Introduction to Radiology

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It’s always exciting when a class starts out with a surprise quiz.


SUPINE
Compress


ERECT

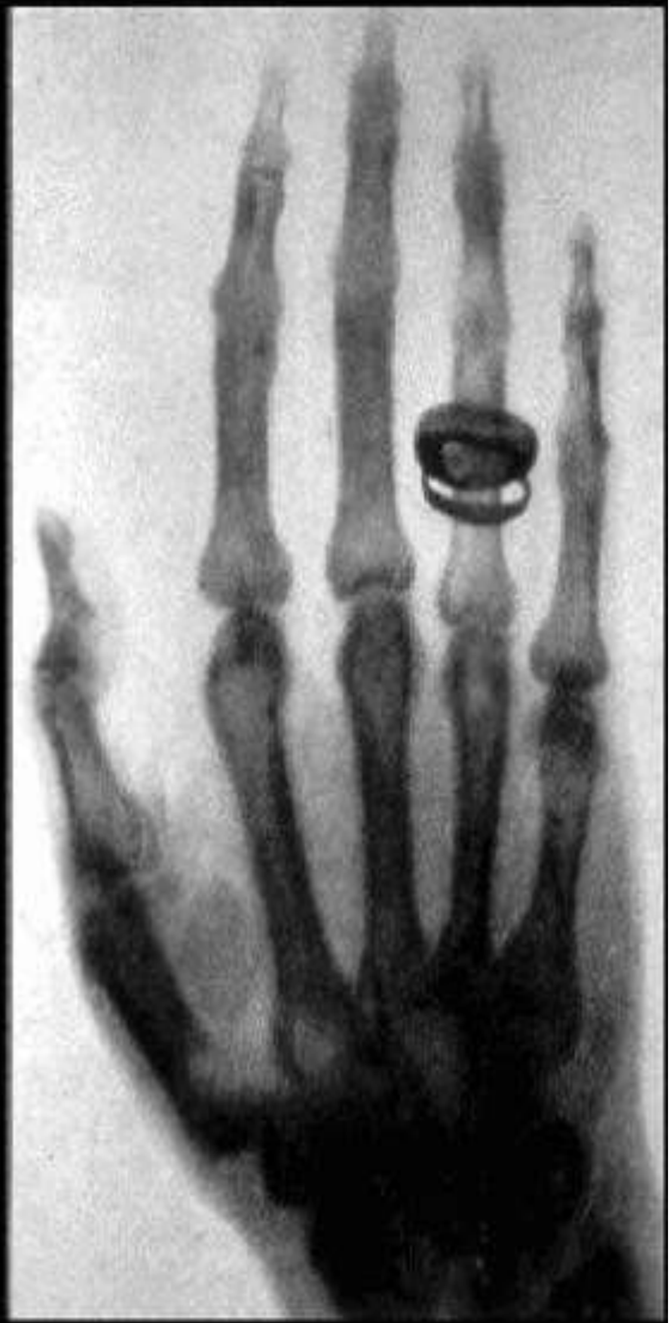

Sagittal right kidney


MK

From darkenss…. to light

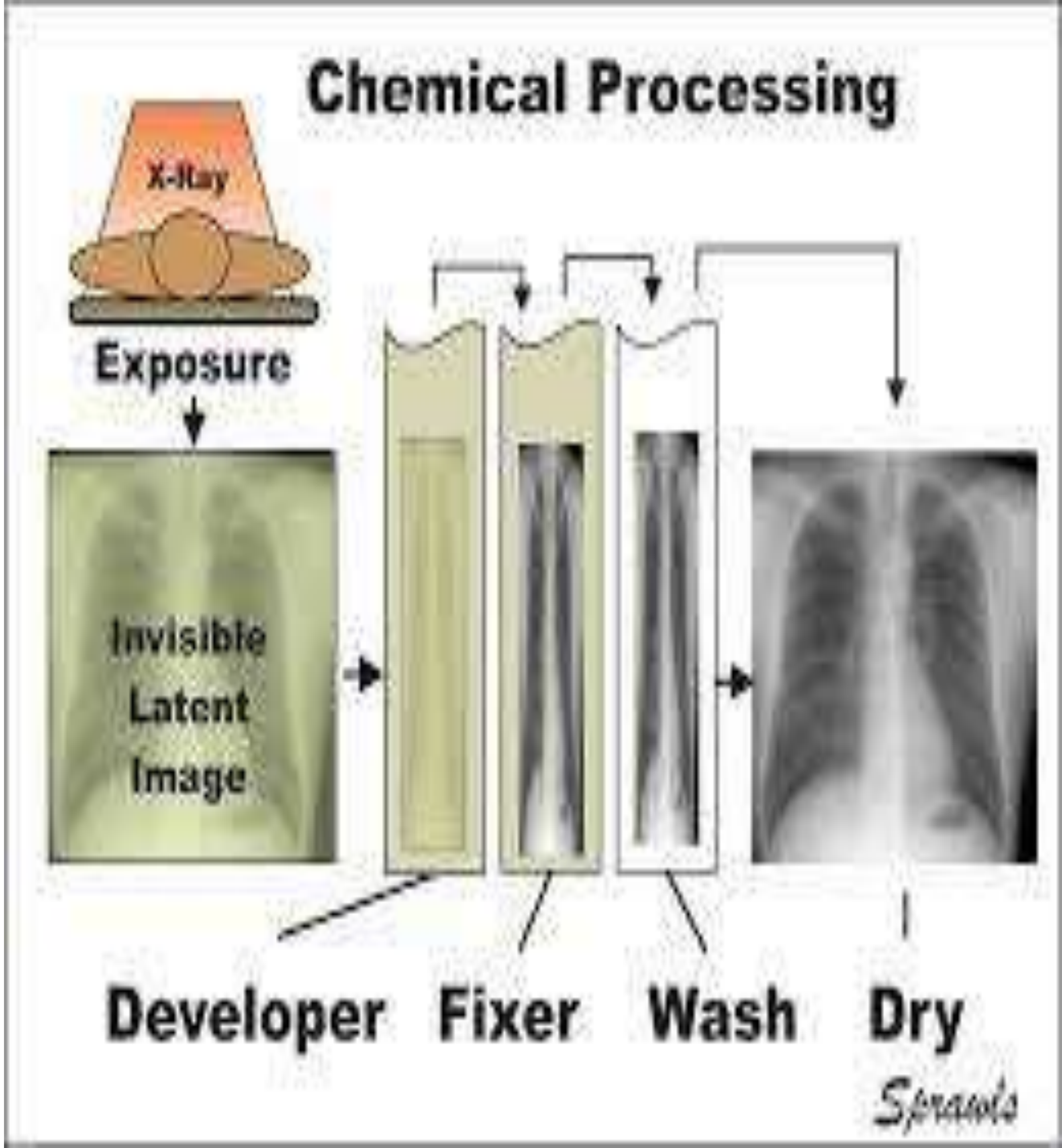
First Image.

- In 1895, Wilihelm Röntgen (or Roentgen), working in a darkened laboratory in Würzburg, Germany, noticed that a screen painted with a fluorescent material in the same room, but a few feet from a cathode ray tube he had energized and made lightproof, started to glow (fluoresce).



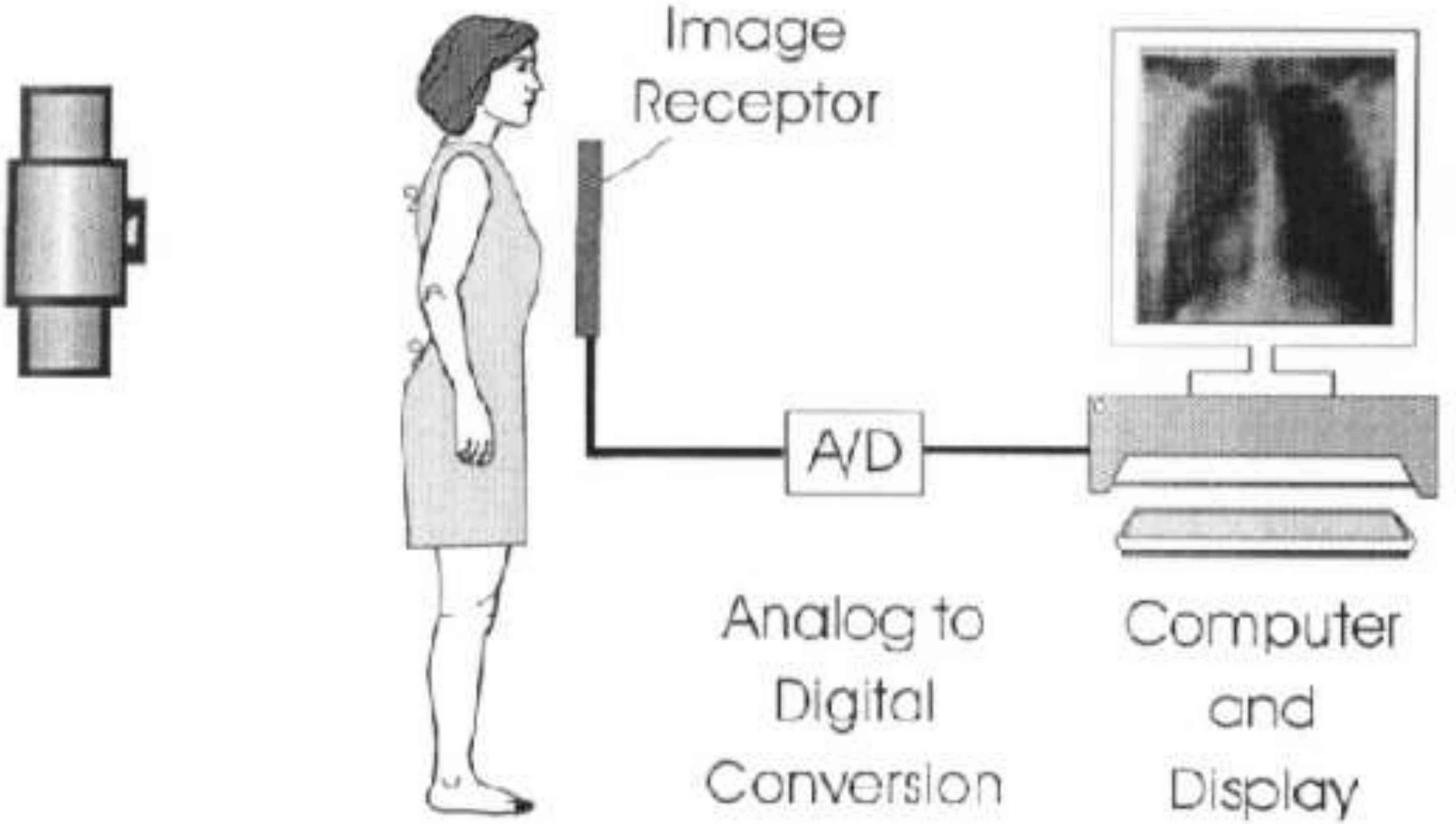
- For about 100 years after that, radiographic images survived their brief birth as a burst of ionizing radiation nestled comfortably on a piece of film. In some places, film is the medium still used, but it’s much less common.

- Today, like in 1895, conventional radiographic images (usually shortened to x-rays) are produced by a combination of ionizing radiation and light striking a photosensitive surface, which, in turn, produces a latent image that is subsequently processed. At first, the processing of film was carried out in a darkroom containing trays with various chemicals; the films were then, literally, hung out and then up to dry



eFIGURE 1-1 Film file room. When medical images were stored on film, they occupied a tremendous amount of space at each facility. This is one aisle containing several thousand patient films among many dozens of similar aisles in a cavernous room that was needed to store all of the images. Today, all of these images can be stored in the space of computer servers and are viewable, with permission, from any location.

