FUNDAMENTALS OF MEDICAL IMAGING

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IMAGING INTERPRETATIONS

- CONVENTIONAL RADIOGRAPHY

- CROSS-SECTIONAL IMAGING TECHNIQUES

CONVENTIONAL RADIOGRAPHY

Film Radiography

* As x-rays pass through the human body, they are attenuated by interaction with body tissues (absorption and scatter) and produce an image pattern on film that is recognizable as human anatomy.
* The final product is an x-ray image of the patient's anatomy on a film

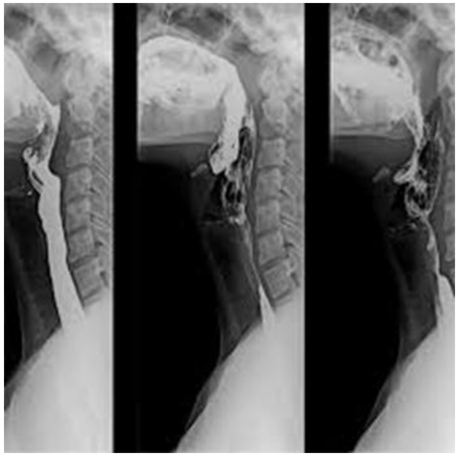
Principles of Interpretation

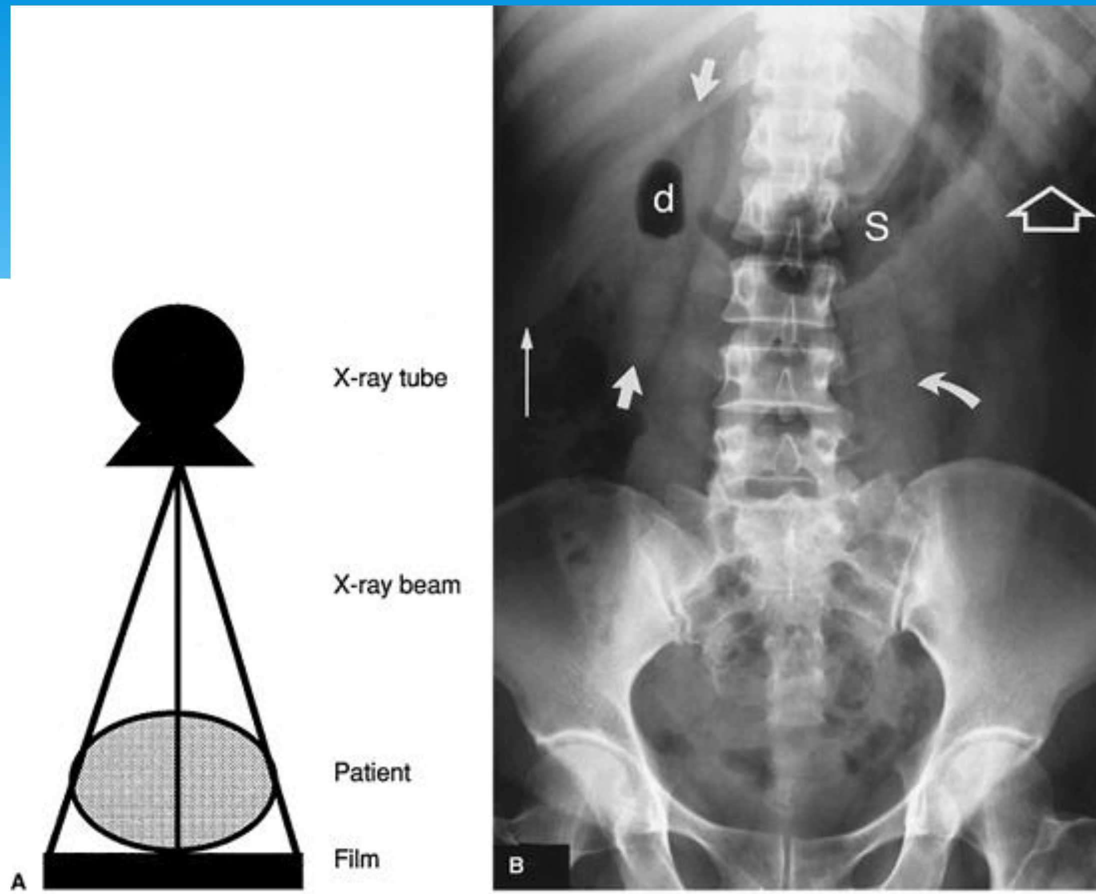
Conventional radiographs demonstrate five basic radiographic densities: Air, fat, soft tissue, bone, and metal (or x-ray contrast agents).

- **Air attenuates very little of the x-ray beam, allowing nearly the full force of the beam to blacken the image.**
- **Bone, metal, and radiographic contrast agents attenuate a large proportion of the x-ray beam, allowing very little radiation through to blacken the image. Thus, bone, metallic objects, and structures opacified by x-ray contrast agents appear white on radiographs.**
- **Fat and soft tissues attenuate intermediate amounts of the x-ray beam, resulting in proportional degrees of image blackening (shades of gray).**

Principles of Interpretation

- **Thick structures** **attenuate more radiation than thin structures of the same composition.**
- **Anatomic structures** **are seen on radiographs when they are outlined in whole or in part by tissues of different x-ray attenuation.**



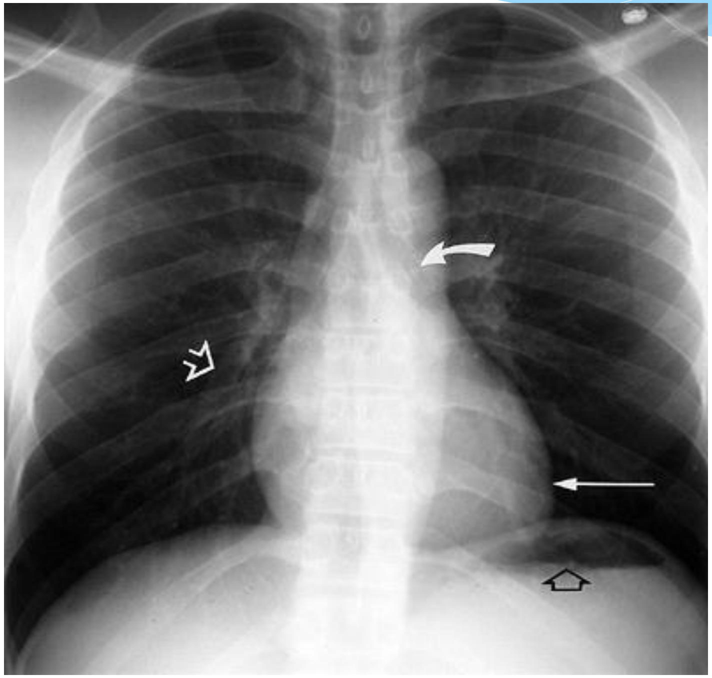


Conventional Radiography. A. Diagram of an x-ray tube producing x-rays that pass through the patient and expose the radiographic film. For digital radiography, a phosphor imaging plate or fixed electronic detector takes the place of the film cassette. B. Supine AP radiograph of the abdomen reveals the patient's anatomy because anatomic structures differ in their capacity to attenuate x-rays that pass through the patient. The stomach (S) and duodenum (d) are visualized because air in the lumen is of different radiographic density than the soft tissues that surround the GI tract. The right kidney (between short straight arrows), edge of the liver (long straight arrow), edge of the spleen (open arrow), and the left psoas muscle (curved arrow) are visualized because fat outlines the soft tissue density of these structures. The bones of the spine, pelvis, and hips are clearly seen through the soft tissues because of their high radiographic density.

