Al-Mustansiriyah University
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Division of Radiology

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Lecture [1]

Introduction to radiology & diagnostic imaging

Learning objectives:

1. To define the radiology and diagnostic imaging.
2. To distinguish between different types of diagnostic imaging modalities and to understand basic principle, indications, advantages, and disadvantages of each modality.

History: Wilhelm Roentgen produced the first x-ray film image of his wife's hand in 1895.
Radiology: is the science that uses medical imaging to diagnose or treat of the diseases. These medical imaging include X-ray, ultrasound, CT, MRI.

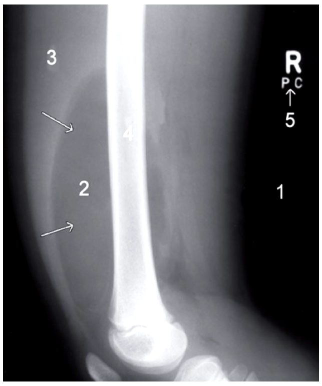
Plain films and fluoroscopy

1. Conventional radiography

Principle: X-rays are part of the electromagnetic spectrum, emitted because of bombardment of a tungsten anode by free electrons from a cathode. Hard copy plain films produced by their passage through the patient and exposing a radiographic film.

Five principal densities recognized on plain radiographs, listed in order of increasing density:

- **Black**, Air/gas: e.g., Lungs, bowel, and stomach
- **Dark grey**, Fat: e.g. subcutaneous tissue layer, retroperitoneal fat
- **Light grey**, soft tissues/water: e.g. Solid organs, heart, blood Vessels, muscle and fluid-filled organs such as bladder.
- **Off-white** Bone:
- **Bright white**, contrast material/metal:



2. Digital radiography

Principle: in digital radiography, the basic principles are the same, but a digital screen replaces the X-ray film. The tissue absorption characteristics are computer analyzed and the image visualized on a monitor.

Advantages of digital radiography:
- Reduce radiation exposure.
- Digital enhancement of image quality.
- Transfer and rapid retrieval of the images
- Elimination of storage problems associated with conventional films.

3. Fluoroscopy

Principle: Fluoroscopy is the term used when a continuous low power X-ray beam is passed through the patient to produce a dynamic image that can be viewed on a monitor.

Uses:
- Contrast studies of GIT.
- Angiography and interventional radiology.
- Guidance of therapeutic joint injections and arthrograms
- Screening in theatre: operative cholangiography, reduction, and fixation of fractures …

Ultrasound

Principle: ultrasound employs high-frequency sound waves, produced by a piezoelectric crystal in a transducer. The waves travel through the body, and reflected variably, depending on the different types of tissue encountered. The same transducer, as well as transmitting ultrasound, receives the reflected sound and converts the signal into an electric current; this is subsequently processed into a grey-scale picture.

- Bone and air are poor conductors of sound, thus appear bright [hyperechoic]
- Fluid has excellent transmission, thus appears dark [hypoechoic or echo free].
- A large differential tissue absorption leads to a greyscale image

Uses
- **Brain:** imaging the neonatal brain.
- **Thorax:** confirms pleural effusions and pleural masses.
- **Abdomen:** visualizes liver, gallbladder, pancreas, kidneys, etc.
- **Pelvis:** useful for monitoring pregnancy, uterus and ovaries.
- **Peripheral:** assesses thyroid, testes and soft - tissue lesions.

Doppler ultrasound

Principle: Doppler ultrasound is a technique to examine moving structures in the body. Blood flow velocities measured using the principle of a shift in reflected sound frequency produced from moving structures.

Uses of doppler ultrasound:
- cardiac Assessment
- Arterial flow studies
- Venous flow studies

Advantages of ultrasound
- Relatively low cost of equipment.
- Non-ionizing and safe.
- Portable equipment.
- Aids biopsy and drainage procedures.

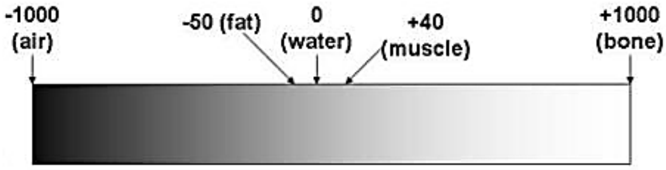
Disadvantages of ultrasound
- Operator dependent.
- Inability to cross the gas or bone
- Poor images in obesity.

