MEDICAL IMAGING

MEDICAL IMAGING

- **RADIOLOGY**
- **NUCLEAR MEDICINE**
- **ULTRASONOGRAPHY (ECHOGRAPHY)**
- **MRI (MAGNETIC RESONANCE IMAGING)**
- **THERMOGRAPHY**

MEDICAL IMAGING

Modality	Radiography Fluoroscopy	Computed Tomography	Ultrasono-graphy	Magnetic Resonance Imaging	Nuclear Medicine
Energy type	X-rays		Ultrasuond	Magnetic field and radiofrequency	Gamma rays
Source of energy	X-ray tube		Piezoelectric crystal	Magnet, RF coils	Raionuclides
Terminology used for black and white	Opacity Lucency	Hyperdensity Hypodensity	Hyperecogenity Hypoecogenity	Hyperintensity Hypointensity	Hyperfixation, (hot spot) Hypofixation (cold spot)
Ionizing radiation	+		-	-	+
Contraindica-tions	Pregnancy, prophylactic investigations in children		-	Implanted metal devices	Pregnancy, children up to one yeary
Contrast substances	High and low density substances		Substances with microbubbles	Paramegetic substances	-

RADIOLOGY

RADIOLOGY

RADIOLOGICAL MODALITIES:

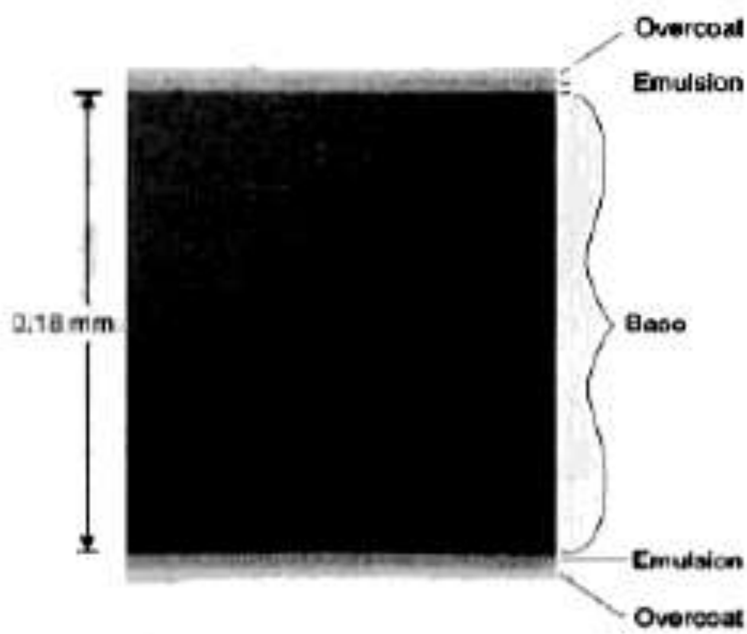
- **Simple (plain) radiography**
- **Fluoroscopy**
- **Conventional Tomography, Tomosynthesis**
- **Computed Tomography (CT)**

Simple (plain) radiography

- X-ray beam modulated through the patient’s body is imprinted on a photographic plate (X-ray film) or received by digital detector (digital radiography)