Principles of Interpretation

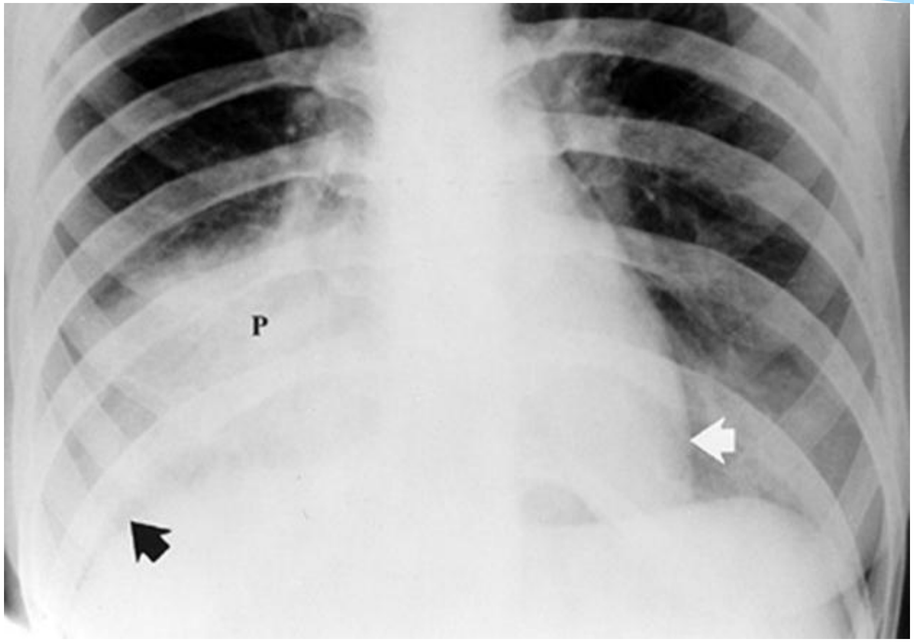
* Fat within the abdomen outlines the margins of the liver, spleen, and kidneys, allowing their visualization .
* The high density of bones enables visualization of bone details through overlying soft tissues.
* Metallic objects such as surgical clips are usually clearly seen because they highly attenuate the x-ray beam.
* Radiographic contrast agents are suspensions of iodine and barium compounds that highly attenuate the x-ray beam and are used to outline anatomic structures.
* Disease states may obscure normally visualized anatomic structures by silhouetting their outline.

Air in the lung outlines pulmonary vascular structures, producing a detailed pattern of the lung parenchyma .



Erect PA Chest Radiograph. The pulmonary arteries (white open arrow) are seen in the lung because the vessels are outlined by air in alveoli. The left cardiac border (long arrow) is crisply defined by the adjacent air-filled lung. The left main bronchus (curved arrow) is seen because its air-filled lumen is surrounded by soft tissue of the mediastinum. An air-fluid level (open black arrow) in the stomach confirms the erect position of the patient during exposure of the radiograph.

For example, pneumonia in the right middle lobe of the lung replaces air in the alveoli with fluid and silhouettes the right heart border.



Right Middle Lobe and Left Lower Lobe Pneumonia. PA erect chest radiograph demonstrates pneumonia (P) in the right middle lobe replacing air density in the lung with soft tissue density and silhouetting the right heart border. The dome of the right hemidiaphragm (black arrow) is defined by air in the normal right lower lobe and remains visible through the right middle lobe infiltrate. The left heart border (white arrow), defined by air in the lingula, remains well defined despite infiltrate in the left lower lobe.

CROSS-SECTIONAL IMAGING TECHNIQUES

* **CT, MR, and US are techniques that produce cross-sectional images of the body.**
* **All three interrogate a three-dimensional volume or slice of patient tissue to produce a two-dimensional image. The resulting image is made up of a matrix of picture elements (pixels), each of which represents a volume element (voxel) of patient tissue.**
* **The tissue composition of the voxel is averaged (volume averaged) for display as a pixel.**

CROSS-SECTIONAL IMAGING TECHNIQUES

- **CT and MR assign a numeric value to each picture element in the matrix.**

- **The matrix of picture elements that make up each image is usually between 128 — 256 and 560 pixels) and is determined by the specified acquisition parameters.**