Digital radiography came into being



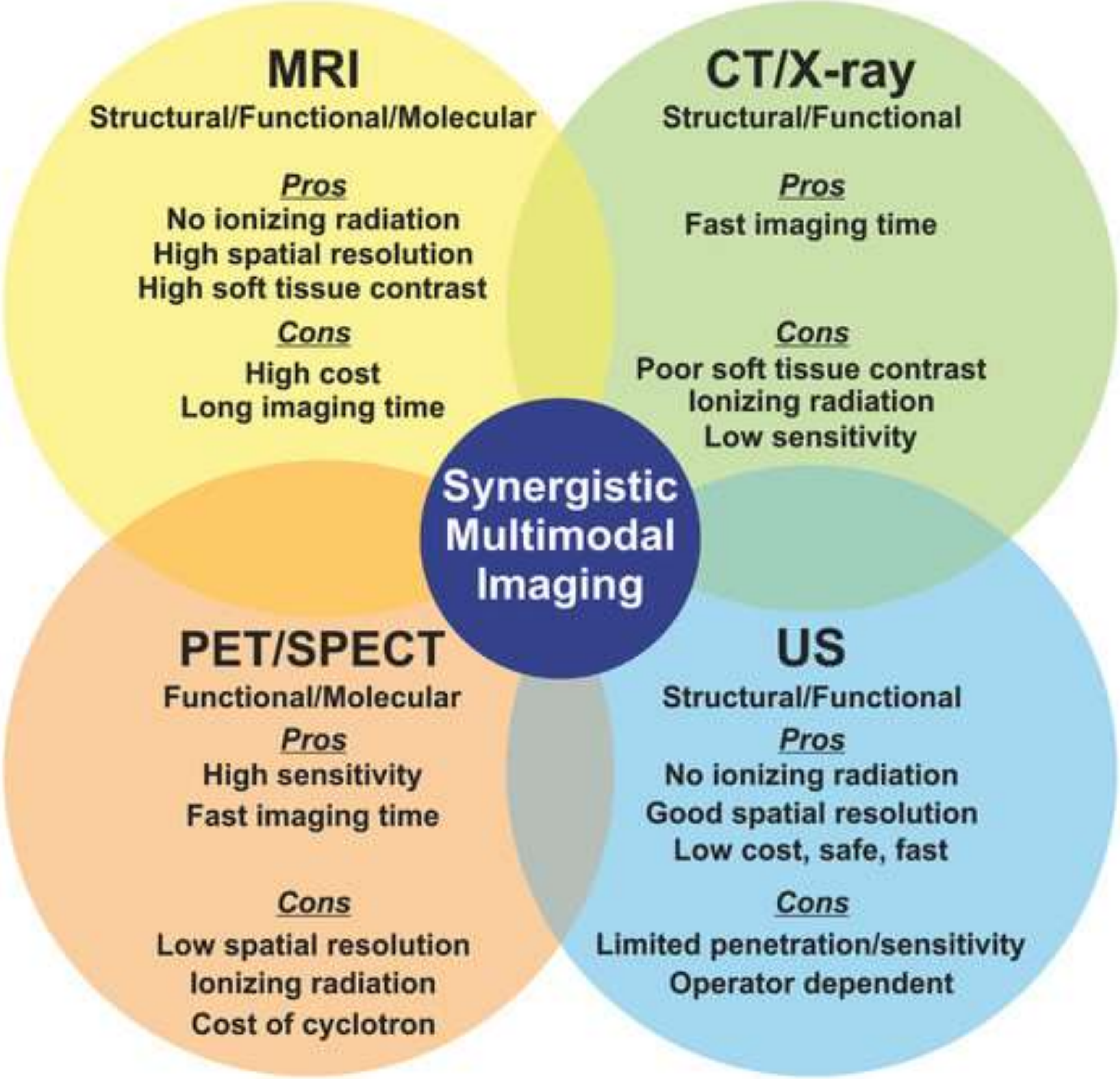
PACS

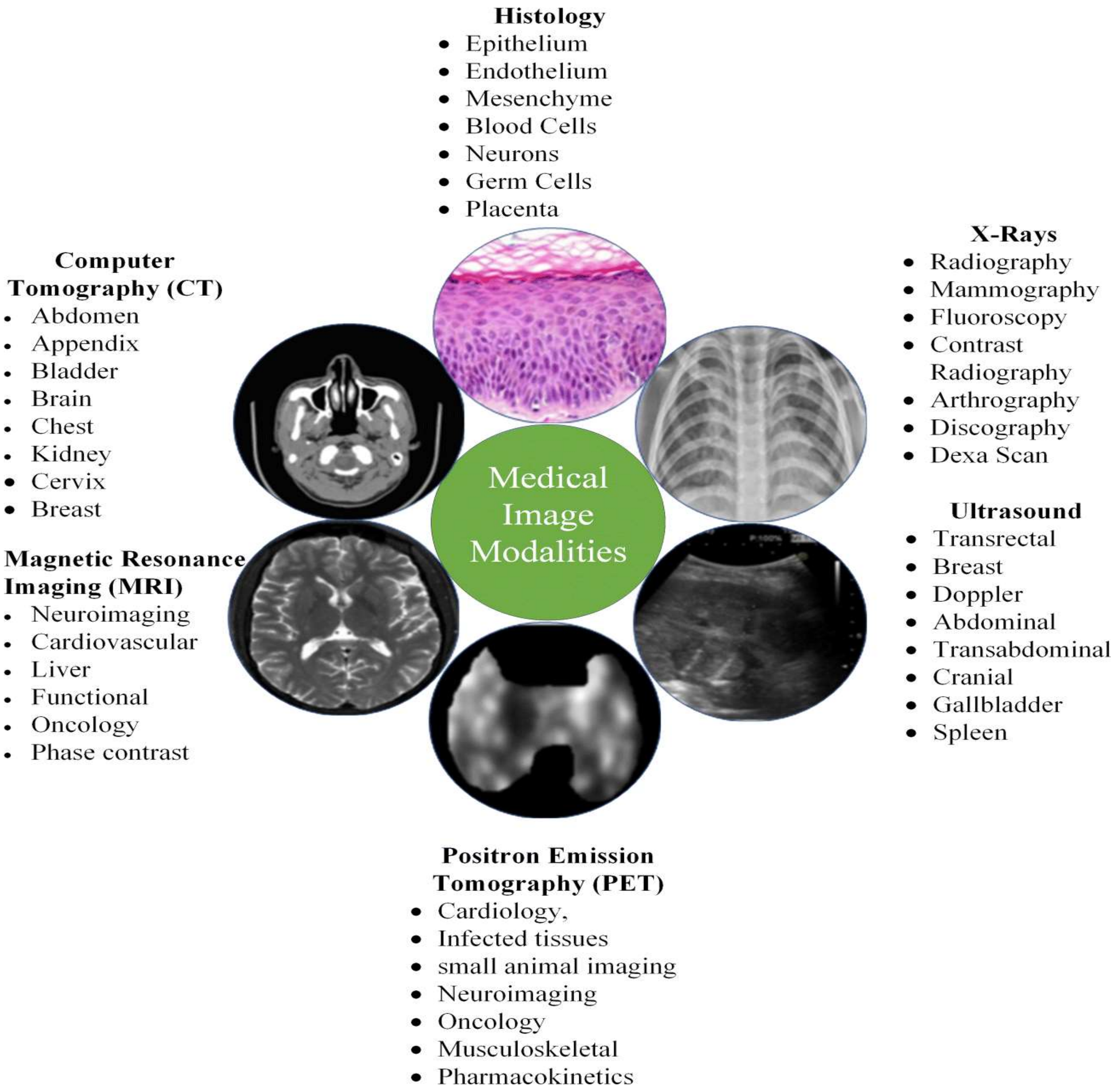
- The images were maintained on computer servers, where they could be stored and archived for posterity and from which they could be communicated to others. This system is referred to as PACS, which stands for picture archiving, communications, and storage.

- Using PACS systems, images created using all modalities can be stored and retrieved. Conventional radiography, computed tomography (CT), ultrasonography, magnetic resonance imaging (MRI), fluoroscopy, and nuclear medicine are examples of images that can be stored in this way.

- Radiology is medical specialty using medical imaging technologies to diagnose and treat the patient.

- Medical imaging: Is non-invasive visualization of internal organs.
    - Requires recognition of NORMAL anatomy.
    - It’s primary purpose is to identify pathologic conditions.

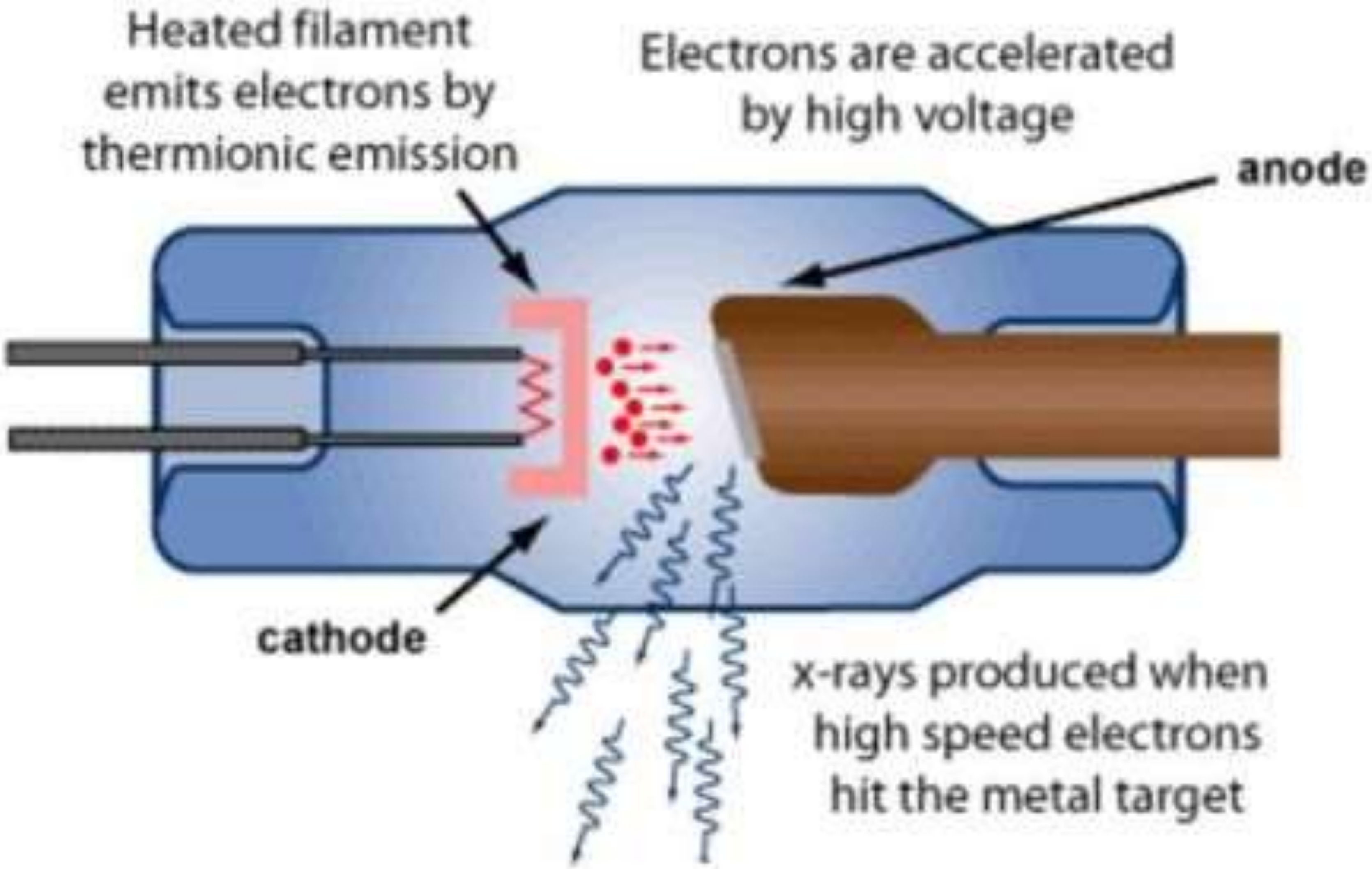

MRI
Structural/Functional/Molecular
Pros
No ionizing radiation
High spatial resolution
High soft tissue contrast
Cons
High cost
Long imaging time
CT/X-ray
Structural/Functional
Pros
Fast imaging time
Cons
Poor soft tissue contrast
Ionizing radiation
Low sensitivity
Synergistic Multimodal Imaging
PET/SPECT
Functional/Molecular
Pros
High sensitivity
Fast imaging time
Cons
Low spatial resolution
Ionizing radiation
Cost of cyclotron
US
Structural/Functional
Pros
No ionizing radiation
Good spatial resolution
Low cost, safe, fast
Cons
Limited penetration/sensitivity
Operator dependent


Histology
Epithelium
Endothelium
Mesenchyme
Blood Cells
Neurons
Germ Cells
Placenta
X-Rays
Radiography
Mammography
Fluoroscopy
Contrast Radiography
Arthrography
Discography
Dexa Scan
Computer Tomography (CT)
Abdomen
Appendix
Bladder
Brain
Chest
Kidney
Cervix
Breast
Medical Image Modalities
Ultrasound
Transrectal
Breast
Doppler
Abdominal
Transabdominal
Cranial
Gallbladder
Spleen
Magnetic Resonance Imaging (MRI)
Neuroimaging
Cardiovascular
Liver
Functional
Oncology
Phase contrast
Positron Emission Tomography (PET)
Cardiology,
Infected tissues
small animal imaging
Neuroimaging
Oncology
Musculoskeletal
Pharmacokinetics

CONVENTIONAL RADIOGRAPHY

- Images produced through the use of ionizing radiation.
- Advantage: Relatively inexpensive, can be obtained almost anywhere by using portable or mobile machines, and are still the most widely obtained imaging studies.
- They require a source to produce the x-rays (the “x-ray machine”), a method to record the image (a film, cassette, or photosensitive plate), and a way to process the recorded image (using either chemicals or a digital reader).

Typical X-ray tube operation



- Common uses for conventional radiography include the ubiquitous chest x-ray, plain films of the abdomen, and virtually every initial image of the skeletal system to evaluate for fractures or arthritis.
- The major disadvantages of conventional radiography are the limited range of densities it can demonstrate and that it uses ionizing radiation.

