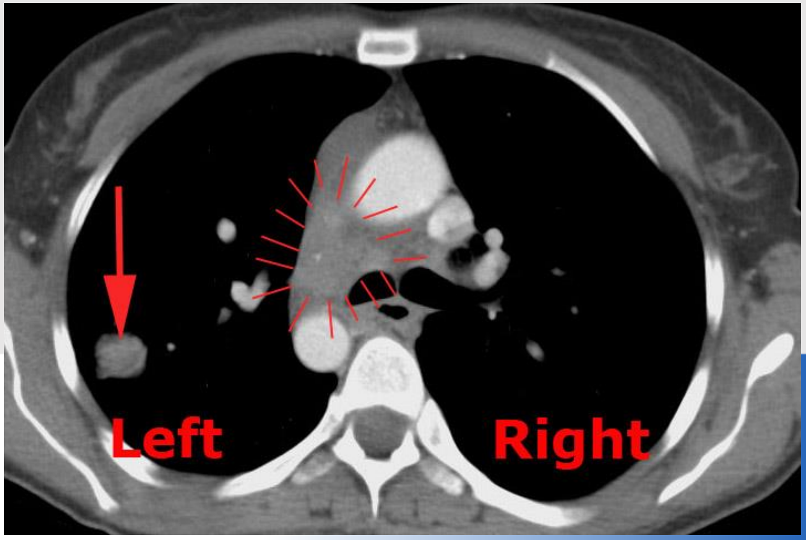


Common Pathology

- Hodgkin's Lymphoma
- Emphysema
- Pneumothorax
- Pulmonary Edema
- PE
- Trauma – Rupture Diaphragm