Simple (plain) radiography

- **X-RAY FILM**



RADIOLOGY

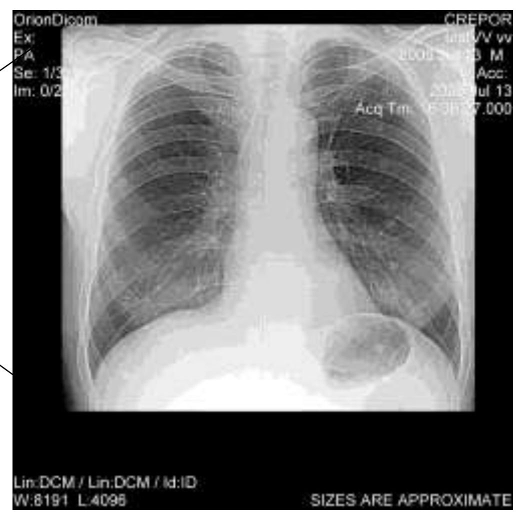
X-RAY FILM CASSETE

DIGITAL DETECTOR

RADIOLOGY

X-RAY ROOM

Radiograph – negative image

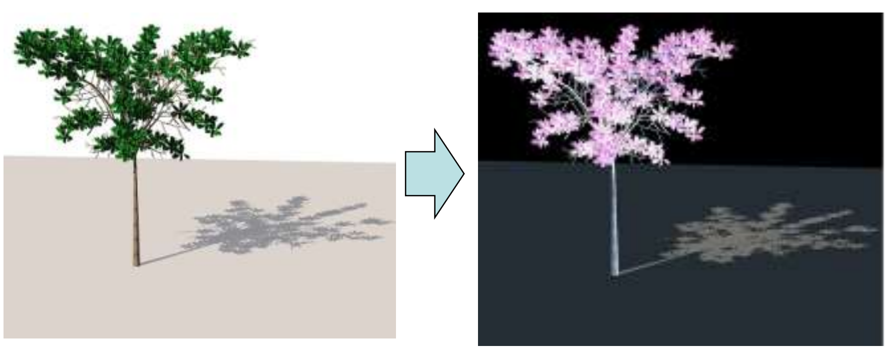


Radiography

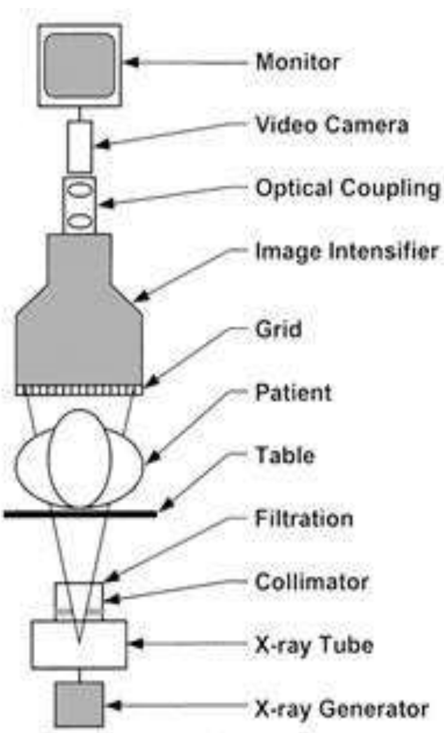
- Radiography is the recording of the image of an object on a special photographic film, obtained with the help of X-rays - radiograph.
- When performing a radiograph, the object is placed between the radiation source and the radiological film (detector).
- As X-rays pass through the object, they are attenuated unevenly in different parts of it (depending on the density and thickness of the object's components), so in the image, different components are differentiated by contrast.

Radiography

- The radiographic image is a "negative" image (after developing, the shadow of dense structures such as the skeleton is bright);
- The higher the density of the structure is, the brighter the shadow in the image.
- The lower the density of the structure is, the darker the shadow in the image.