CROSS-SECTIONAL IMAGING TECHNIQUES

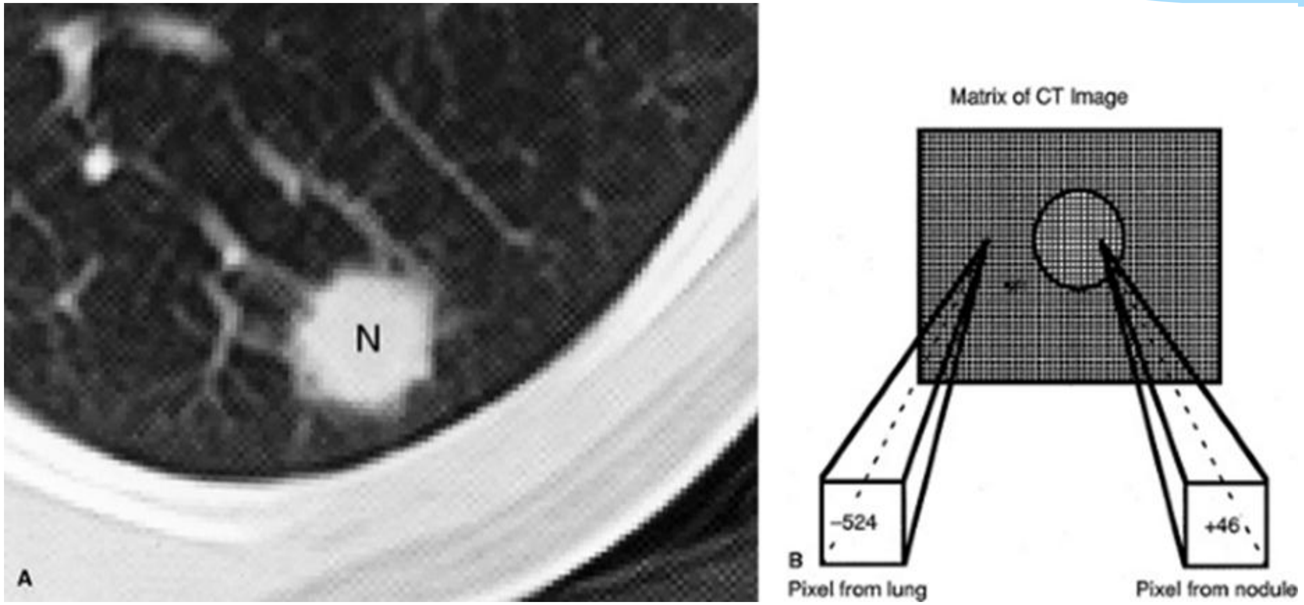
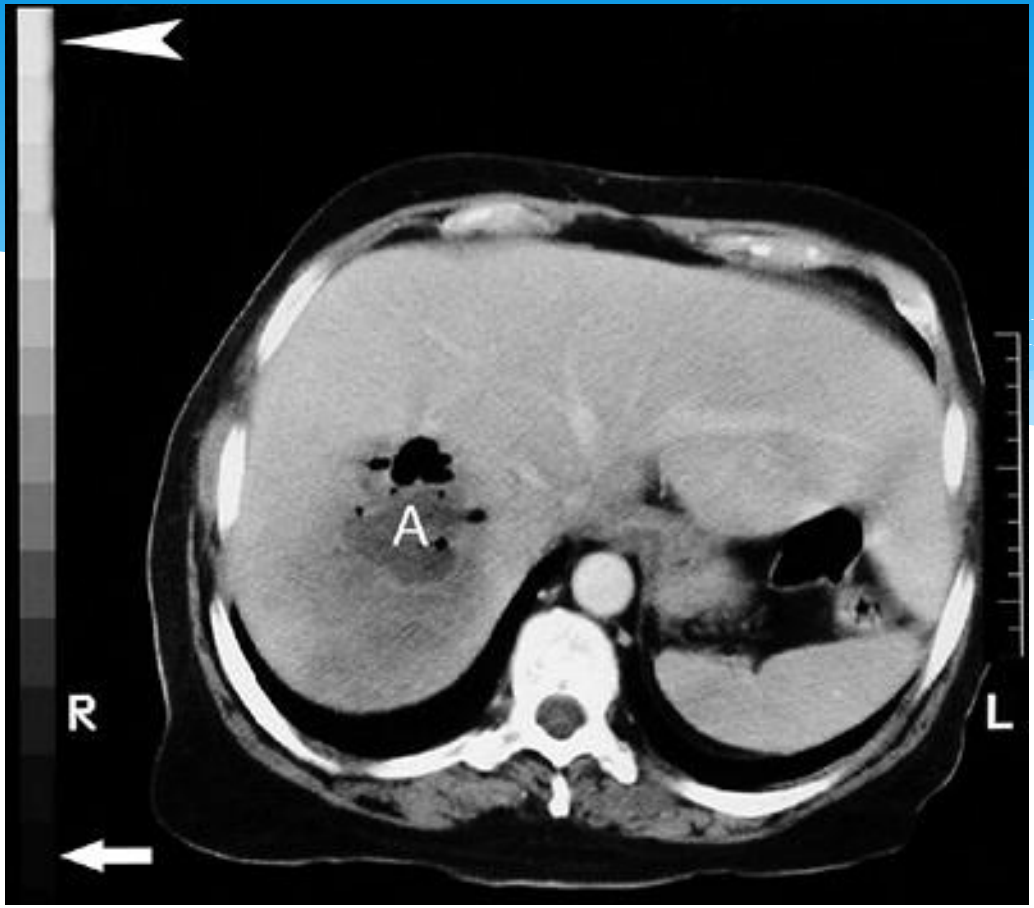


Image Matrix. A. Magnified CT image of a pulmonary nodule (N). The pixels that make up the image are evident as tiny squares within the image. The window width is set at 2,000 H with a window level of 600 H to accentuate visualization of the white soft tissue nodule on a background of gray, air-filled lung. B. Diagram of the matrix that constitutes the CT image. A pixel from the air-filled lung with a calculated CT number of 524 H is gray, whereas a pixel from the soft tissue nodule with a calculated CT number of +46 H is white.

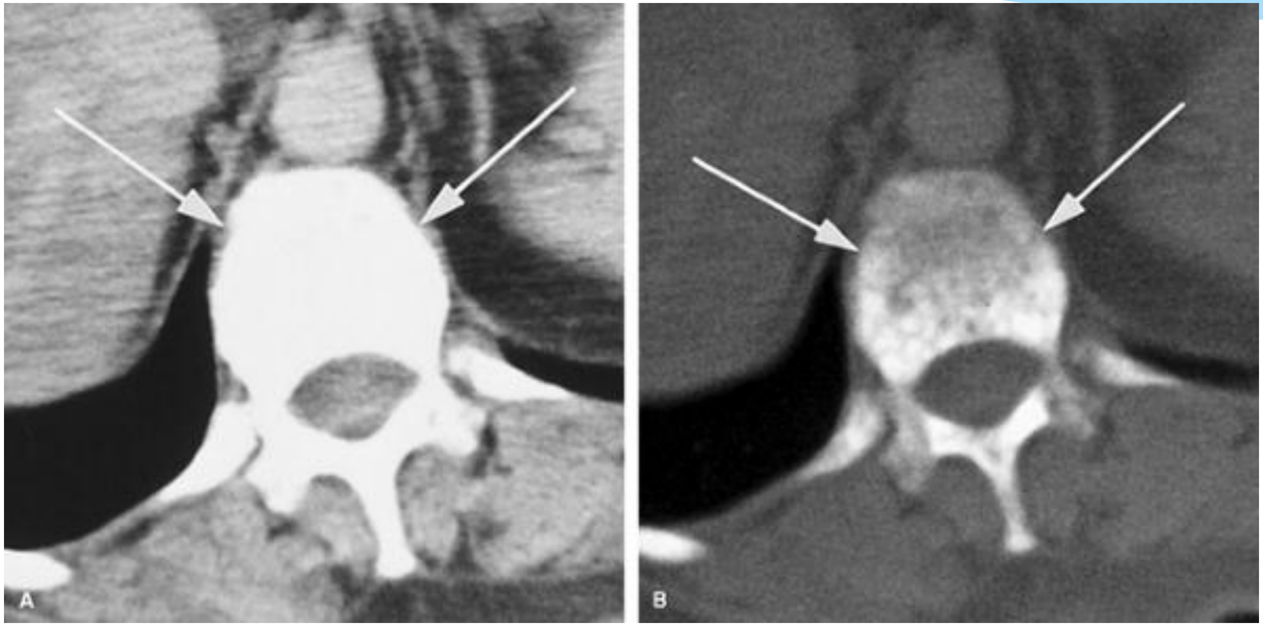
CROSS-SECTIONAL IMAGING TECHNIQUES

- **To produce an anatomic image, shades of gray are assigned to ranges of pixel values. For example, 16 shades of gray may be divided over a window width of 320 pixel values .**
- **Groups of 20 pixel values are each assigned one of the 16 gray shades.**
- **The middle gray shade is assigned to the pixel values centered on a selected window level.**
- **Pixels with values greater than the upper limit of the window width are displayed white, and pixels with values less than the lower limit of the window width are displayed black.**