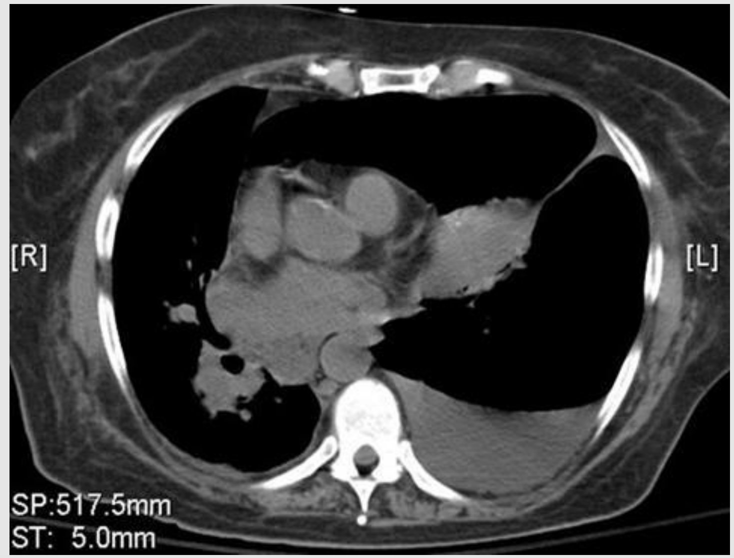
Chest Pathology





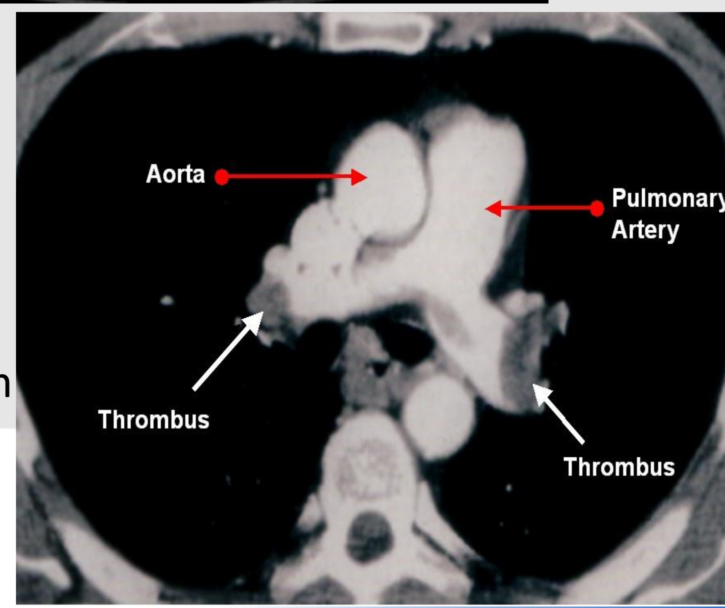
Chest Pathology

Pneumothorax



Pulmonary Edema

Pulmonary Embolism



ADVANCED HEALTH EDUCATION CENTER®

EDUCATION ▲ STAFFING ▲ CONSULTING

Exam / Patient Preparation

- **Remove metallic object**
- **Fasting not required but recommended for contrast injections**
- **Empty Bladder**
- **Contrast Injection requires a through history**
- **Place in a comfortable position**
- **Cardiac Scans –**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

- IV Contrast Demonstrates
  - Vessels as apposed to lymph nodes
  - Choroid plexus dura mater & meningiomas
  - Scar tissue from recurrent disk herniation
  - Intracerebral tumors that break the blood brain barrier (glioblastomas)
  - Walls of abscesses
- Intrathecal Contrast
  - Enhance visualization of disk disease and outlines the cord and cauda equina
  - Cranial cisterns

General Information – Chest Scanning

- Spiral CT allows entire chest to be imaged in one breath hold
  - Most important advancement in chest scanning
  - Eliminates misregistration
  - Allows for excellent 3D reformations
  - Excellent vascular visualization

General Imaging Methods

- A short scan time helps to reduce artifacts created by respiratory motion
- Whenever possible, scans of the chest should be acquired within a single breath-hold
- Because of the high intrinsic natural contrast, iodinated contrast is not necessary for all thoracic indications
  - IV agents are typically used to differentiate vascular from nonvascular structures
- High-resolution CT (HRCT) of the chest is used for the assessment of lung parenchyma in patients with diffuse lung disease
  - Usually done prone and supine