The five basic densities

TABLE 1-1 FIVE BASIC DENSITIES SEEN ON CONVENTIONAL RADIOGRAPHY

Density	Appearance
Air	Absorbs the least x-ray and appears "blackest" on conventional radiographs
Fat	Gray, somewhat darker (blacker) than soft tissue
Fluid or soft tissue	Both fluid (e.g., blood) and soft tissue (e.g., muscle) have the same densities on conventional radiographs
Calcium	The most dense, naturally occurring material (e.g., bones); absorbs most x-rays
Metal	Usually absorbs all x-rays and appears the "whitest" (e.g., bullets, barium)

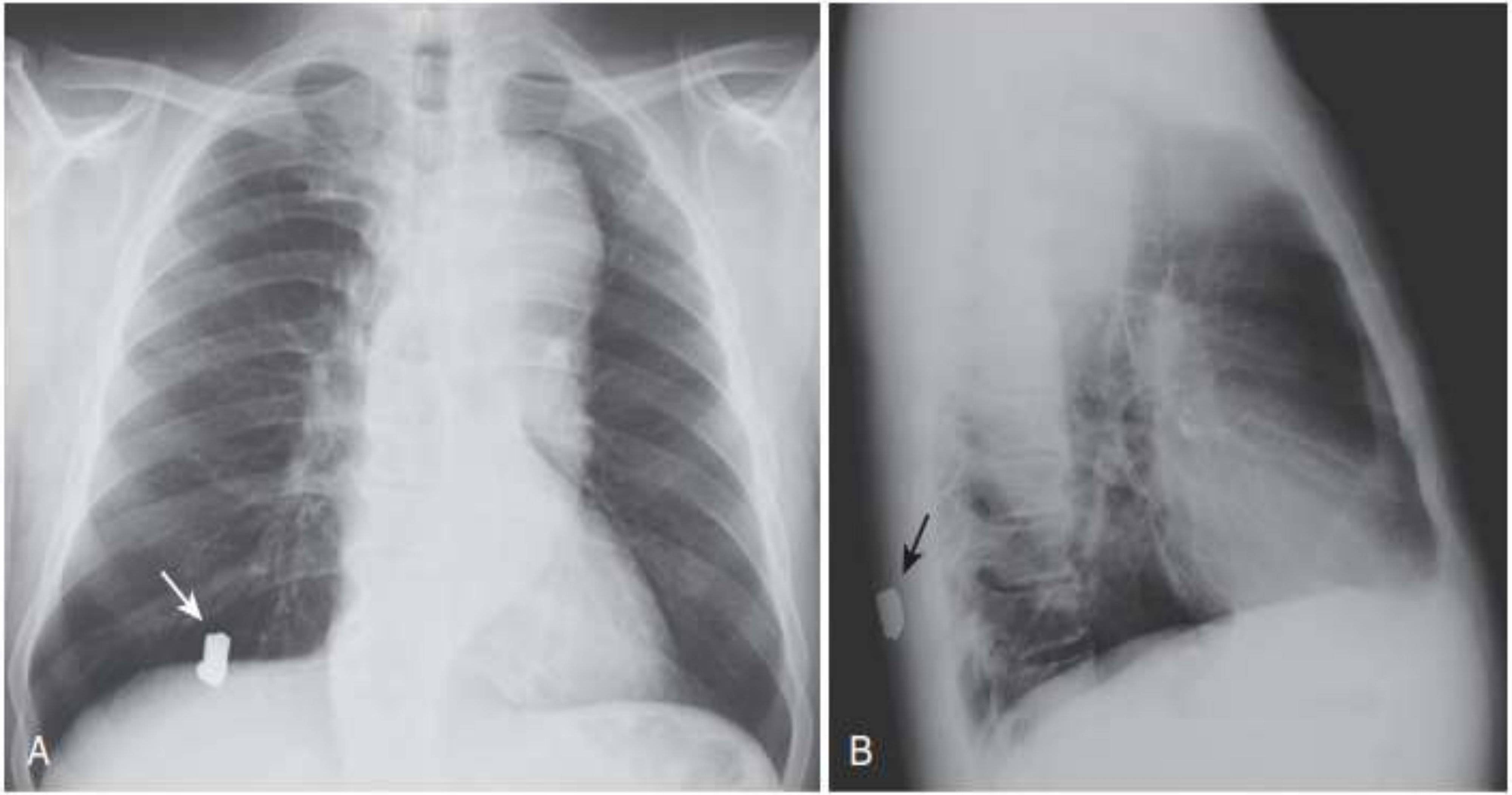


FIGURE 1-7 **Bullet in the chest. A,** The dense (white) metallic foreign body overlying the right lower lung field (*white arrow*) is a bullet. It is much denser (whiter) than the bones (calcium density), represented by the ribs, clavicles, and spine. Fluid (such as the blood in the heart) and soft-tissue density (such as the muscle of the heart) have the same density, which is why we cannot differentiate the two using conventional radiography. The air in the lungs is the least dense (blackest). **B,** Two views at 90° angles to each other, such as these frontal and lateral chest radiographs, are called ***orthogonal*** views. With only one view, it would be impossible to know the location of the bullet. On the lateral view, the bullet can be seen lying in the soft tissues of the back (*black arrow*). Orthogonal views are used throughout conventional radiography to localize structures in all parts of the body.

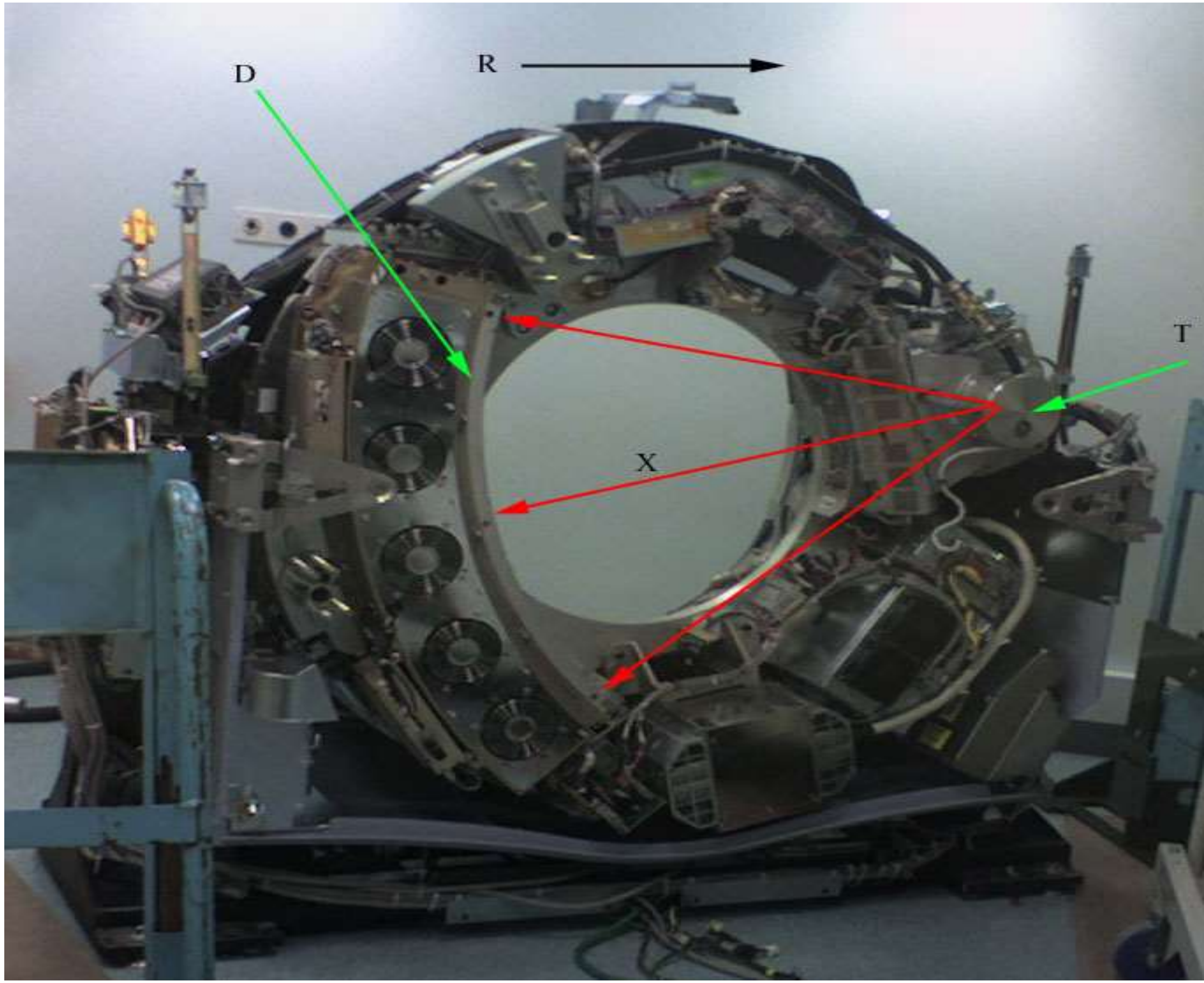
- Radiation has the potential to produce cell mutations, which could lead to many forms of cancer or anomalies.

- Only medically necessary diagnostic examinations should be performed.

- Imaging using x-rays should be avoided during potentially teratogenic times, such as pregnancy.

Computerized Tomography

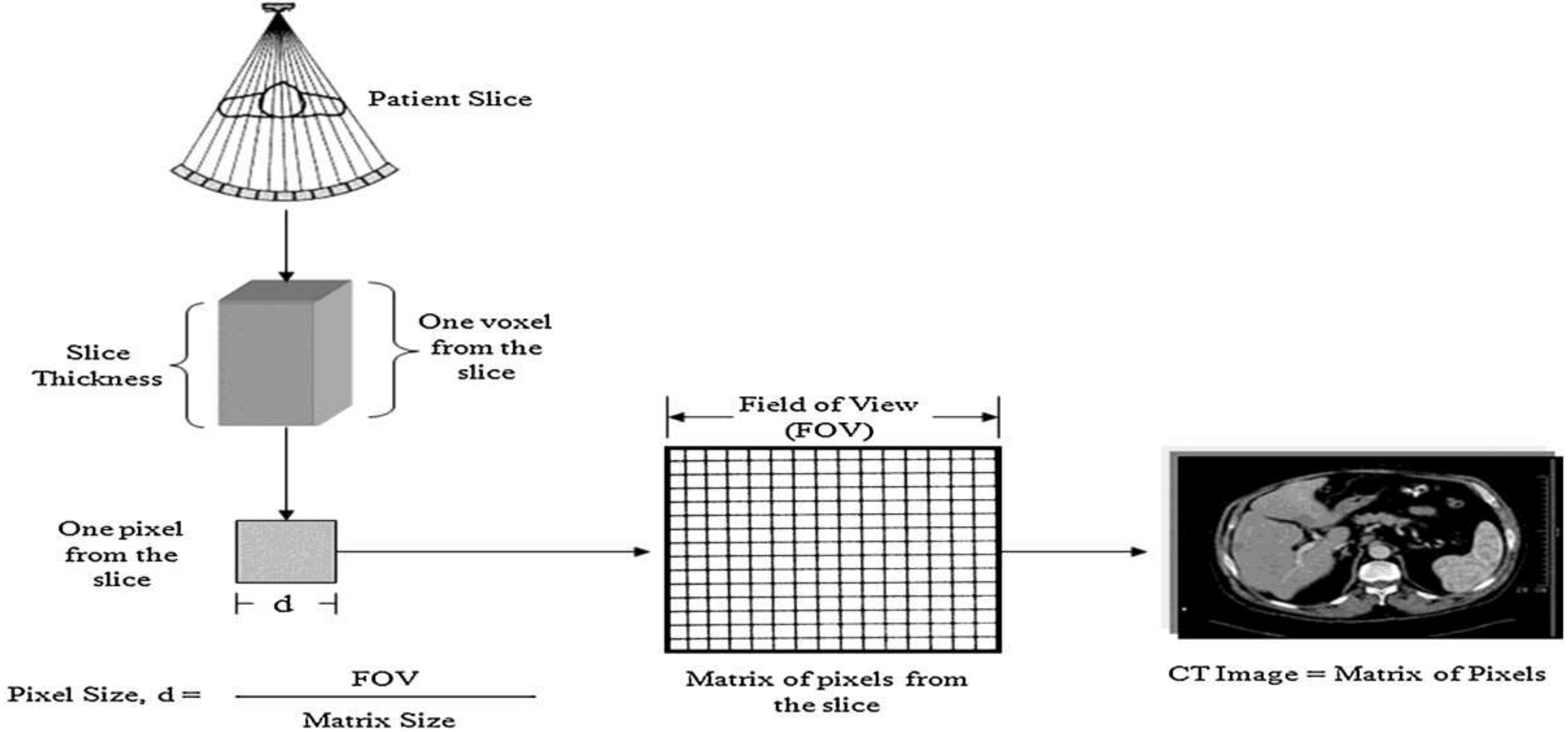
- CT (or "CAT") scanners, first introduced in the 1970s.
- Using a gantry with a rotating x-ray beam.