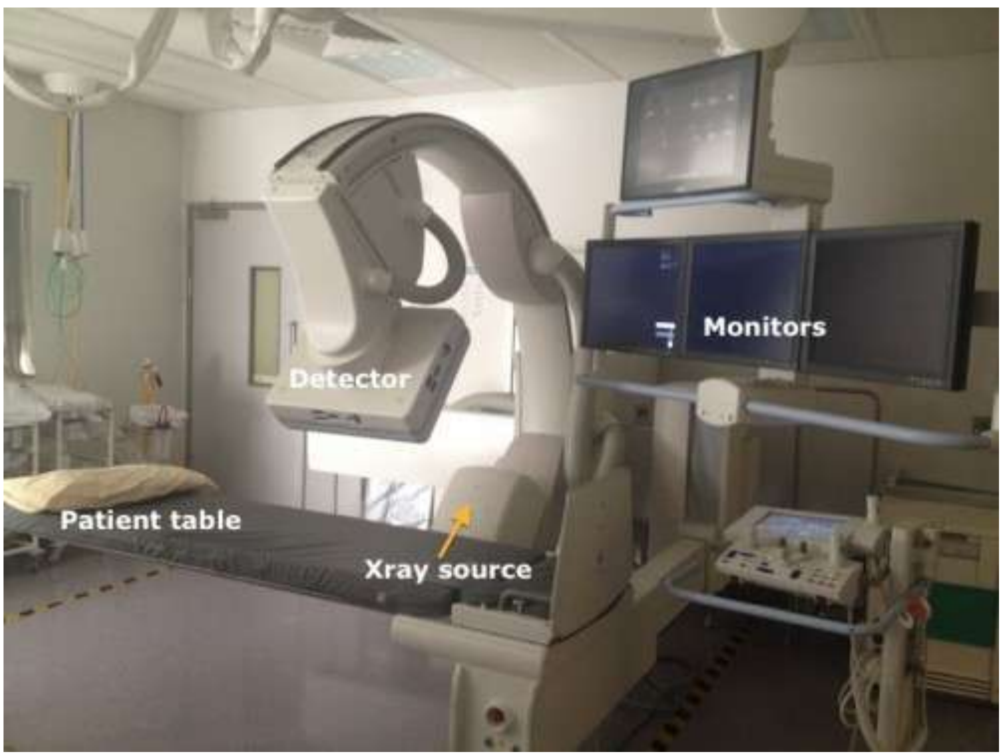
FLUOROSCOPY



- **X-ray beam modulated through the patient's body is projected on a fluorescent screen. The image is viewed on the monitor.**

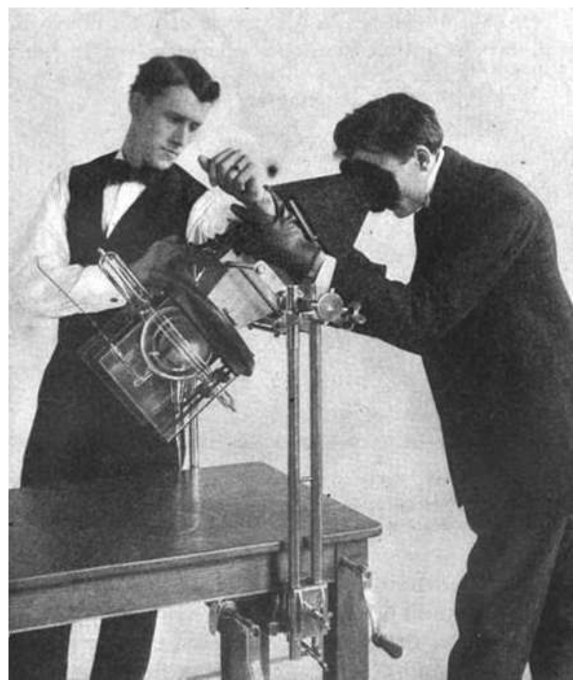
positive image

FLUOROSCOPY



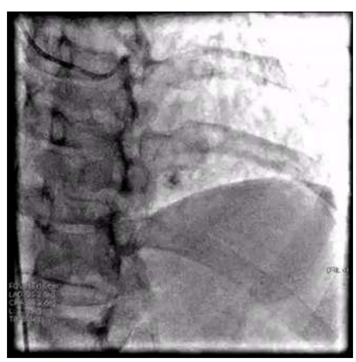
FLUOROSCOPY

- Fluoroscopy is the oldest method of radiological examination and consists in examining on the screen the images formed by the X-ray beam after it passed through a certain anatomical region.
- The first devises consisted of a hand-held fluorescent visor (phosphor-coated screen) that the doctor used during continuous exposure.



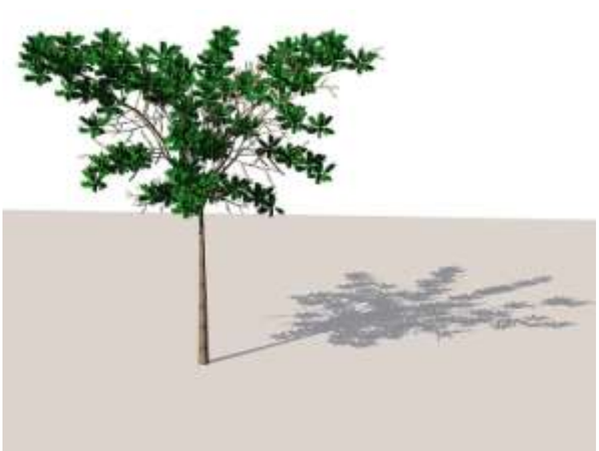
FLUOROSCOPY

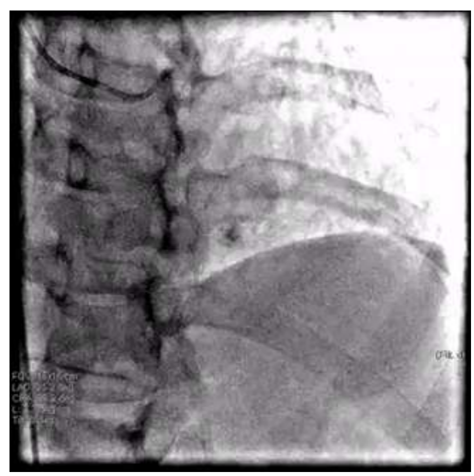
- Fluoroscopy is dynamic X-ray examination used to obtain real-time images of the patient's internal structures.
- Examples include cardiac catheterization, coronary angiography, barium examination of the digestive tube, needle or catheter positioning in various procedures such as guided biopsy, selective arterial catheterization, etc.