Special Protocols

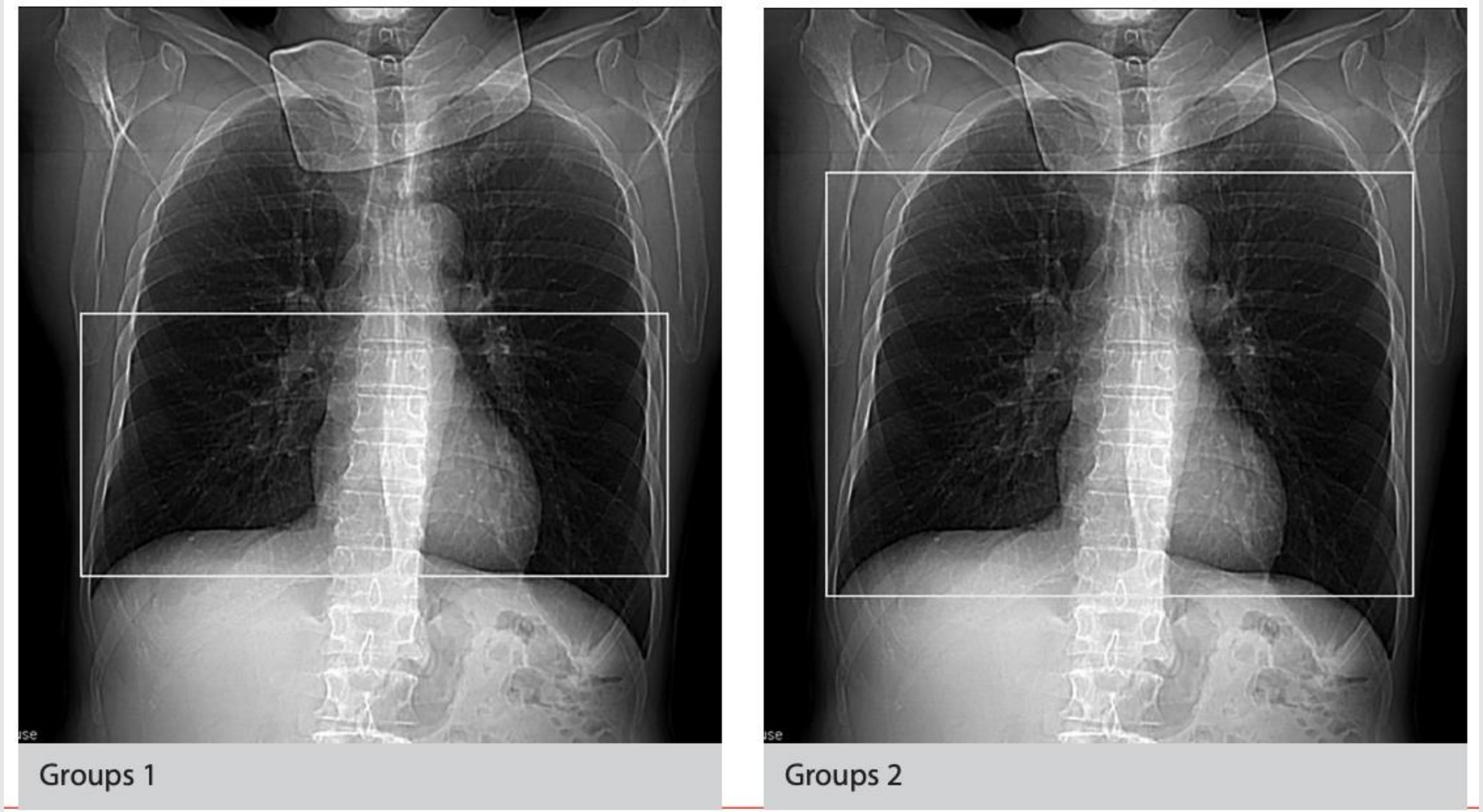
Chest

- Low Dose Lung Nodule
- High Resolution CT (ILD)

Vascular

- PE (Pulmonary Embolism)
- CTA Chest
- CTA Heart
- CTA Coronary
- CTA Pulmonary Veins

CT Cardiac Imaging



CT Cardiac Imaging

Cardiac Imaging

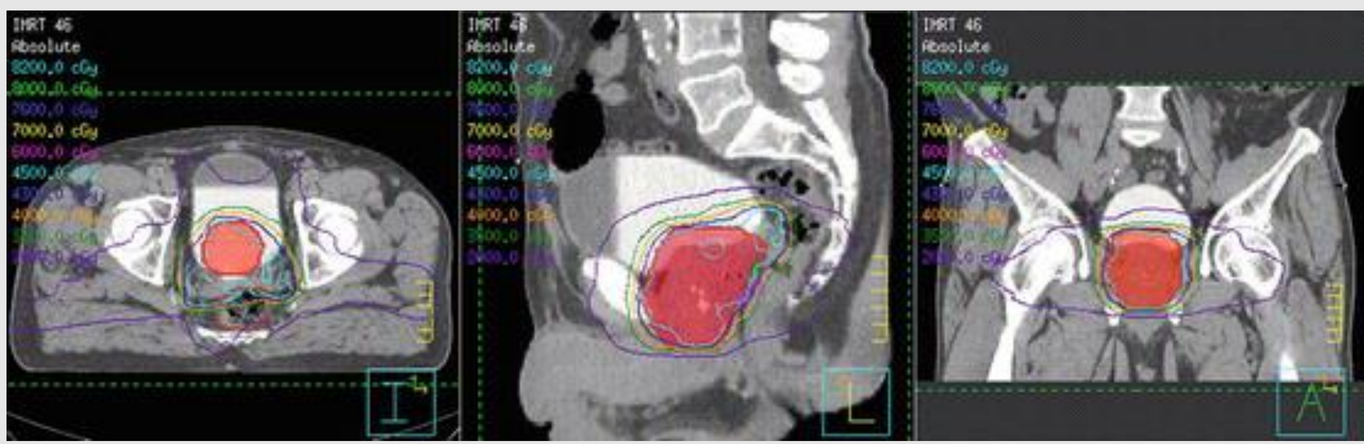
- Better Temporal Resolution was needed for effective cardiac imaging