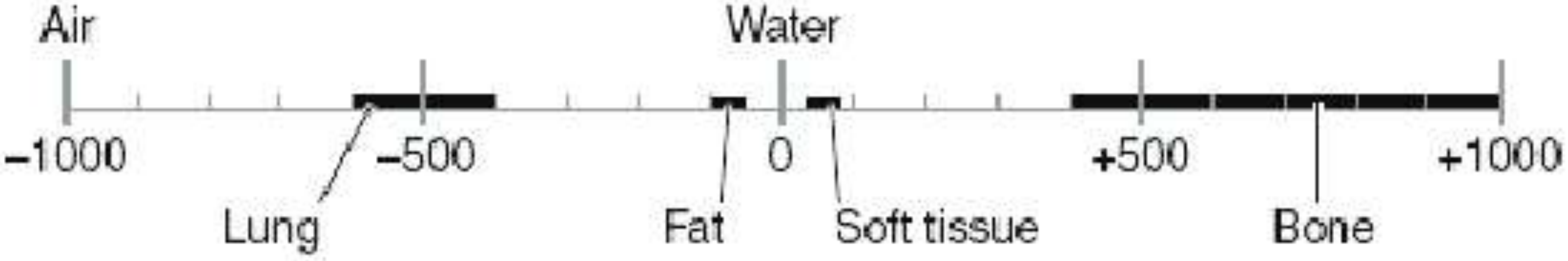

THE BEATLES


OF EMI

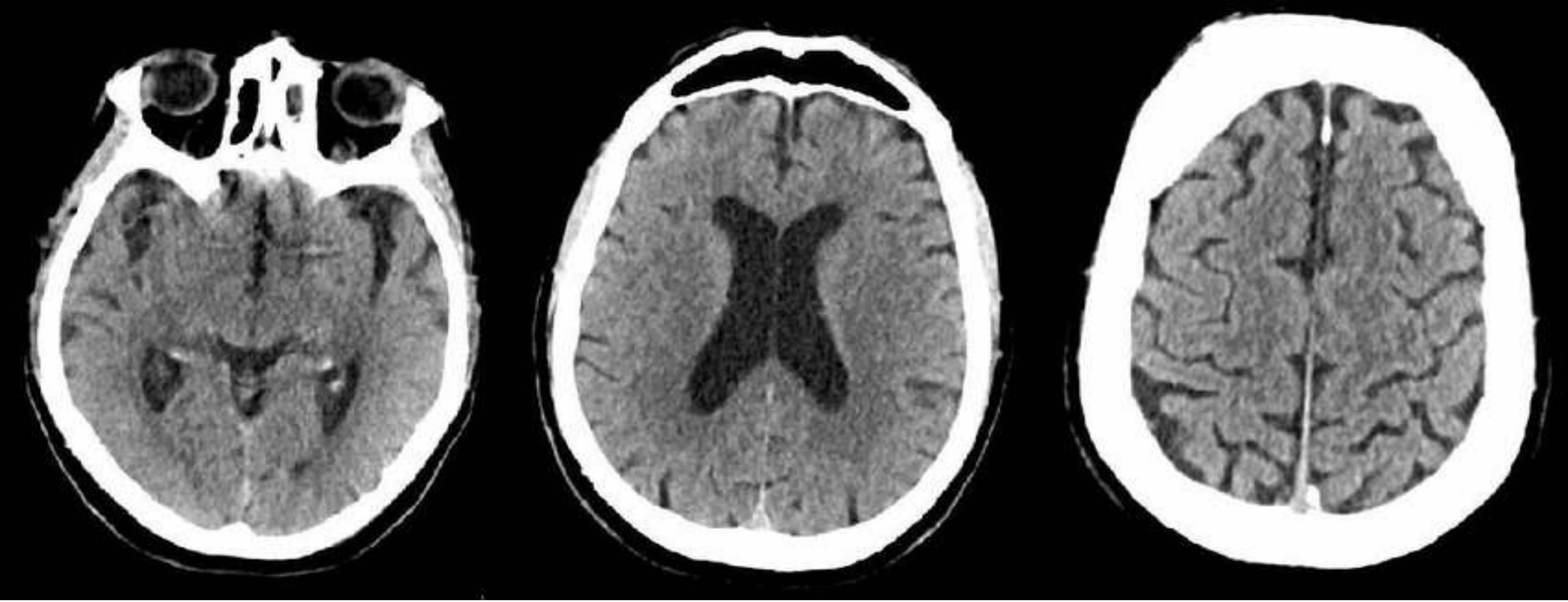
- A CT image is composed of a matrix of thousands of tiny squares called pixels, each of which is computer-assigned a CT number from −1000 to +1000 measured in Hounsfield units (HUs).



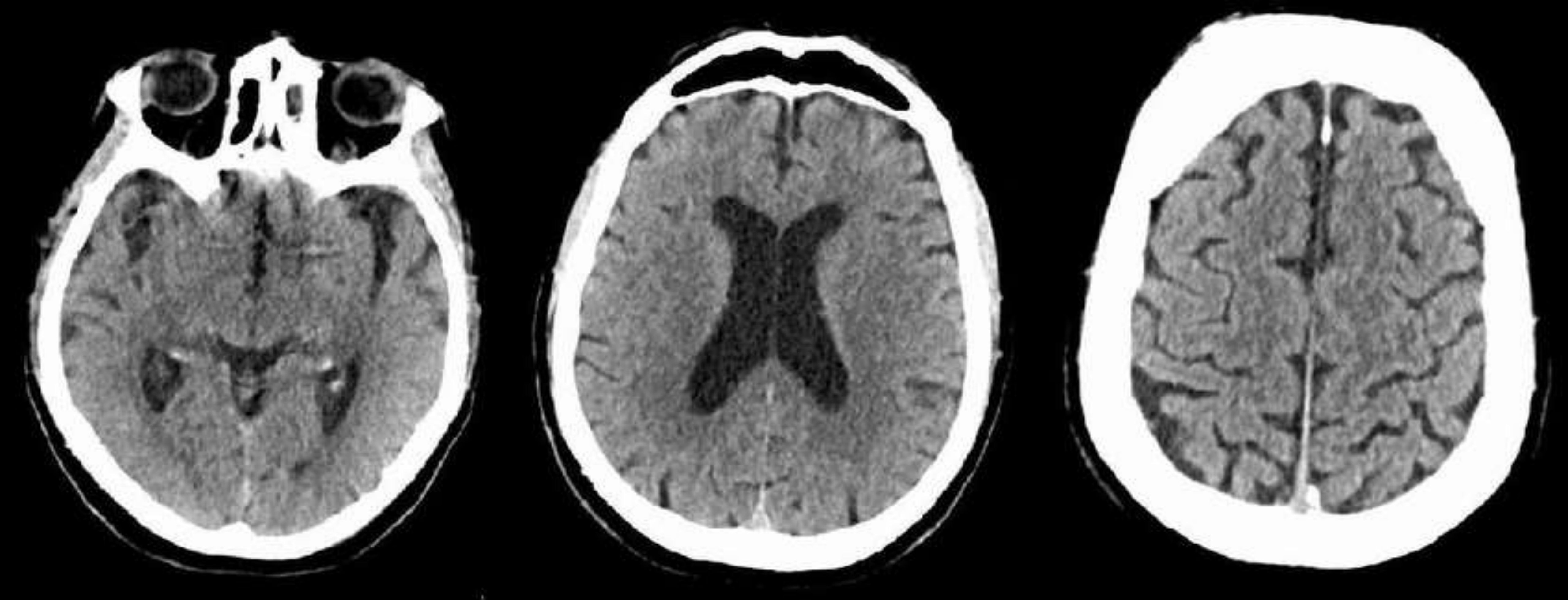
• The CT number will vary according to the density of the tissue scanned.



Bone	+400 → +1000
Soft tissue	+40 → +80
Water	0
Fat	–60 → –100
Lung	–400 → –600
Air	–1000



Denser substances that absorb more x-rays have high CT numbers, are said to demonstrate increased attenuation, and are displayed as whiter densities on CT scans.



Less dense substances that absorb fewer x-rays have low CT numbers, are said to demonstrate decreased attenuation, and are displayed as blacker densities on CT scans.

Postprocessing allows for additional manipulation of the raw data to best demonstrate the abnormality without repeating a study and without reexposing the patient to radiation

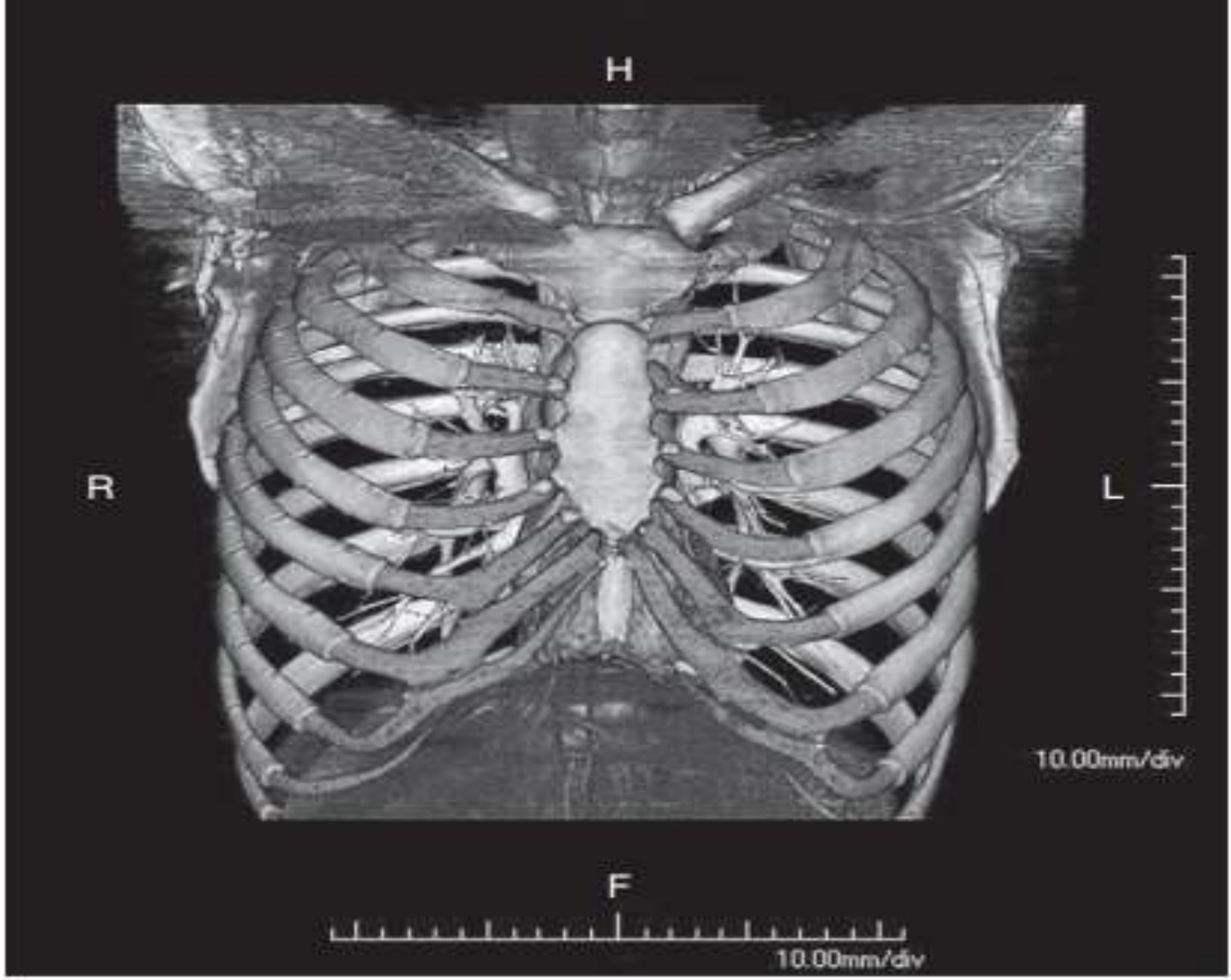
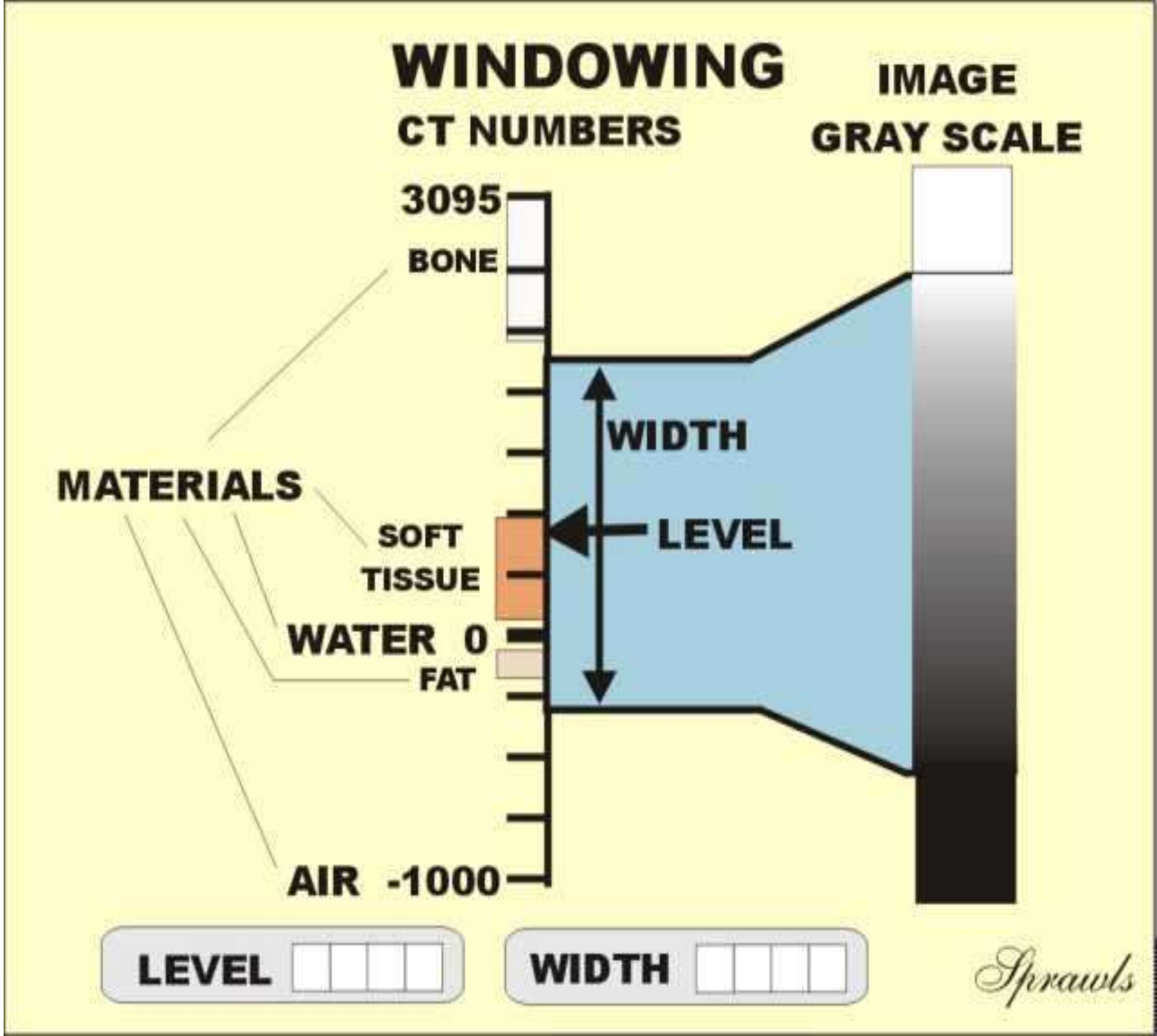


FIGURE 1-9 Three-dimensional computed tomography rendering of normal rib cage. This grayscale version (color online) of a three-dimensional surface rendering of the rib cage is made possible by the acquisition of multiple, thin computed tomographic sections through the body. These sections can then be reconstructed to demonstrate surface anatomy, as in this illustration. The same data set could have been manipulated to show the heart or lungs (which are digitally removed here) and not the rib cage. Such renderings are especially helpful in demonstrating the exact anatomic relationships of structures, especially for surgical planning. *F,* Foot; *L,* left; *H,* head; *R,* right.