Gray Scale. A CT image of the abdomen includes a gray scale along its left edge. Each individual pixel in the CT image is assigned a shade of gray, depending on its calculated CT number (H unit) and the window width and window level selected by the CT operator. Pure white (arrowhead) and pure black (arrow) are at the top and bottom of the gray scale. Along the right side of the CT image is a centimeter scale that can be used to measure the size of objects in the image. R indicates the patient's right side, and L indicates the patient's left side. Cross-sectional images in the transverse plane are routinely viewed from above below,and as if standing at the patient's feet. This orientation allows easy correlation with plain-film radiographs, which are routinely viewed as if facing the patient with the patient's right side to the viewer's left. This patient has an abscess (A) in the liver.

To analyze optimally all of the anatomic information of any particular slice, the image is viewed at different window-width and window-level settings, which are optimized for bone, air-filled lung, soft tissue, and so forth.



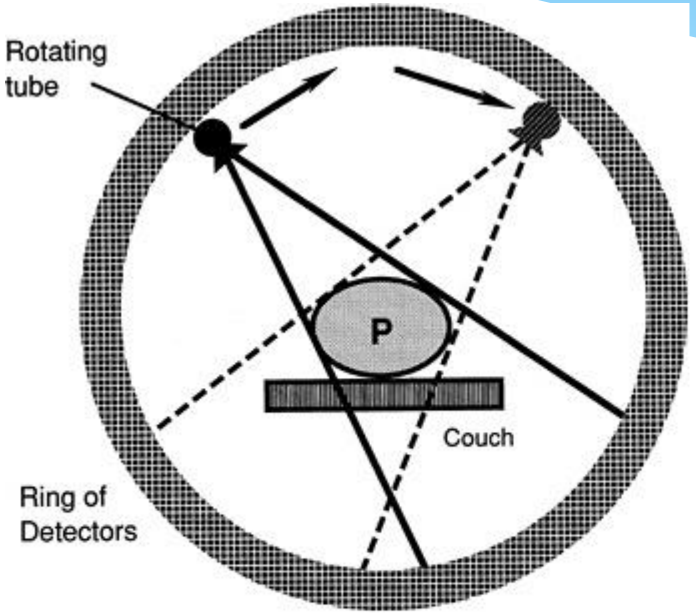
CT Windows. A. A CT image of the upper abdomen photographed with soft tissue window (window width = 482 H, window level = 14 H) portrays a thoracic vertebra (arrows) entirely white with no bone detail.
B. The same CT image re-photographed with bone window (window width = 2,000 H, window level = 400 H) demonstrates destructive changes in the vertebral body (arrows) owing to metastatic lung carcinoma.

- **The digital images obtained by CT, MR, and US examination are ideal for storage and access on PACS.**
- **Current PACSs allow a broad range of image manipulation during viewing and interpretation of images.**
- **Among the features that can be used are interactive alterations in window width and window level, magnification, fusing of images from different modalities, reformatting serial images in different anatomic planes, creation of three-dimensional reconstructions, and marking of key images that summarize major findings.**

Computed Tomography

* CT uses a computer to reconstruct mathematically a cross-sectional image of the body from measurements of x-ray transmission through thin slices of patient tissue.
* CT displays each imaged slice separately, without the superimposition of blurred structures that is seen with conventional tomography.
* A narrow, well-collimated beam of x-rays is generated on one side of the patient.
* The x-ray beam is attenuated by absorption and scatter as it passes through the patient.
* Sensitive detectors on the opposite side of the patient measure x-ray transmission through the slice.

Computed Tomography



Computed Tomography. Diagram of a CT scanner. The patient (P) is placed on an examination couch within the core of the CT unit. An x-ray tube rotates 360 °آaround the patient, producing pulses of radiation that pass through the patient. Transmitted x-rays are detected by a circumferential bank of radiation detectors. X-ray transmission data are sent to a computer, which uses an assigned algorithm to calculate the matrix of CT numbers used to produce the anatomic cross-sectional image. With the helical CT scan technique, the patient couch moves the patient continuously through the rotating x-ray beam. In MDCT, multiple image slices are obtained simultaneously as the patient is moved through the scanner.

Computed Tomography

- These measurements are systematically repeated many times from different directions while the x-ray tube is pulsed as it rotates 360 around the patient.
- CT numbers are assigned to each pixel in the image by a computer algorithm that uses as data thes measurements of transmitted x-rays.
- CT pixel numbers are proportional to the difference in average x-ray attenuation of the tissue within the voxel and that of water.

Computed Tomography

A Hounsfield unit (H) scale, named for Sir Godfrey N. Hounsfield, the inventor of CT, is used.

- Water is assigned a value of 0 H, with the scale extending from 1,024 H for air to +3,000 to 4,000 H for very dense bone.
- H units are not absolute values but, rather, are relative values that may vary from one CT system to another. In general, bone is +400 to +1,000 H, soft tissue is +40 to +80 H, fat is -60 to -100 H, lung tissue is -400 to -600 H, and air is -1,000 H.