- Temporal Resolution is the measure of the data acquisition time for one image

- Adequate Temporal resolution accomplished by:
  - Multi-Row Detectors
  - Dual Source CT (2 tube at 90 degree angles)

Special Procedures

- Lung Biopsy
- Aspiration
- Drain
- Chest Tube Placement
- Radiation Planning



Common Indications for CT-Guided Procedures

- Drainage of abscesses and pneumothoraces
- Percutaneous administration of chemotherapeutic agents
- Tissue Biopsies
- Percutaneous vertebroplasty

CT Guided Biopsies

- Risk associated with Needle Biopsies increase with increase in needle size
- Most common complication overall is bleeding
- Most common complication with lung biopsy is a pneumothorax

Basic Steps to CT-Guided Biopsy

1. Explain the procedure to patient; obtain written consent
2. Obtain appropriate laboratory values
3. Plot the scan using the patient's previous imaging studies
4. Scan the selected area; breathing instructions are crucial
5. The best location for needle entry is selected; place a metallic marker on the skin
6. Repeat scan to confirm the suitability of selected location

Basic Steps to CT-Guided Biopsy

7. Measure the distance from the marker on the patient's skin to the lesion; this determines the optimal depth and angle for needle placement

8. The patient's skin is prepared according to aseptic guidelines; the biopsy needle is placed

9. Repeat the scan at the needle location and one slice above and below the expected needle location until the tip of the needle is visualized