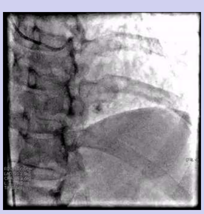
FLUOROSCOPY

- The fluoroscopic image is a "positive" image (the shadow of dense structures such as the skeleton is dark).
- The higher the density of the structure is, the darke the shadow in the image.
- The lower the density of the structure is, the brighter the shadow In the image.





Radiography and Fluoroscopy

Modality	Benefits	Disadvantages
Radiography 	•Accessible •More details are viewed •Can serve as a medicolegal document and can be archived •Low radiation dose	•Does not allow functional investigation •Does not allow guidance of invasive manipulations
Fluoroscopy 	•Allows functional investigation •Allows guidance of invasive manipulations	•High radiation dose •Fewer details are viewed •Relatively subjective •It cannot serve as a medicolegal document

Nowadays, digitalization allows archiving fluoroscopy data

RADIOLOGY

TERMINOLOGY:

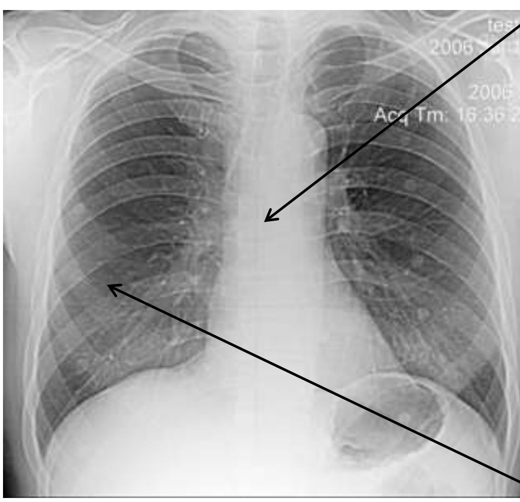
- **High dens structures – opaque (opacity)**
  - **bones, calcification, metallic foreign bodies**

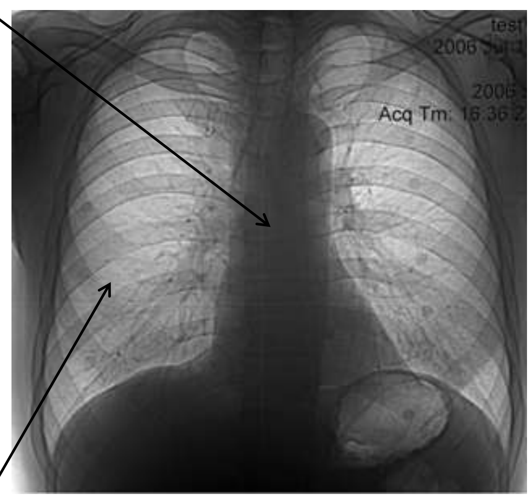
- **Low dens structures – lucent (lucency, translucency, transparency)**
  - **air**