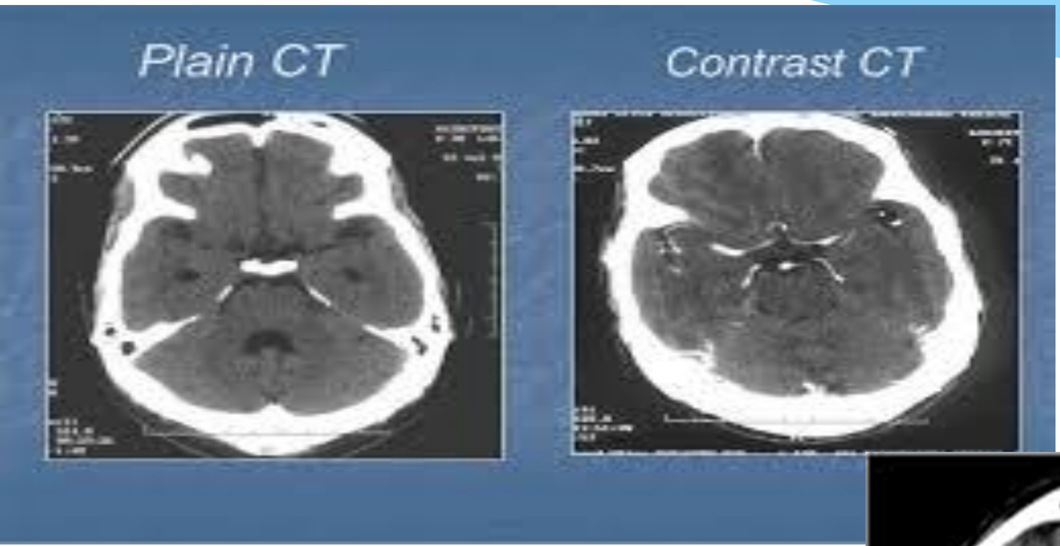
Computed Tomography

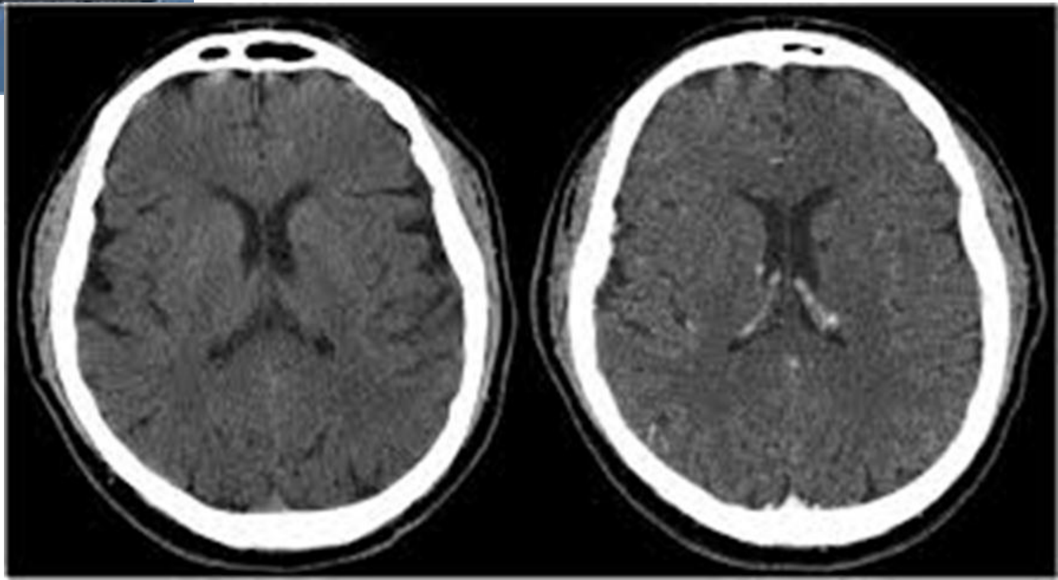
- Voxel dimensions are determined by the computer algorithm chosen for reconstruction and the thickness of the scanned slice.
- Most CT units allow slice thickness specifications between 0.5 and 10 mm.
- Data for an individual slice, 360° tube rotation, are routinely acquired in 1 s or less.
- The advantages of CT compared with MR include rapid scan acquisition, superior bone detail, and demonstration of calcifications.
- CT scanning is generally limited to the axial plane; however, images may be reformatted in sagittal, coronal, or oblique planes or as three-dimensional images.

Contrast Administration in CT

- **Intravenous iodine-based contrast agents are administered in CT to enhance density differences between lesions and surrounding parenchyma, to demonstrate vascular anatomy and vessel patency, and to characterize lesions by their patterns of contrast enhancement.**
- **Optimal use of intravenous contrast depends upon the anatomy, physiology, and pathology of the organ of interest.**
- **In the brain, the normal blood-brain barrier of tight neural capillary endothelial junctions prevents access of contrast into the neural extravascular space.**
- **Defects in the blood-brain barrier associated with tumors, stroke, infection, and other lesions enable contrast accumulation within abnormal tissue, improving its visibility.**
- **In non-neural tissues, the capillary endothelium has loose junctions, enabling free access of contrast into the extravascular space.**

CT BRAIN (PRE&POSTCONTRAST)





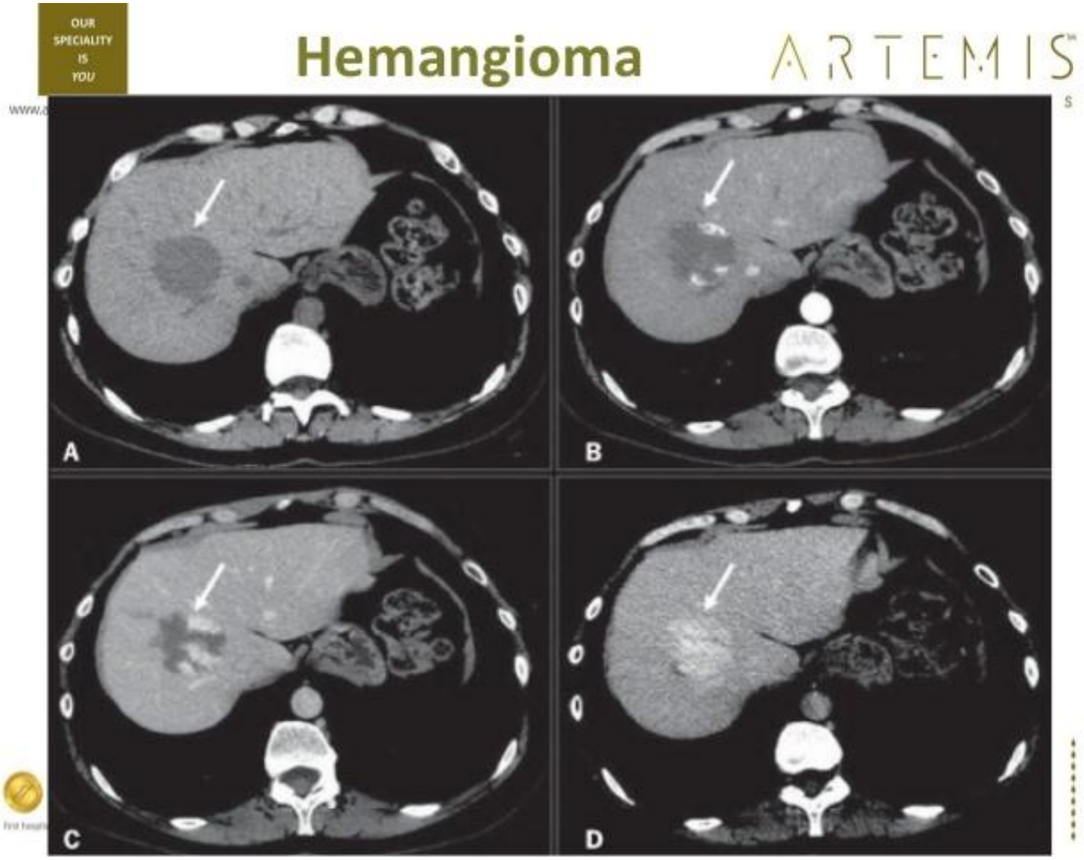
Contrast Administration in CT

- **Contrast administration and the timing of CT scanning must be carefully planned to optimize differences in enhancement patterns between lesions and normal tissues.**