- CT images are displayed or viewed using a range of Hounsfield numbers preselected to best demonstrate the tissues being studied (e.g., from −100 to +300).
- Anything within that range of CT numbers is displayed over the levels of density in the available gray scale.



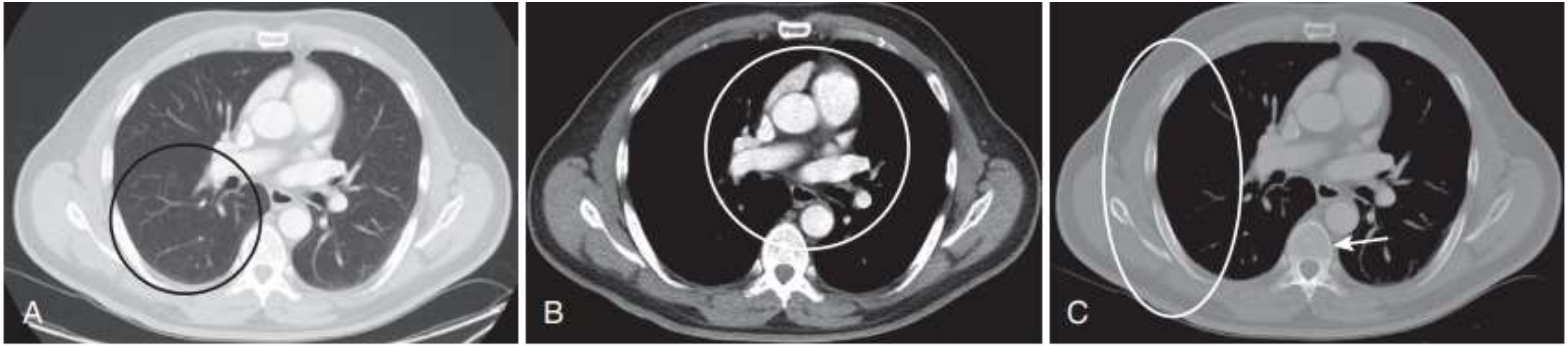


FIGURE 1-8 Windowing the thorax. Chest computed tomography scans are usually "windowed" and displayed in several formats to optimize anatomical definition. **A,** Lung windows are chosen to maximize the ability to image abnormalities of the lung parenchyma and to identify normal and abnormal bronchial anatomy *(black circle)*. **B,** Mediastinal windows are chosen to display the mediastinal, hilar, and pleural structures to best advantage *(white circle)*. **C,** Bone windows are utilized as a third way of displaying the data to visualize the bony structures to their best advantage *(white oval and arrow)*. It is important to recognize that the displays of these different windows are manipulations of the data obtained during the original scan and do not require rescanning the patient.

Ultrasonography

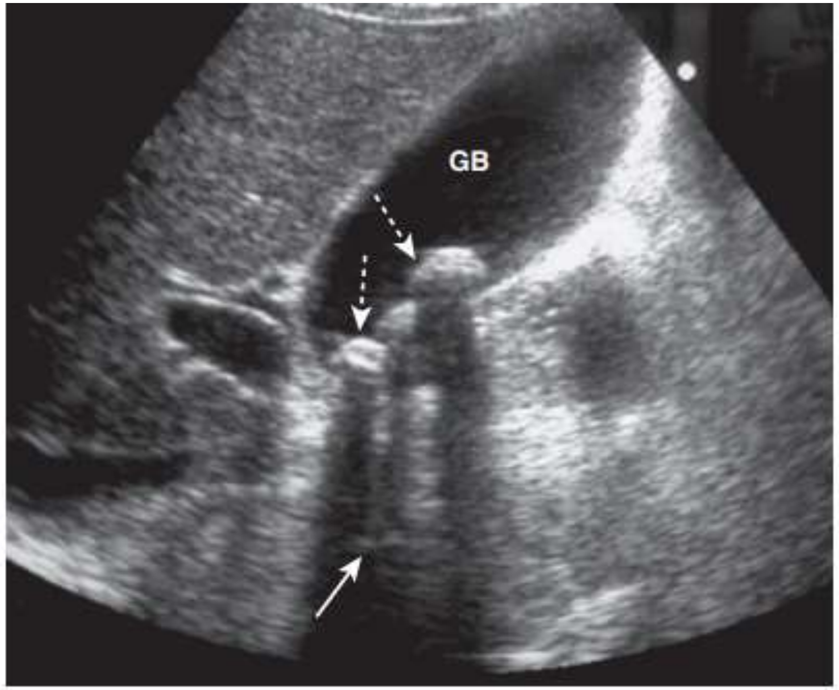
- Ultrasound probes utilize acoustic energy above the audible frequency of humans to produce images.
- An ultrasound probe or transducer both produces the ultrasonic signal and records it.
- The signal is processed for its characteristics by an onboard computer.

- Ultrasound images are recorded digitally and are easily stored in a PACS system.
- Images are displayed either as static images or in the form of a movie (or “cine”).
- Ultrasound scanners are relatively inexpensive compared with CT and MRI scanners.
- They are widely available and can be made portable to the point of being handheld.

- Because ultrasonography utilizes no ionizing radiation, it is particularly useful in obtaining images of children and women of childbearing age and during pregnancy.

Applications

- First choice in imaging the female pelvis and in pediatric patients.
- In differentiating cystic versus solid lesions in patients of all ages.
- In noninvasive vascular imaging.
- In imaging of the fetus and placenta during pregnancy, and in real-time, image-guided fluid aspiration and biopsy.
- Other common uses are evaluation of cystic versus solid breast masses, thyroid nodules, and tendons and in assessment of the brain, hips, and spine in newborns.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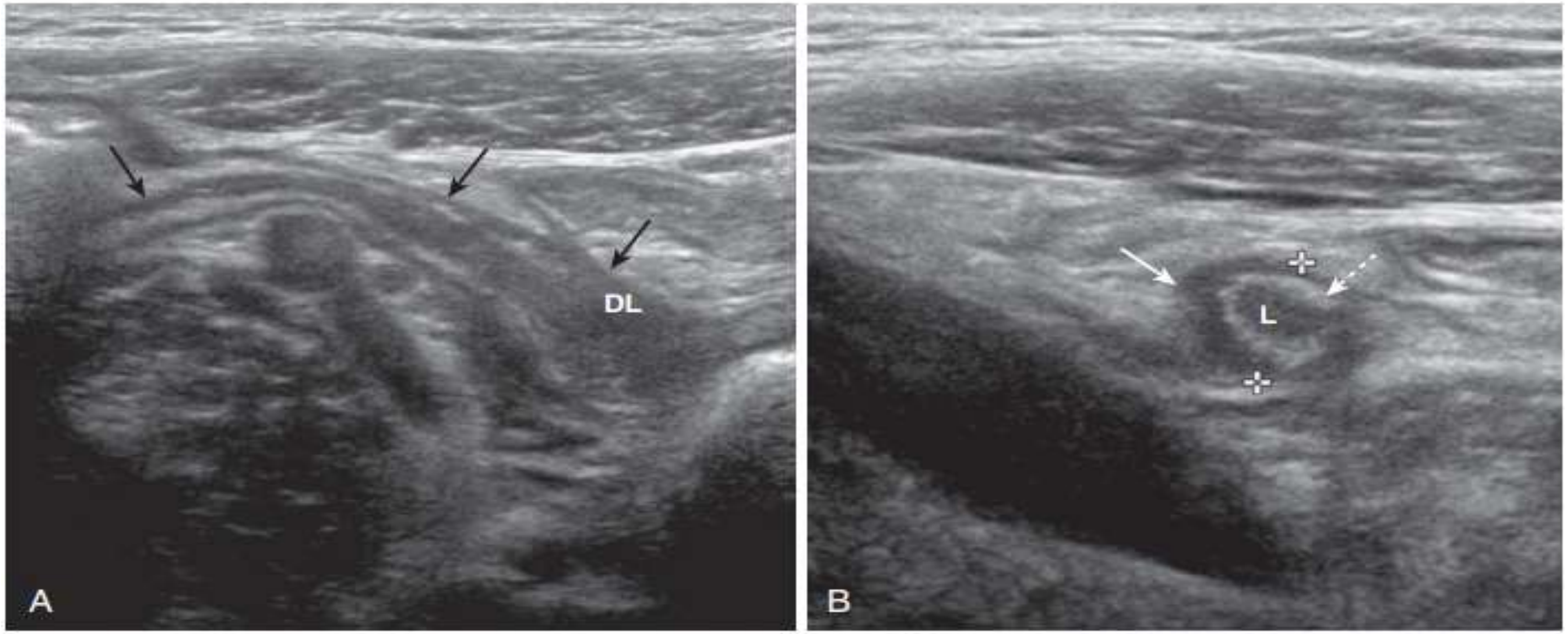
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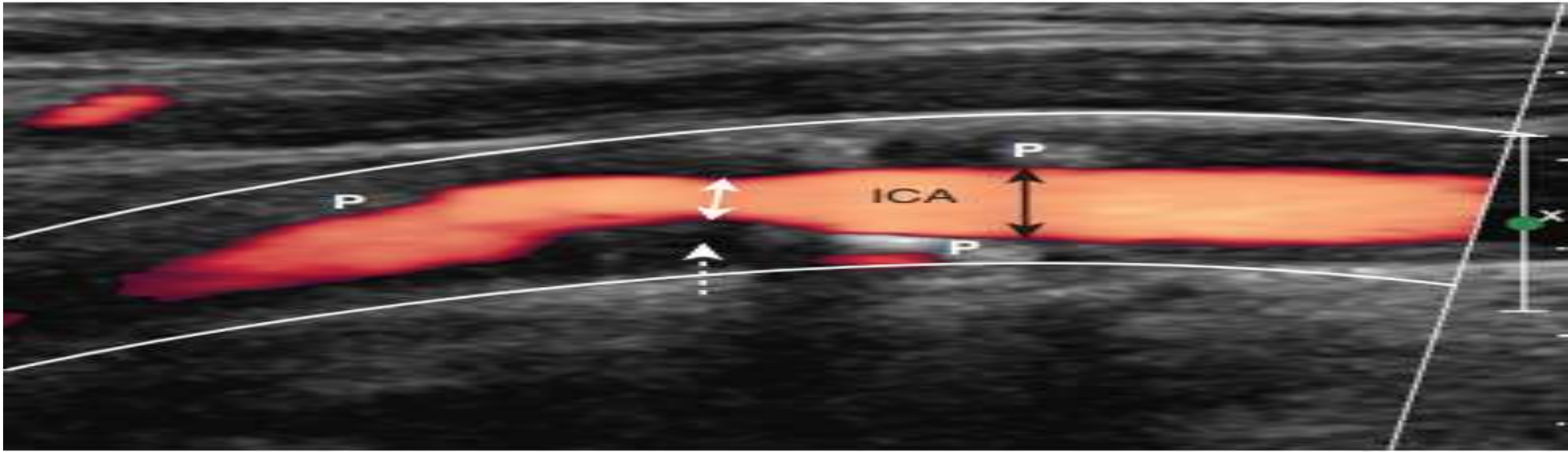
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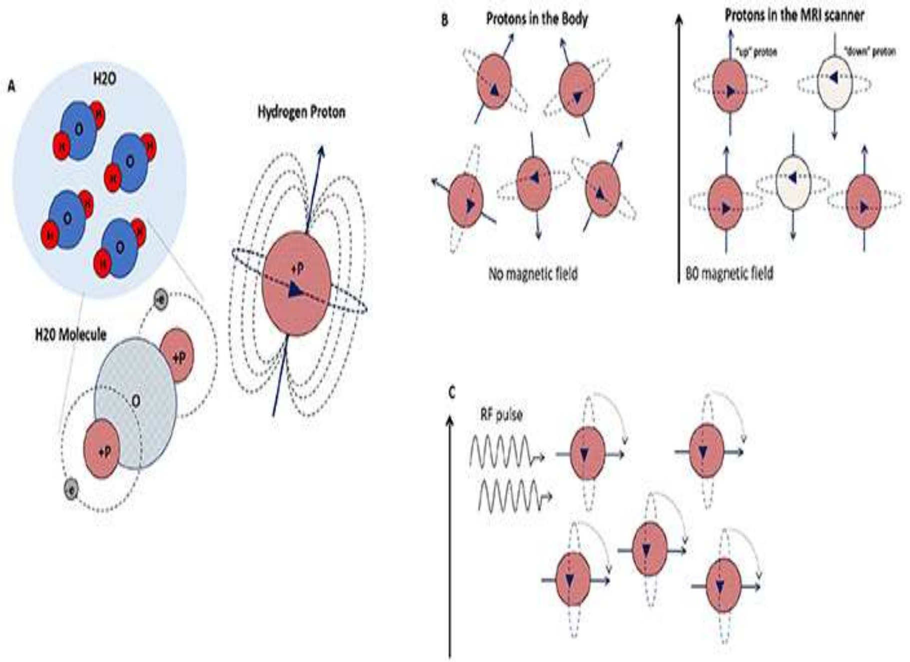
Magnetic Resonance Imaging

- MRI utilizes the potential energy stored in the body’s hydrogen atoms.
- The atoms are manipulated by very strong magnetic fields and radiofrequency pulses to produce enough localizing and tissue-specific energy to allow highly sophisticated computer programs to generate two- and threedimensional images



- MRI scanners are not as widely available as CT scanners. They are expensive to acquire and require careful site construction to operate properly. In general, they also have a relatively high ongoing operating cost.