RADIOGRAPH

negative image **positive image**

bright **opacity** dark





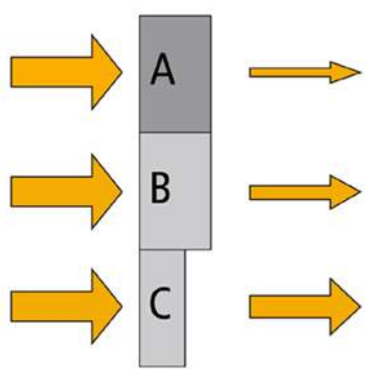
dark **lucency** bright

RADIOLOGY

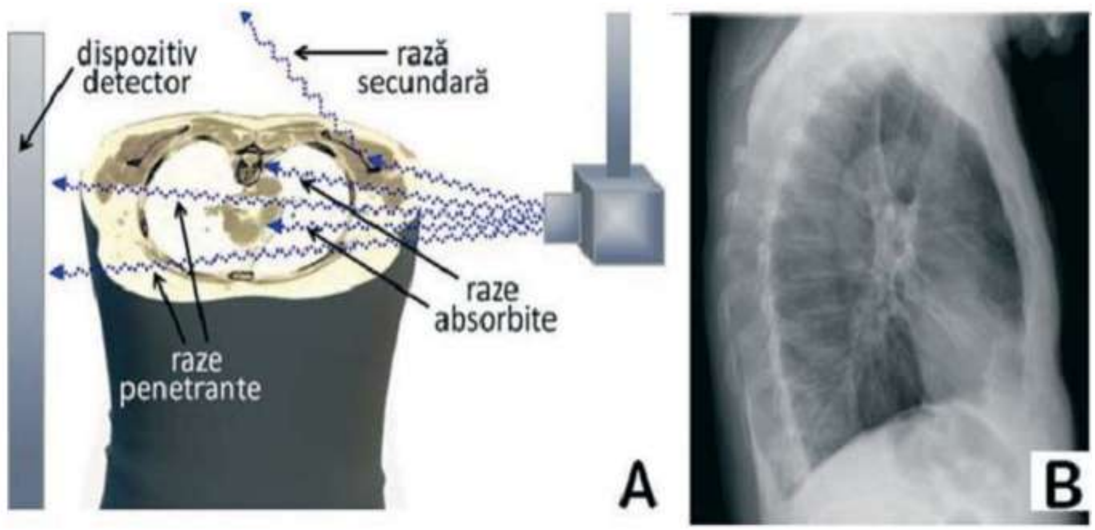
BASED ON ABSORPTION OF X-RAYS BY THE TISSUES

ABSORPTION OF X-RAYS DEPENDS ON:

- **Density of the structure**
- **Thickness of the structure**



Radiological image formation
(negative image)

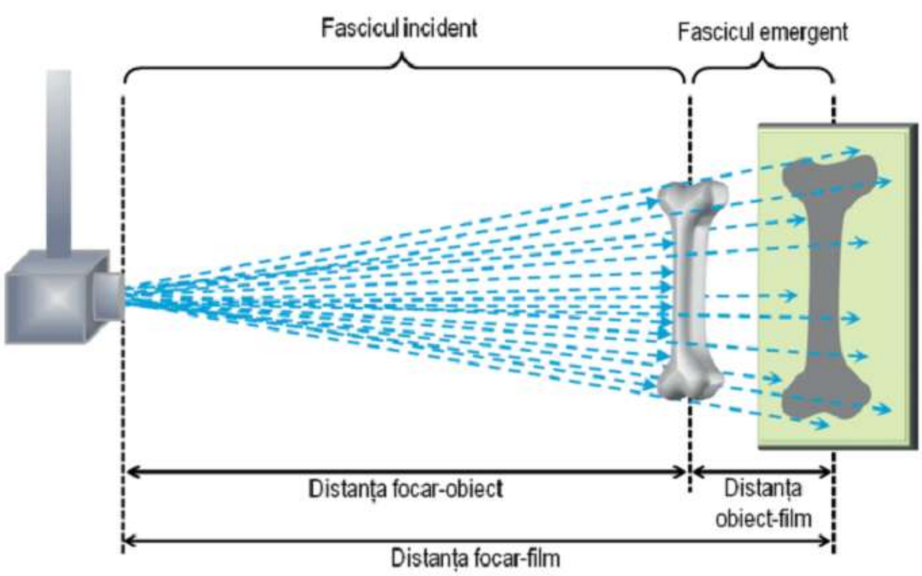


• *The more x-rays are absorbed, the less they reach the detector, creating a white color (bones and thick structures)*

• *The less x-rays are absorbed, the more they reach the detector, creating a black color (air)*