Contrast Administration in CT

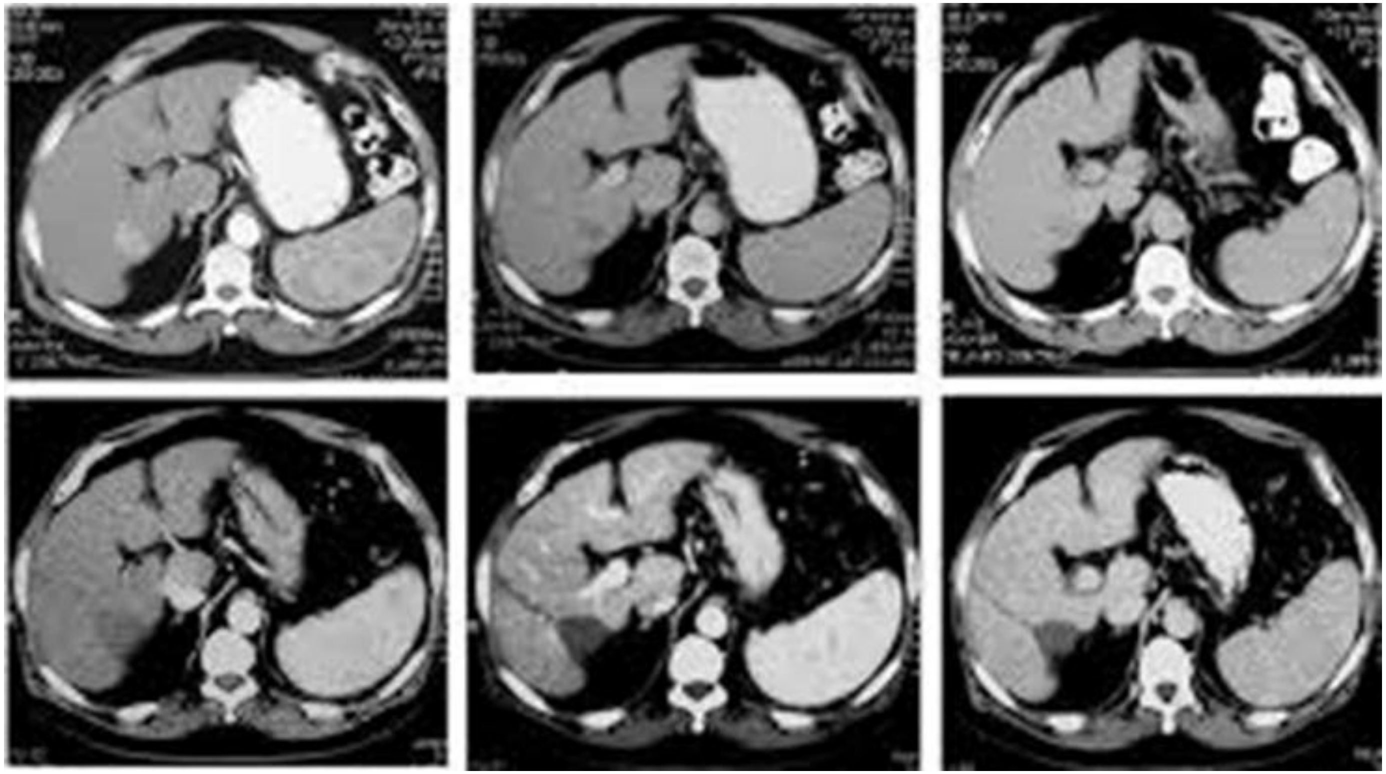
- For example, most liver tumors are supplied predominantly by the hepatic artery, whereas the liver parenchyma is supplied predominantly by the portal vein (about 70%), with a lesser contribution from the hepatic artery (about 30%).
- Contrast given by bolus injection into a peripheral arm vein will arrive earliest in the hepatic artery and enhance (that is, increase the CT density of) many tumors to a greater extent than the liver parenchyma.
- Maximal enhancement of the liver parenchyma is delayed 1 to 2 minutes until the contrast has circulated through the intestinal tract and returned to the liver via the portal vein.
- Differentiation of tumor and parenchyma by contrast enhancement can thus be maximized by administration of an IV bolus of contrast and by performing rapid CT scanning of the liver in the first 1 to 2 minutes following contrast administration.
- Helical CT is ideal for this early and rapid scanning of the liver.

Liver tumors



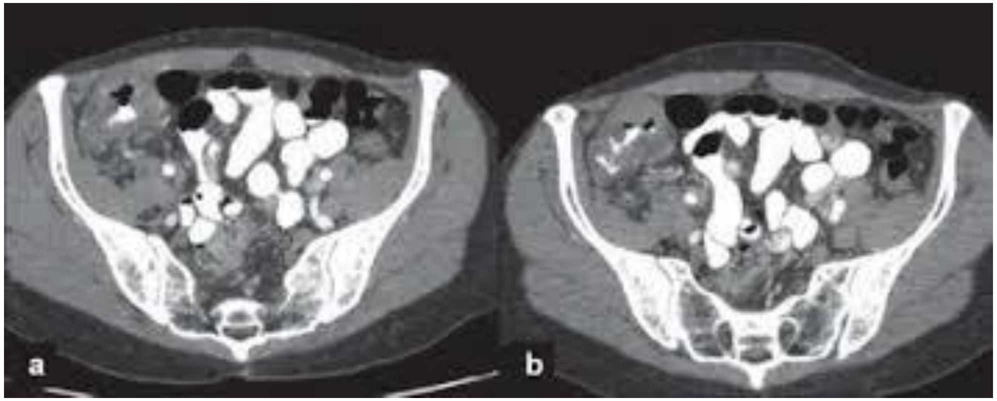
Liver tumors

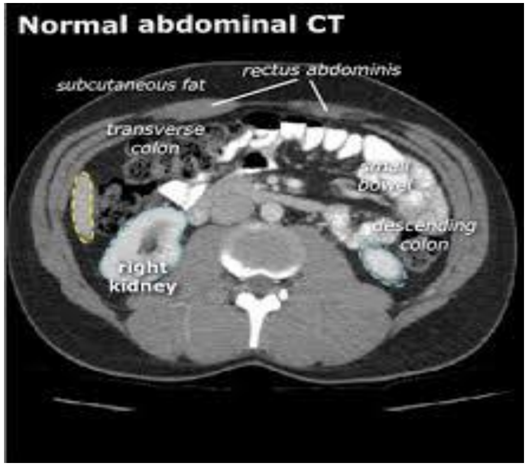
Hepatocelluar carcinoma



Contrast Administration in CT

- **Oral or rectal contrast is generally required to opacify the bowel for CT scans of the abdomen and pelvis.**
- **Bowel without intraluminal contrast may be difficult to differentiate from tumors, lymph nodes, and hematomas.**