- No ionizing radiation and produce much higher contrast between different types of soft tissues than is possible with CT.
- MRI is widely used in neurologic imaging and is particularly sensitive in imaging soft tissues such as the muscles, tendons, and ligaments.
- There are safety issues (e.g., cardiac pacemakers) and for ferromagnetic projectiles in the MRI scanner environment (e.g., metal oxygen tanks in the room).


PICKER

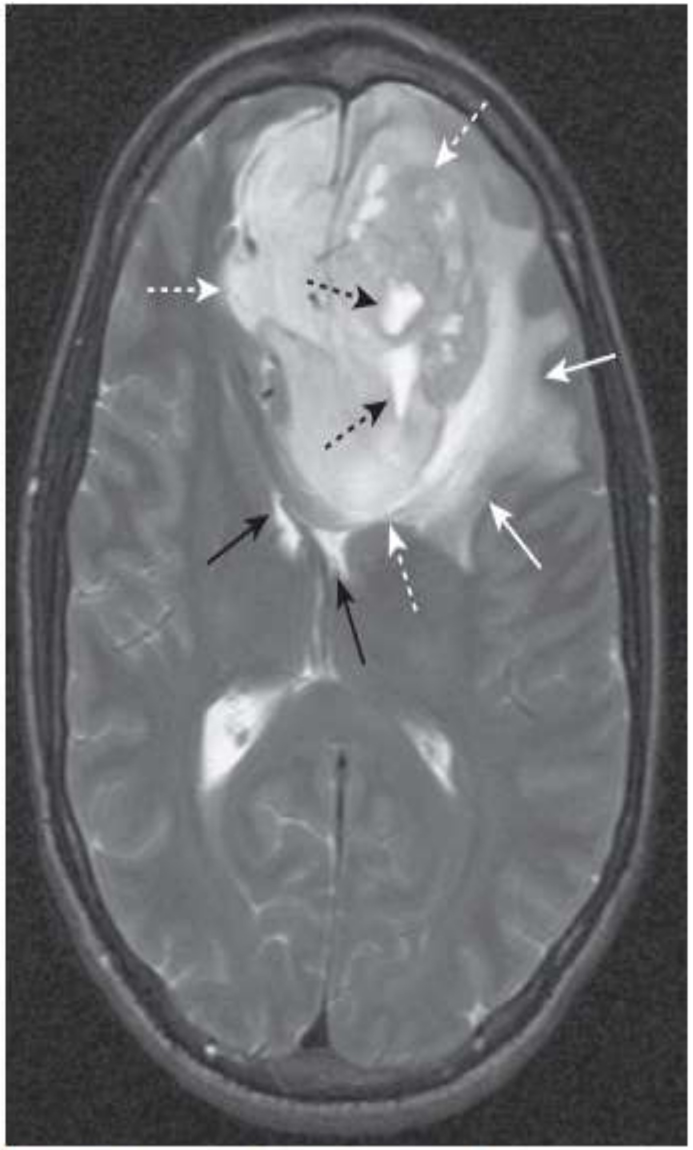


FIGURE 22-5 Glioblastoma multiforme with surrounding edema. Axial T2-weighted imag demonstrates bright vasogenic-type edema *(solid white arrows)* surrounding a large, lobulated fronta lobe mass *(dotted white arrows)*, representing glioblastoma multiforme, an aggressive brain tumo There are a few bright areas of cystic degeneration *(dotted black arrows)* within this mass. The fronta horns of the lateral ventricles are compressed *(solid black arrows)*.

FIGURE 22-6 Bone marrow edema due to transient lateral patellar dislocation. Axial proton-density, fat-saturated image (a T2-like sequence) demonstrates bright bone marrow edema involving the lateral (L) femoral (F) condyle *(dotted white arrows)* and the medial aspect of the patella (P) *(solid black arrow)*. This edema is due to recent lateral patellar dislocation with contusion of the patella as it struck the tibia.

FIGURE 23-2 Normal magnetic resonance imaging scan of knee. This sagittal view of the knee demonstrates the superior display of the internal matrix of bone and the surrounding soft tissues. There is fatty marrow in the distal femur (F), proximal tibia (T), and patella (P). The quadriceps *(solid black arrow)* and patellar *(dotted white arrow)* tendons are shown. The anterior cruciate ligament *(solid white arrow)* is visible. There is high-signal fat in the infrapatellar fat pad (FP). Notice how the cortex of bone has a very weak signal *(dotted black arrow)*.

Flouroscopy

- Fluoroscopy (or “fluoro”) is a modality in which ionizing radiation (x-rays) is used in performing real-time visualization of the body in a way that allows for evaluation of the motion of body parts, real-time positioning changes of bones and joints, and the location and path of externally administered barium or iodine contrast agents through the gastrointestinal and genitourinary tracts and blood vessels. Images can be viewed as they are acquired on video screens and captured as either a series of static images or moving (video) images.

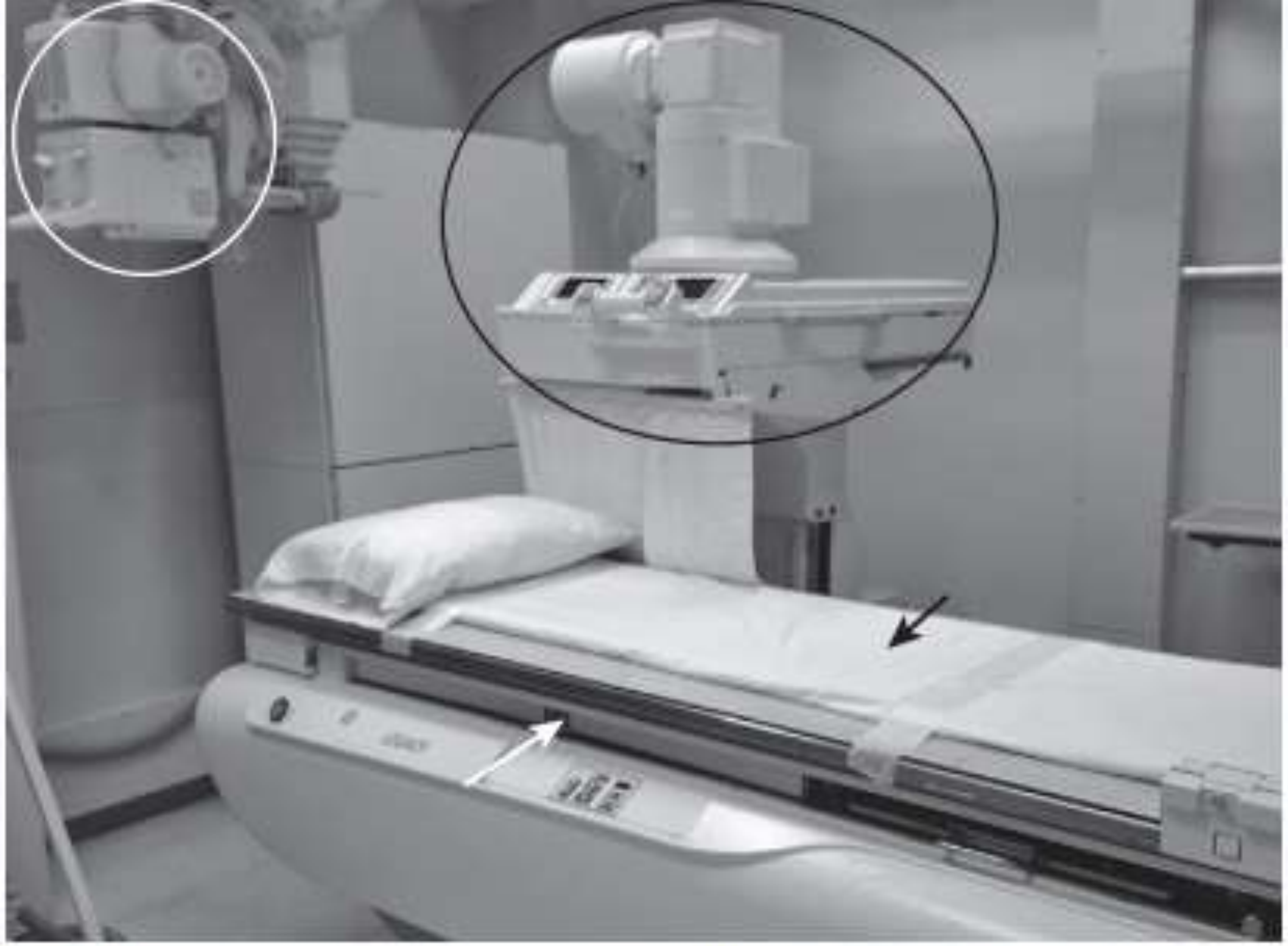


FIGURE 1-10 A standard radiology room equipped for both conventional radiography and fluoroscopy. The patient lies on the table *(black arrow)*, which has the capacity to tilt up or down. Images can be obtained using the tube on the fluoroscopic carriage *(black oval)*, which can be moved over the patient by the operator and then manipulated more or less freely to follow the barium column. Static images can be obtained using the overhead x-ray tube *(white circle)*. The x-ray tube can be moved into place over an x-ray cassette, which would be located under the patient *(white arrow)*.

- In interventional radiology, iodinated contrast is selectively injected into blood vessels or other ducts that can be imaged fluoroscopically to demonstrate normal anatomy, pathology, or the position of catheters or other devices

- Radiation doses in fluoroscopy can be substantially higher than those used in conventional radiography because so many images are acquired for every minute of fluoroscopy time. Therefore the dose is reduced by using the shortest possible fluoroscopy time to obtain diagnostic images

Patient Encounter

- History
- Clinical examination
- Labs
- Differential diagnosis and plan
- Indication to perform imaging study
- Choice of imaging modality
  - i.e ILD, Temporal bones → HRCT
  - Looking for urinary tract stones → Urinary tract CT
  - Looking for causes of acute abdomen → Abdomen and Pelvis CT

With / without contrast??

Contrast

- Contrast can be administered IV, IA, Oral or Rectal
- IV contrast administration ?
  - Valid clinical indication for contrast medium administration
  - Justification (Benefit VS Side effects allergic like and physiologic)
  - Imaging alternatives that would provide the same or better diagnostic information

Contrast (Cont'd)

- Before administration IV contrast
  - Patient consent form
  - Check Serum Cr levels / eGFR
  - Check Contraindications and the need for premedication.
    - Contraindication: Prior allergic like reactions to contrast medium
    - Premedication i.e Allergy to medications, Asthma…etc.

IV iodinated contrast media

- Contrast side effects
  - *Physiologic reactions* (reactions related directly to contrast chemical composition and osmolarity or molecular binding to certain activators) which include:
    - Nausea
    - Vomiting
    - Feeling of warmth

IV iodinated contrast media (Cont’d)

- Cardiovascular effects (cardiac arrythmias, depressed myocardial contractility, cardiogenic pulmonary edema→ (more common and significant in patients with underlying cardiac disease) and seizures. These phenomena are likely related to either contrast media-related hyperosmolality and/or calcium binding leading to functional hypocalcemia.
- Hypertension

- Vasovagal reactions (Hypotension and bradycardia) exact pathogenesis still unknown. Related to anxiety during obtaining informed consent or during placement of needle / catheter, or during IV administration of contrast media.