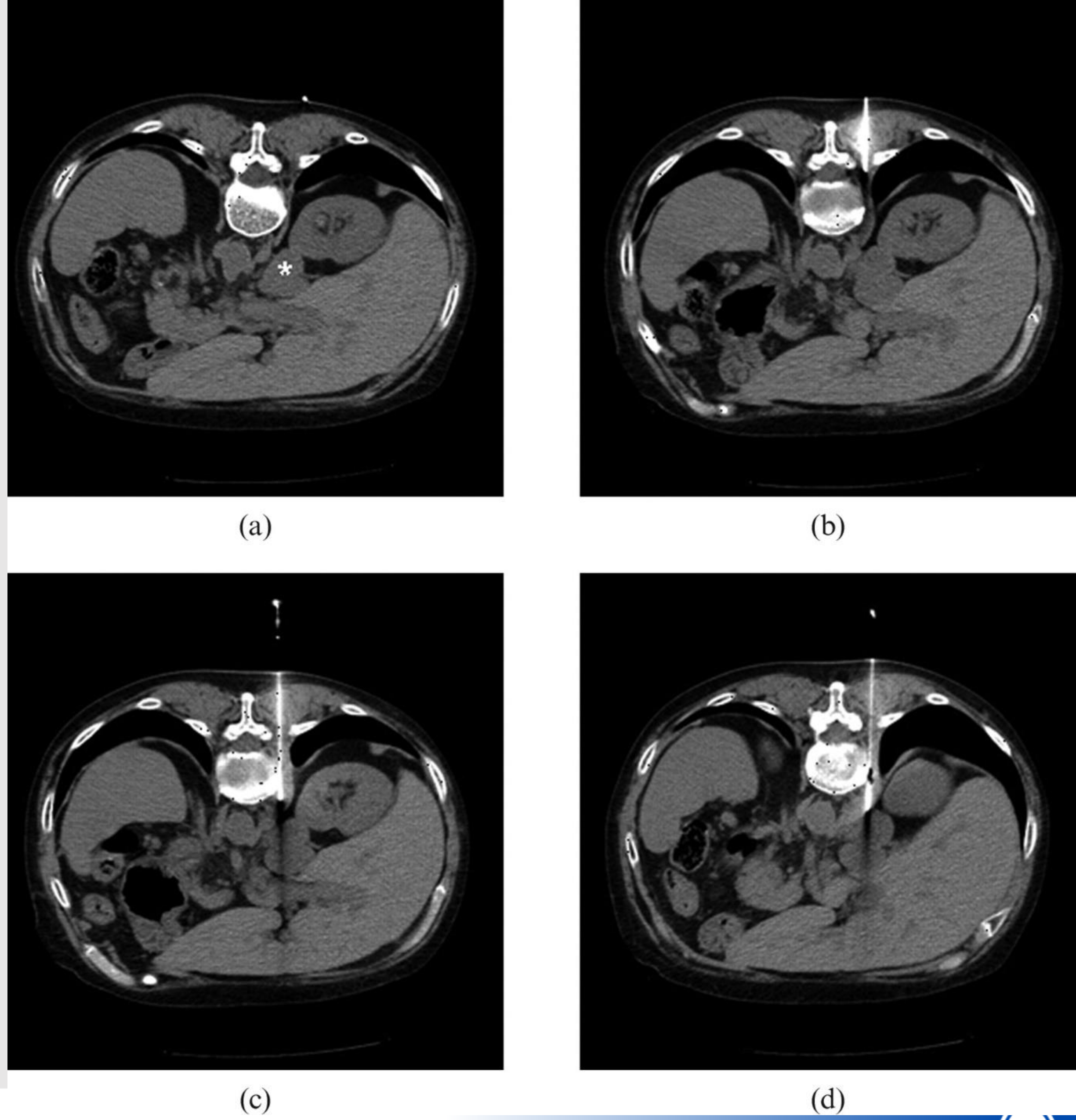
10. If the CT image confirms the correct location a tissue sample is taken and prepared according to laboratory protocols

11. Post-procedure scan is taken to identify complications

Needle Biopsy

(a) Location of mass with skin marker

(b-d) shows the advancement of needle



Abdomen & Pelvis

Abdomen / Pelvis CT Scans

<u>Routine</u>

- Routine AP
- Renal Stone
- Hematuria / Urogram

- **<u>Multi-Phase</u>**
- Adrenal / Kidney
- Pancreas
- Liver

<u>Vascular</u>

- CTA Abdomen / Pelvis
- Mesenteric
- Enterography
- CTA Coronary
- CTA Pulmonary Veins

<u>Specials:</u>

- Virtual Colonography

Indications for Abdomen Pelvis Imaging

- Trauma
  - Soft tissue and bone abnormality
  - Pain
  - Foreign Body
  - Stenosis
- Inflammatory
  - Abcess
  - Infection
  - Diverticulitis
  - Appendicitis
- Tumors / Cancer
  - Primary and metastasis
  - Tumors / Mass
  - Lymphoma
- Disease Anomalies
  - GI Bleed
  - Hematuria
  - Stones
  - Polyps
- CTA
  - Vacularity
  - Embolism
  - Aortic Anyuerism