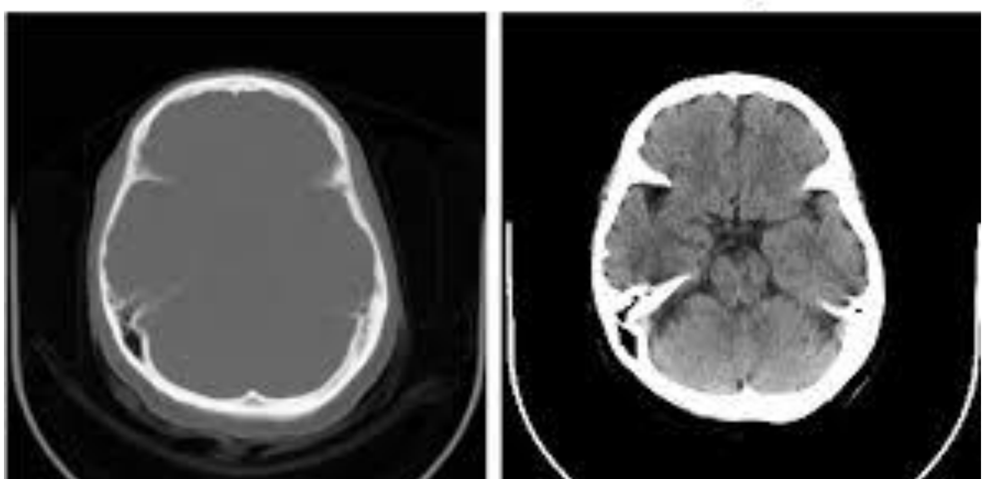
Principles of CT Interpretation

- Like all imaging analysis, CT interpretation is based on an organized and comprehensive approach. CT images are viewed in sequential anatomic order, with each slice examined with reference to slices above and below.
- The radiologist must seek to develop a three-dimensional concept of the anatomy and pathology displayed. The study must be interpreted with reference to the scan parameters, slice thickness and spacing, administration of contrast, and artifacts.
- Images are oriented so that the observer is looking at the patient from below. The patient's right side is oriented on the left side of the image.

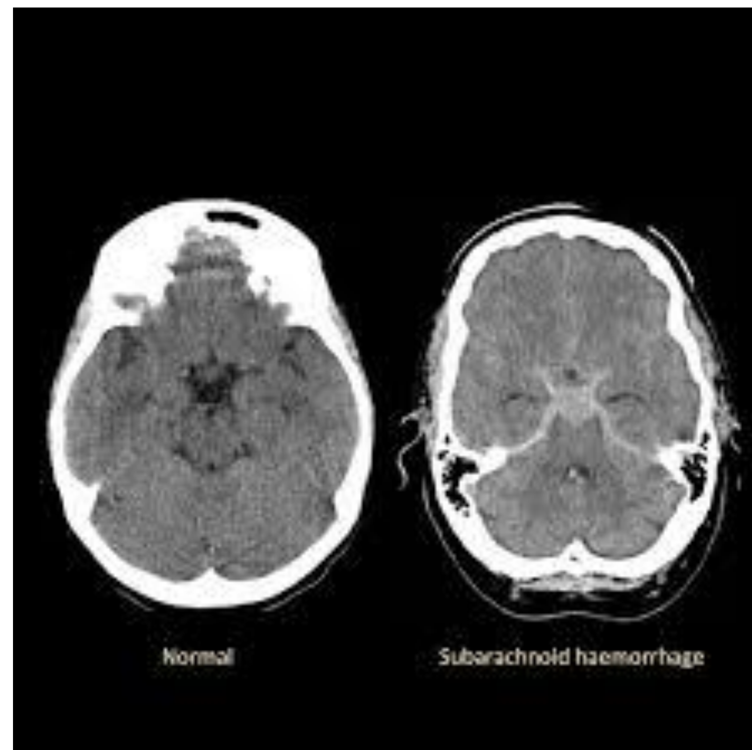
Principles of CT Interpretation

- Optimal bone detail is viewed at the bone window , generally a window width of 2,000 H and a window level of 400 to 600 H.
- Lungs are viewed at lung windows, with a window width of 1,000 to 2,000 H and window levels of about 500 to 600 H.
- Soft tissues are examined at a window width of 400 to 500 H and window level 20 to 40 H.
- Narrow windows (width of 100 to 150 H, level of 70 to 80 H) increase image contrast and aid in the detection of subtle liver and spleen lesions.
- PACS workstation viewing allows the interpreter to actively change window width and level settings to optimize visualization of anatomic structures.

CT BRAIN (BONE&BRAIN window)



(a) (b)



CT CHEST (lung & mediastinal windows)

CT angiogram

CT Angiogram. A three-dimensional, shaded surface display, angiogram image of the aorta and its branches was created from a series of axial plane MDCT images obtained during rapid bolus IV contrast agent administration. Contrast enhancement greatly increases the CT numbers of the arteries and kidneys and allows removal of structures with lower CT density from the image .Only pixels with CT numbers higher than a specified threshold value are displayed. Computer algorithms create a three-dimensional image from data provided by many overlapping axial slices. The three-dimensional image can be rotated and viewed from any desired angle. â€œShading,â€ simulating light cast from a remote light source, enhances the three-dimensional visual effect.

CT Artifacts

Artifacts

- Are components of the image that do not faithfully reproduce actual anatomic structures because of distortion, addition, or deletion of information.