IV iodinated contrast media (Cont'd)

- *Allergic like reactions*
  - Hives (Urticaria)
  - Diffuse erythema
  - Bronchospasm
  - Laryngeal edema
  - Anaphylactic shock

Contrast media physiologic and Allergic like reactions

Mild

Signs and symptoms are self-limited without evidence of progression. Mild reactions include:

Allergic-like	Physiologic
Limited urticaria / pruritis	Limited nausea / vomiting
Limited cutaneous edema	Transient flushing / warmth / chills
Limited "itchy" / "scratchy" throat	Headache / dizziness / anxiety / altered taste
Nasal congestion	Mild hypertension
Sneezing / conjunctivitis / rhinorrhea	Vasovagal reaction that resolves spontaneously

Moderate

Signs and symptoms are more pronounced and commonly require medical management. Some of these reactions have the potential to become severe if not treated. Moderate reactions include:

Allergic-like	Physiologic
Diffuse urticaria / pruritis	Protracted nausea / vomiting
Diffuse erythema, stable vital signs	Hypertensive urgency
Facial edema without dyspnea	Isolated chest pain
Throat tightness or hoarseness without dyspnea	Vasovagal reaction that requires and is responsive to treatment
Wheezing / bronchospasm, mild or no hypoxia	

SEVERE

Allergic-like	Physiologic
Diffuse edema, or facial edema with dyspnea	Vasovagal reaction resistant to treatment
Diffuse erythema with hypotension	Arrhythmia
Laryngeal edema with stridor and/or hypoxia	Convulsions, seizures
Wheezing / bronchospasm, significant hypoxia	Hypertensive emergency
Anaphylactic shock (hypotension + tachycardia)	

GENERAL RULES for contrast administration

- Allergy to previous IV contrast examination is absolute contraindication for contrast re-administration.

- Pre-medication is required for patients with history of allergy using 13 or 12 hour regimen (Allergy to food, medications, medical conditions like Asthma, seasonal allergy…..etc)
  - Corticosteroids
  - Chlorpheniramine (Mandatory 13 hr regimen / optional 12 hr regimen)

Postcontrast acute kidney injury & CIN

- PC-AKI: sudden deterioration in renal function that occurs within 48 hours following the intravascular administration of iodinated contrast medium.
- The exact pathophysiology of CIN is not understood. Etiologic factors that have been suggested include renal hemodynamic changes (vasoconstriction) and direct tubular toxicity.
- One of the most commonly used criteria has been an absolute increase of 0.5 mg/dL over a baseline serum creatinine.

Postcontrast acute kidney injury & CIN (Cont'd)

- According to Acute Kidney Injury Network (AKIN)-definition of acute kidney injury: "If one of the following occurs within 48 hours after a nephrotoxic event (e.g., intravascular iodinated contrast medium exposure) "
  - 1) Absolute serum creatinine increase ≥0.3 mg/dL (>26.4 µmol/L).
  - 2) A percentage increase in serum creatinine ≥50% (≥1.5-fold above baseline).
  - 3) Urine output reduced to ≤0.5 mL/kg/hour for at least 6 hours.

Postcontrast acute kidney injury & CIN (Cont’d)

- Risk factors:
  - The most important risk factor is pre-existing severe renal insufficiency.
  - Multiple iodinated contrast medium doses in a short time interval (<24 hours)
  - Other risk factors include diabetes mellitus, dehydration, cardiovascular disease, diuretic use, advanced age, multiple myeloma, hypertension, hyperuricemia

Postcontrast acute kidney injury & CIN (Cont'd)

- Prevention:
  - Avoidance of iodinated contrast medium administration.
  - Volume expansion.
    - Use Isotonic fluids (Lactated Ringer's or 0.9% normal saline). Normal saline (0.9%) at rate 100 mL/hr 6-12 hours before and continued 4 to 12 after contrast administration.
    - Oral hydration has also been utilized.

Gadolinium based contrast media

- Most adverse reactions are physiologic and mild , however allergic like reactions are uncommon. Severe life threatening anaphylactic reactions are rare.
- Mild physiologic adverse reactions associated with GBCM administration:
  - Include coldness, warmth, or pain at the injection site; nausea with or without vomiting; headache; paresthesias; and dizziness.

Safer

Gadolinium based contrast media (Cont’d)

- Important side effect →NSF (Nephrogenic Systemic Fibrosis)
  - Patients at risk are those with underlying kidney disease. (Patients with acute kidney injury or severe chronic kidney disease)
  - eGFR (Normal => 60, not administrated if < 30)
  - Thus its incidence was reduced significantly.

Administration of contrast to pregnant / potentially pregnant patients

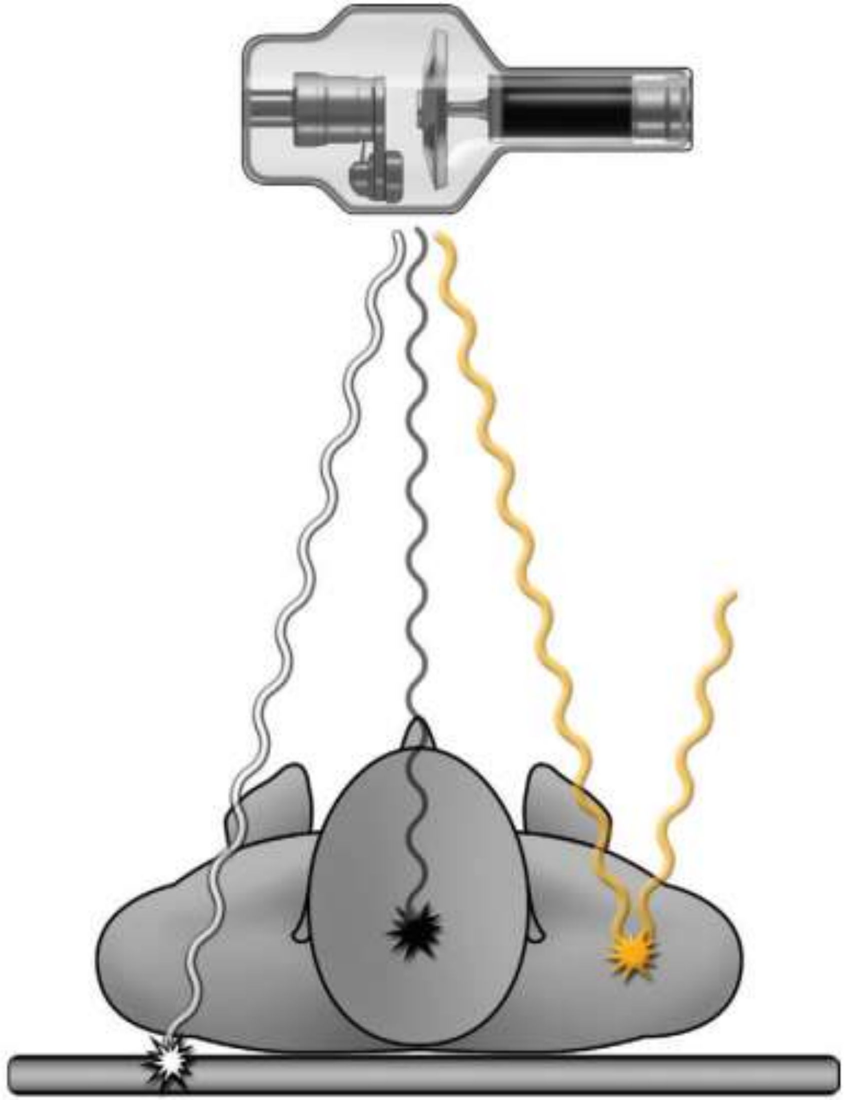
- All IV iodinated and gadolinium-based contrast media behave in a similar fashion and cross the blood-placental barrier and into the fetus.
- Their administration to pregnant and potentially pregnant patients should be limited.

RADIATION DOSE AND SAFETY

- All health care providers should understand the risks associated with radiation exposure and limit exposure when possible

Three Fates of Radiation During an Imaging Procedure

- Transmitted.
- Absorbed radiation
- Scatter radiation



eFIGURE 1-2 Diagram of the three fates of radiation.

Measurements of Radiation

- The absorbed radiation is measured by the absorbed dose. The unit for absorbed dose is the gray (Gy), which is the energy absorbed per unit of mass (kilogram).
- Absorbed dose does not take into account the biological effect of that radiation.

- The equivalent and effective doses attempt to correlate the absorbed dose with the potential biological effects on different types of tissues.
- The unit for these doses is the Sievert (Sv) or rem, where 1 Sv = 100 rem.

Biological Effects of Radiation

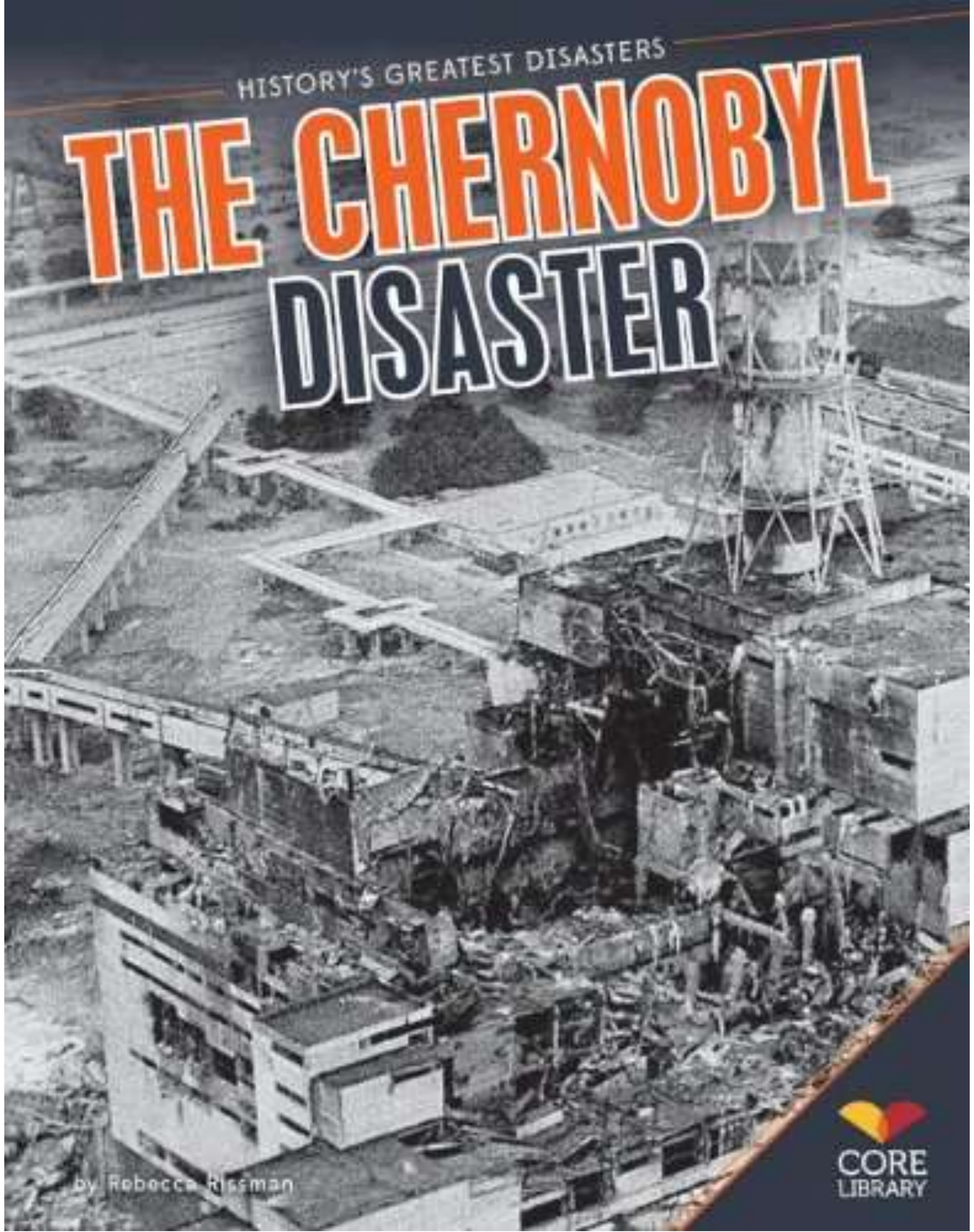
- Radiation causes biological effects on a cellular level either

(1) by directly damaging molecules

(2) by indirectly creating free radicals to disrupt cellular metabolism.

Types of Biological Effect

- Deterministic effects (nonrandom), occurs when a threshold level is met
- Stochastic effects (random), Damage that may occur at any level of exposure, without a threshold dose


HISTORY'S GREATEST DISASTERS
THE CHERNOBYL
DISASTER
by Rebecca Rissman
CORE
LIBRARY

eTABLE 1-1 DETERMINISTIC EFFECTS AT VARIOUS ACUTE ABSORBED DOSES

Skin erythema	2 Gy
Hair loss	3 Gy
Sterility	2-3 Gy
Cataracts	5 Gy
Lethality (whole-body radiation)	3-5 Gy

- In general, slowly dividing mature cells, such as bone cells, have a low sensitivity to radiation damage, whereas undifferentiated, rapidly dividing cells, such as intestinal epithelial cells, have a higher sensitivity. The most radiosensitive organs are bone marrow, colon, lung, female breast, stomach, and childhood thyroid.

Sources of Radiation for Humans

- Cosmic radiation, naturally occurring radioactive materials in soil, and radon gas.
- This background radiation dose does not include additional radiation exposure from diagnostic imaging procedures.
- The average yearly background radiation dose for a person living in the United States is about 3 mSv

Practices for Radiation Safety

- ALARA principle.
- High-quality images should be obtained by using the lowest possible dose to limit the exposure of patients and health care workers. The goal is to prevent deterministic effects and limit stochastic effects.
- There are three major radiation safety practices: time, distance, and shielding.

Special Circumstances

- Children: Children have a three to five times higher risk of mortality due to radiation-induced cancer than adults. Ultrasonography and MRI should be employed when possible.

- Pregnant women.

FIGURE 1-1 A 56-year-old patient with abdominal pain.

FIGURE 1-1 Small-bowel obstruction. There are multiple air-filled and dilated loops of smal bowel *(white arrows)* with virtually no gas in the large bowel. The stomach (S) is also dilated. The disproportionate dilatation of small bowel is indicative of a mechanical small bowel obstructior caused, in this case, by adhesions from previous surgery.