Computed Tomography

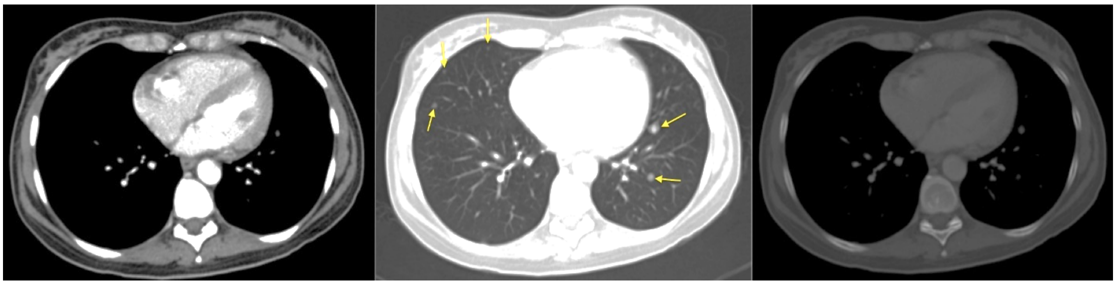
Principle: CT is an imaging technique whereby cross-sectional images are obtained with the use of X-rays; the patient is passed through a rotating gantry that has an X-ray tube on one side and a set of detectors on the other. Information from the detectors is analyzed by computer and displayed as a grey-scale image.

Hounsfield scale: the relative density of an area of interest may be measured electronically. This density measurement is given as an attenuation value, expressed in Hounsfield units (HU) (named for Godfrey Hounsfield, the inventor of CT). Approximate attenuation values for common substances on CT are as follows:

- **Water: 0**
- **Muscle: 40**
- **Contrast-enhanced artery: 130**
- **Cortical bone: 500**
- **Fat: −50**
- **Air: −1000**



Grey scale window width and level:



Mediastinal soft tissue w. Lung window Bone window

Uses of CT
- Whole body scan.
- Staging primary tumors
- Radiotherapy planning.
- Detail vascular and structural anatomy.

Advantages
- Good contrast resolution.
- Precise anatomical detail.
- Rapid examination technique.

Disadvantages
- High dose of ionizing radiation.
- High cost of equipment and scan.

Magnetic resonance imaging

Principle: Magnetic resonance scanning produces images of the body by utilizing the magnetic properties of hydrogen. The patient is placed in the scanner tunnel & subjected to a high-intensity magnetic field. This forces the hydrogen atom nuclei to align with the magnetic field. A pulse of radiofrequency applied to these nuclei then displaces them from their position; when the pulse ceases, they return to their original state, releasing energy (in the form of a radio-frequency signal). Computer analysis processes this energy into a digital signal with conversion to a grey-scale image.

Sequences:

- **Spin echo sequences** includes **T1-weighted, T2- weighted and proton density**.
- **Inversion recovery sequences** are used to suppress specific signals such as fat **(STIR)** and water **(FLAIR)**.
- **Gradient- echo sequences** are extremely sensitive to the presence of specific substance such as iron and calcification. It has known as **susceptibility weighted imaging**.
- **Functional MRI sequences:**
  - **Diffusion-weighted imaging (DWI)** is sensitive to the random Brownian motion (diffusion) of water molecules within tissue. The greater the amount of diffusion, the greater the signal loss on DWI and vice versa. DWI is the most sensitive imaging test for the diagnosis of acute cerebral infarction.
  - **Perfusion-weighted imaging (PWI)** may be used in patients with cerebral infarct to map out areas of brain at risk of ischemia that may be salvageable with thrombolysis called **penumbra**.
  - **Magnetic resonance spectroscopy (MRS)** uses different frequencies to identify certain metabolites such lipid, lactate, NAA (*N*-acetyl aspartate), choline, creatinine, citrate and myoinositol. Uses of MRS include characterization of metabolic brain disorders in children, differentiation of recurrent cerebral tumor from radiation necrosis, and diagnosis of prostatic carcinoma.
- **Magnetic resonance angiography and magnetic resonance venography** used for visualization of blood vessels with or without using contrast material.

Uses:

- Central nervous system imaging.
- Musculoskeletal: accurate imaging of joints, tendons, ligaments, and muscular disease.
- Diagnosis of many cardiac conditions.
- Assessment of mediastinal pathology.
- Abdominal imaging including MRCP.
- Pelvis: staging of prostate, bladder and pelvic neoplasms.

Advantages:

- Multiplanar.
- No risk ionization radiation.
- No bony artefacts.
- Excellent soft tissue contrast.
- Visualizes blood vessels without contrast: MRA & MRV

Disadvantages:

- High costs.
- Poor images of lung fields.
- Calcification and fresh blood in recent hemorrhage not as well visualized as by CT.
- Long examination time.
- Contraindicated in patients with pacemakers and metallic foreign bodies.
- Claustrophobia

Further readings:

Diagnostic imaging, seventh edition
Andrea Rockall
Andrew Hatrick
Peter Armstrong
Martin Wastie