Abdomen & Pelvis CT Scan Protocol

- **Positioning Landmark**:
  - Mid Chest
  - Pubic symphysis
  - Dependent on exam ordered
- **Scout View:**
  - AP
  - Lateral
- **Scan Extent:**
  - Start mid chest and scan through greater trochanter or ordered exam (pelvis, abdomen, pancreas, adrenlas, liver, etc)
- **Parameter Selection:**
  - DFOV: 25-50 cm
  - SFOV: Med/Large Body
  - Algorithm: Standard
- **Scan Technique:**
  - kVp 120-140
  - mAs: 200-max
  - Helical
  - Slice thickness: 0.625, 1.25mm, 2.5mm, 3mm, 5mm
  - Standard Window W: 350-500 ww
  - Standard Window L: 50 wl
  - Lung Window W: 1500-2000 ww
  - Bone Window L: -500 - -700wl
- **Reformats**:
  - Done in Standard
  - Coronal
  - Sagittal
  - Axial
- **Angiography:**
  - MIP
  - 3D planning

Common Pathology

- Pain
- Mass / Tumor
- Appendicitis
- Blood
- GI Bleed
- Trauma
- Diverticulitis
- Polyps
- Lymphoma
- Cancer
- Abscess

Exam / Patient Preparation

- **Remove metallic object**
- **Empty Bladder**
- **Contrast Injection requires a through history**
- **Place in a comfortable position**
- **Abdomen Scans – require specific instructions**

- **If IV contrast is needed:**
  - 18G IV needed for CTA / Venogram
  - 22G IV needed for routine contrast

Contrast Agents

- IV Contrast Demonstrates
  - Vessels as apposed to lymph nodes
  - Choroid plexus dura mater & meningiomas
  - Scar tissue from recurrent disk herniation
  - Intracerebral tumors that break the blood brain barrier (glioblastomas)
  - Walls of abscesses

- Intrathecal Contrast
  - Enhance visualization of disk disease and outlines the cord and cauda equina
  - Cranial cisterns

Special Protocols

Abdomen / Pelvis

- Hematuria
- Renal Stone
- Multiphase Scans (Adrenals, Kidneys, Pancreas, Liver)

Vascular

- Aortic Aneurysm
- Runoff

Special Procedures

- Biopsy
- Aspiration
- Drain
- Radiation Planning

General Imaging Methods

- Patient preparation is particularly important when imaging the abdomen or pelvis
- Most scans require oral contrast
- The rectal administration of CM is typically reserved for specific situations, such as colon cancer staging
- The bladder is best appreciated on CT when filled with urine or contrast material

General Imaging Methods (cont.)

- IV contrast opacifies the blood vessels, increases the CT density of vascular abdominal organs, and improves image contrast between lesions and normal structures.
- The appropriate timing, rate, and dose of the IV contrast agent are essential.
  - For most examinations of the body, image acquisition must be completed before CM reaches the equilibrium phase.
- Multiphasic imaging is frequently used for specialized studies of the pancreas, liver, and kidney as well as in many abdominal CTA protocols.

General Imaging Methods (cont.)

- In any given slice, much more information is present than can be displayed by any single window width and level setting.
  - Hence, images are often reviewed in two or more window settings.
- The DFOV should be just large enough to include the skin surface over the key areas being imaged.
  - If previous studies are available, it is generally advisable to use the same DFOV, unless a change in patient condition necessitates adjustment.

Q & A

Question 1

Abdomen/Pelvis CT scans include:

A) Top of diaphragm to the Pubic Symphysis

B) Top of diaphragm to the top of the kidneys

C) Top of diaphragm to the top of the crest

- **Answer: A**

Question 2

True or False: CT scan of the Abdomen Pelvis is better visualized with IV and oral contrast.

- **Answer: True**

Question 3

CT scan of the Chest requires:

A) Mid neck to the top of kidneys

B) Mid neck to the top of the crest

C) Mid neck to the pubic symphysis

- **Answer: A**

Question 4

True or False: High Resolution CT scan shows pulmonary nodules.

- **Answer: True**

Resources

- Romans, Lois, 2019. Computed Tomography for Technologists: A Comprehensive Text., *Wolters Kluwer*. Philadelphia

- Seeram, Euclid, 2016. Computed Tomography: Physical Prinicples, Clinical Applications, and Quality Control. *Elsevier*. St. Louis Missouri.