FIGURE 1-2 A 49-year-old who fell off a ladder.

FIGURE 1-2 Subdural hematoma. A curvilinear band of increased attenuation in the right parietal region *(black arrows)* is causing a subfalcine shift of the midline structures to the left *(white arrow)*. The crescentric increased density, paralleling the inner table, is classic for a subdural collection. The patient fell from a height and struck his head.

FIGURE 1-3 A 22-year-old with sudden chest pain.

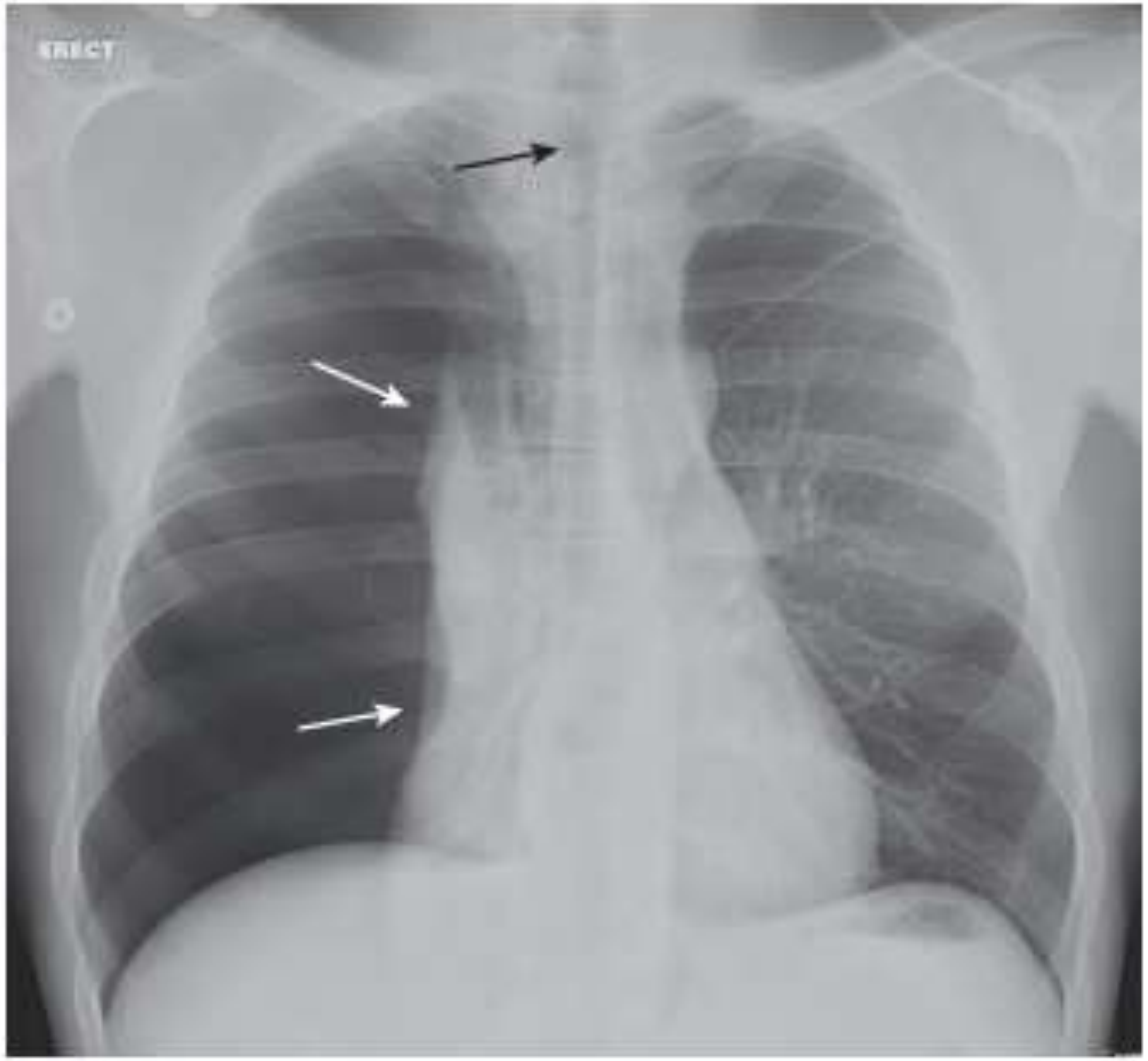


FIGURE 1-3 Pneumothorax, right. A large, right-sided pneumothorax completely collapsed the right lung toward the hilum *(white arrows)*. A slight shift of the trachea to the left *(black arrow)* raises suspicion that the pneumothorax is under slight tension. The patient had a spontaneous pneumothorax.

FIGURE 1-5 Cystogram of a 56-year-old who was in an automobile accident.

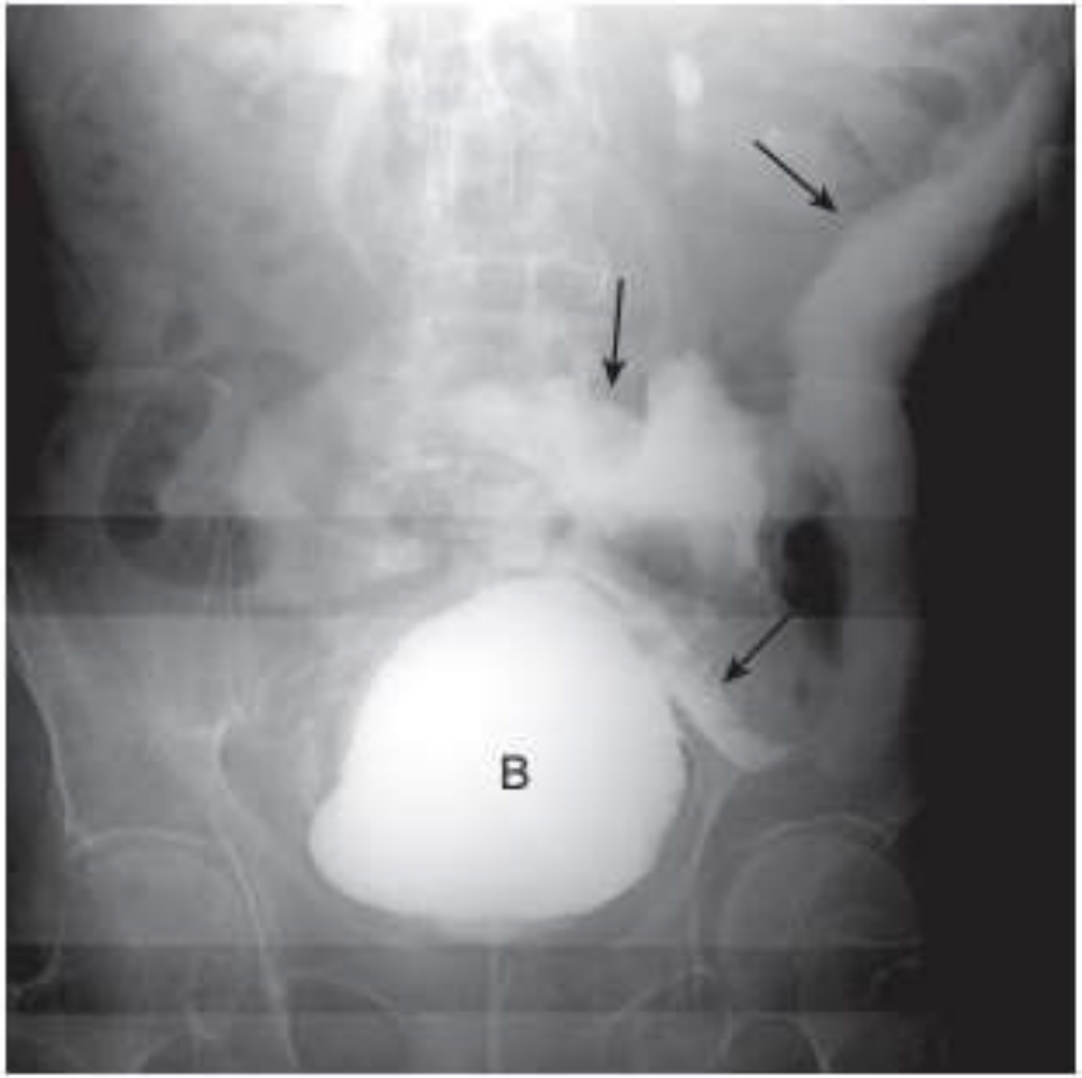


FIGURE 1-5 Extraperitoneal bladder rupture. This is a cystogram in which contrast is instilled into the urinary bladder (B) through a Foley catheter. Such images are obtained to determine if the contrast remains in the bladder as it should. In this case, contrast flows freely out of the bladder into the peritoneal cavity *(black arrows)* from a hole in the dome of the bladder. The patient had been in an automobile collision.

FIGURE 1-4 Incidental finding on abdominal ultrasound.

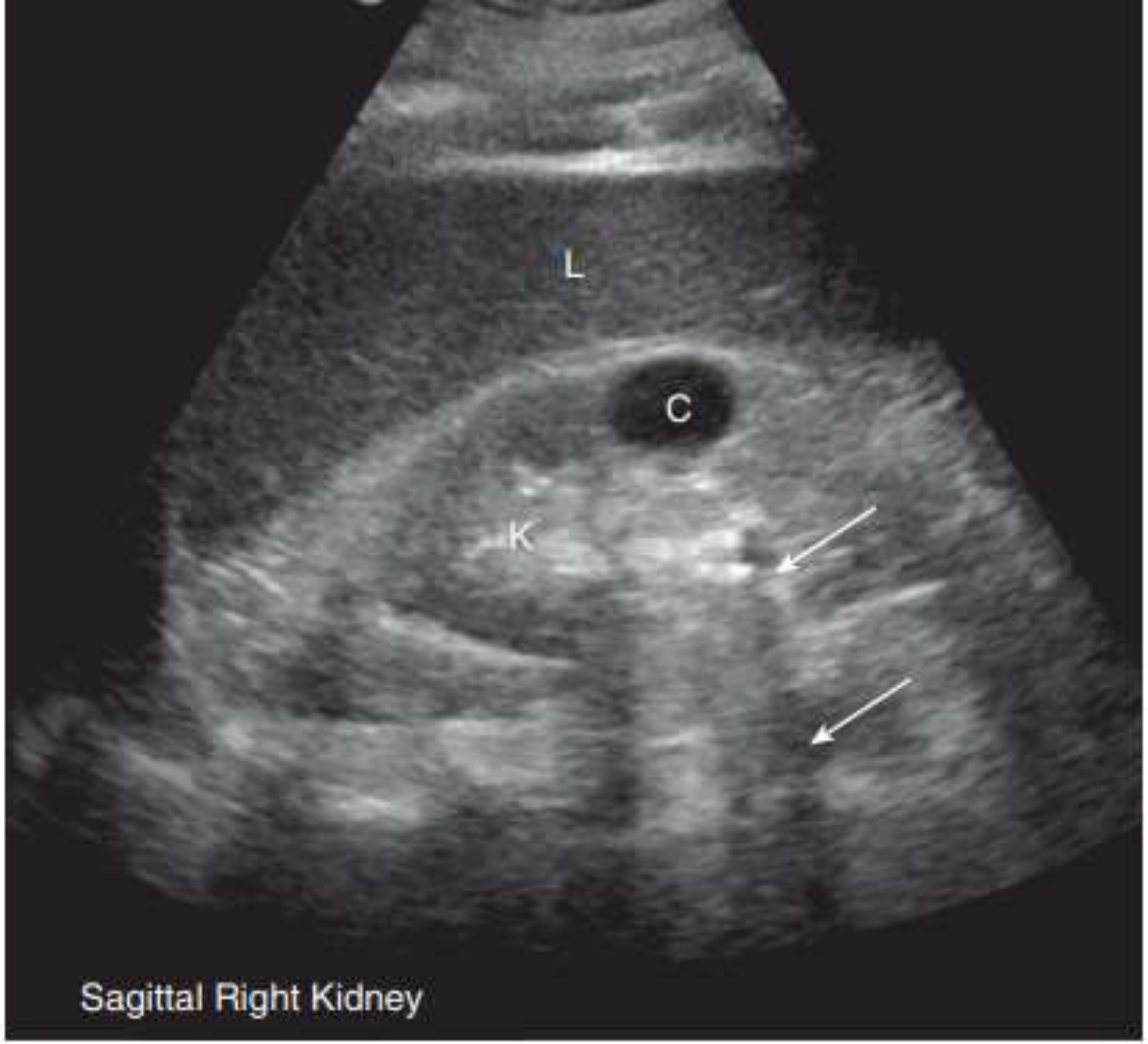


FIGURE 1-4 Simple kidney cyst. There is a round sonolucent mass (C) in the mid-right section of the kidney (K) with a strong back wall of echoes *(white arrows)*, indicating that the mass is a fluid-filled renal cyst. This was found incidentally on a scan of the kidneys performed for flank pain. *L*, Liver.

FIGURE 1-6 A 4-month-old with irritability.

FIGURE 1-6 Child abuse. Child abuse may sometimes be suspected only on the basis of injuries seen on imaging studies that would be unusual for accidental trauma. This 4-month-old was brought to the Emergency Department for irritability, but a chest x-ray revealed bilateral healing rib fractures *(white arrows)*, an injury that is very unlikely to be accidental at this age. A thorough history confirmed the suspicion of child abuse.

ANY QUESTIONS?

Thank you