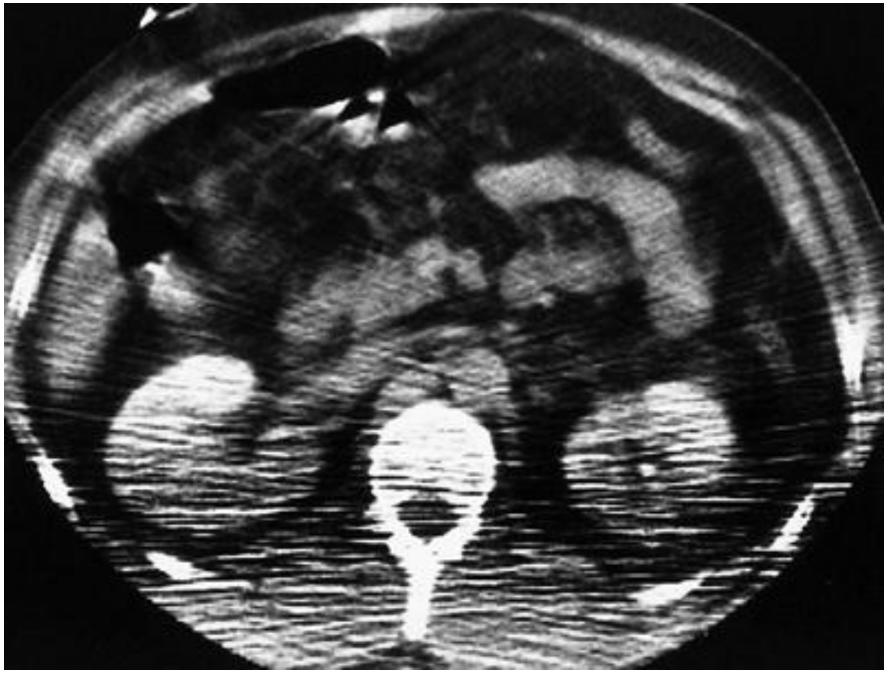
- Artifacts degrade the image and may cause errors in diagnosis .

- **Volume averaging** is present in every CT image and must always be considered in image interpretation.
- ✓ The displayed two-dimensional image is created from data obtained and averaged from a three-dimensional volume of patient tissue.
- ✓ Slices above and below the image that is being interpreted must be examined for sources of volume averaging that may be misinterpreted as pathology.

CT Artifacts

- **A beam-hardening** artifact results from greater attenuation of low-energy x-ray photons than high-energy x-ray photons as they pass through tissue.
- ✓ The mean energy of the x-ray beam is increased, resulting in less attenuation at the end of the beam than at its beginning.
- ✓ Beam-hardening errors are seen as areas or streaks of low density extending from structures of high x-ray attenuation, such as the petrous bones, shoulders, and hips.

CT Artifacts

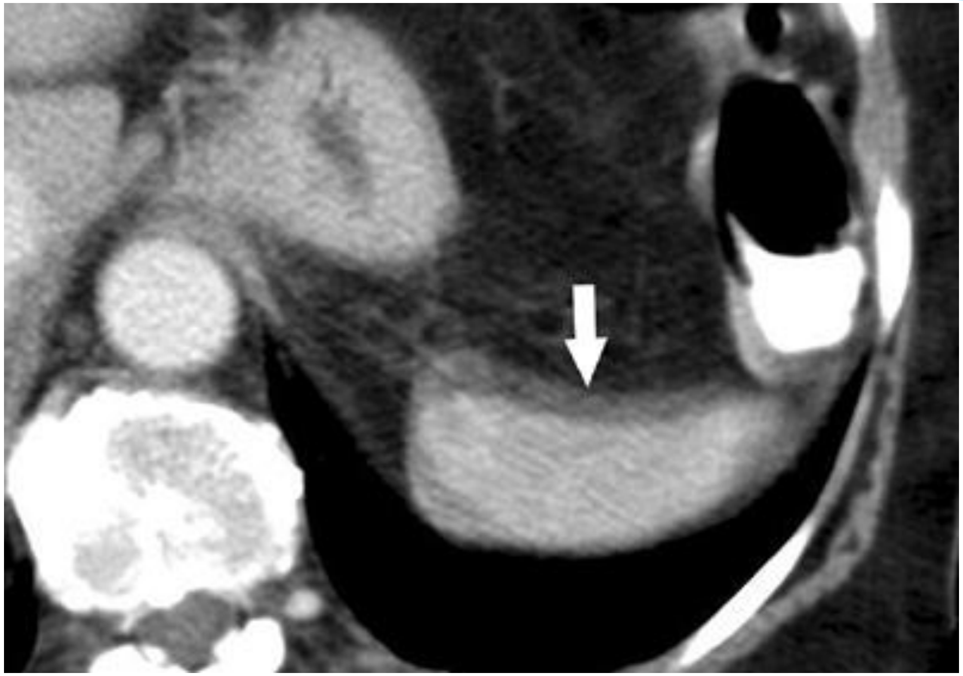


Beam-Hardening Artifact: A CT image of the abdomen is severely degraded by a beam-hardening artifact that produces dark streaks across the lower half of the image. The artifact was caused by marked attenuation of the x-ray beam by the patient's arms, which were kept at his sides owing to injury.

CT Artifacts

- **A motion artifact** results when structures move to different positions during image acquisition.
- ✓ Motion occurs as a result of voluntary or involuntary patient movement, breathing, heartbeat, vessel pulsation, or peristalsis.
- ✓ Motion is demonstrated in the image as prominent streaks from high- to low-density interfaces or as blurred or duplicated images.

CT Artifacts

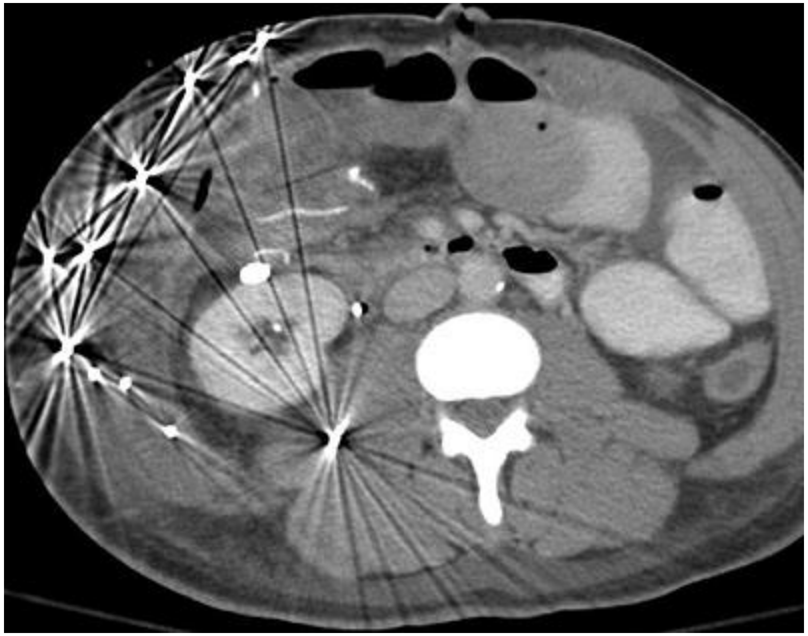


Motion Artifact. **Breathing motion during image acquisition duplicates the margin (arrow) of the spleen, simulating a subcapsular hematoma in this patient, who was imaged because of abdominal trauma.**

CT Artifacts

- **Streak artifacts** emanate from high-density sharp-edged objects, such as vascular clips and dental fillings.
- Reconstruction algorithms cannot handle the extreme differences in x-ray attenuation between very dense objects and adjacent tissue.

CT Artifacts



Streak Artifact. Shotgun pellets produce a severe streak artifact on this CT image.

THANK YOU