Radiological image formation

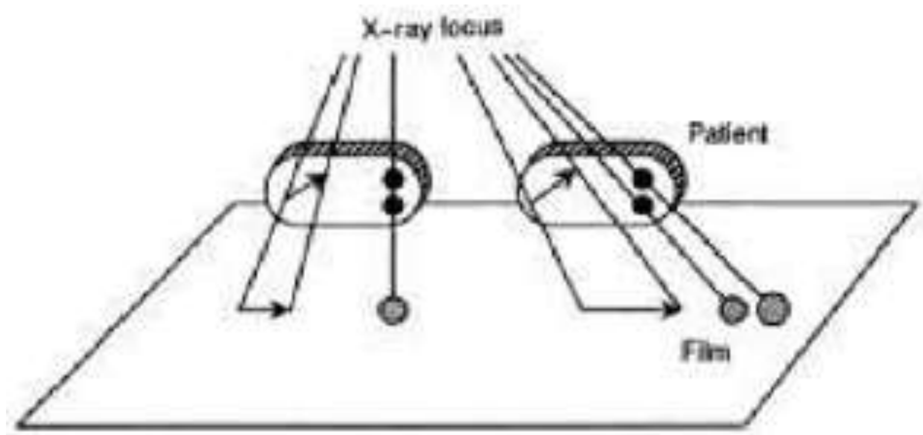
- The image of an object interposed between the X-ray source and the detector device represents the projection of a three-dimensional body in a two-dimensional plane and is subject to optical laws.



Radiological image formation

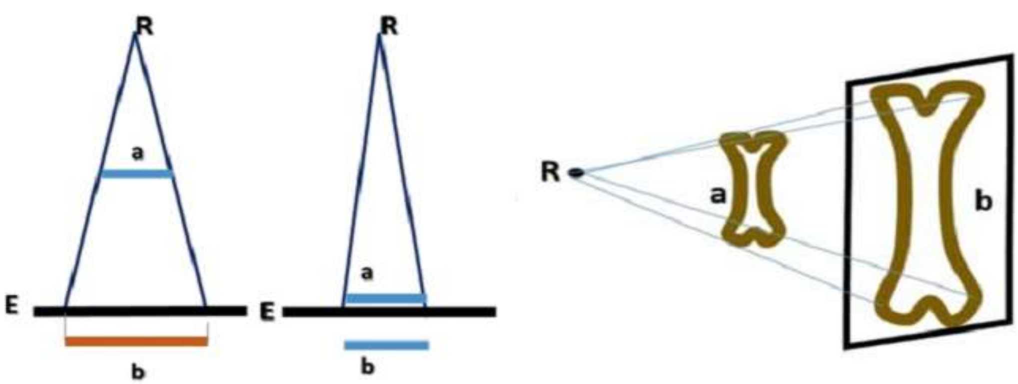
IMAGING GEOMETRY

- **Distortions arise in an image due to imaging geometry and the characteristics of an object**



Conical projection

- Due to the conical shape of the X-ray beam, the phenomenon of magnifying the image of the examined object takes place;
- The magnification of the image of the object is minimal along the central ray and maximum towards the periphery of the image;
- The farther the object is from the film and the closer it is to the X-ray tube, the larger the image of the object.



R –X-ray tube, E – screen (detector), a – examined object, b – object projection on the screen (detector)

Conical projection

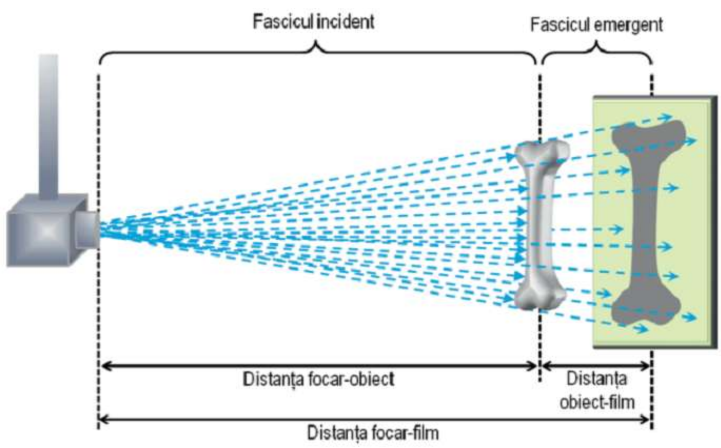
- In order to obtain an image of an object as close as possible to the real dimensions, the object must be placed as far as possible from the X-ray tube and as close as possible to the screen (matrix X-ray detector), and the distance between the tube and the screen must be increased.

- At a distance of 1.8-2 meters from the object and screen to the X-ray tube (**teleradiography**), the dimensions in the image are practically equal to the real ones (their magnification is negligible).

- The technique is called **teleradiography** due to the large distance between the X-ray tube and the object. The method is used to obtain isometric images (identical in size to the object), with importance in some areas such as stereotaxic neurosurgery or orthodontics for accurate measurement of sizes and angles of anatomical structures in the skull region (cephalometry) or three-dimensional intracerebral detection.

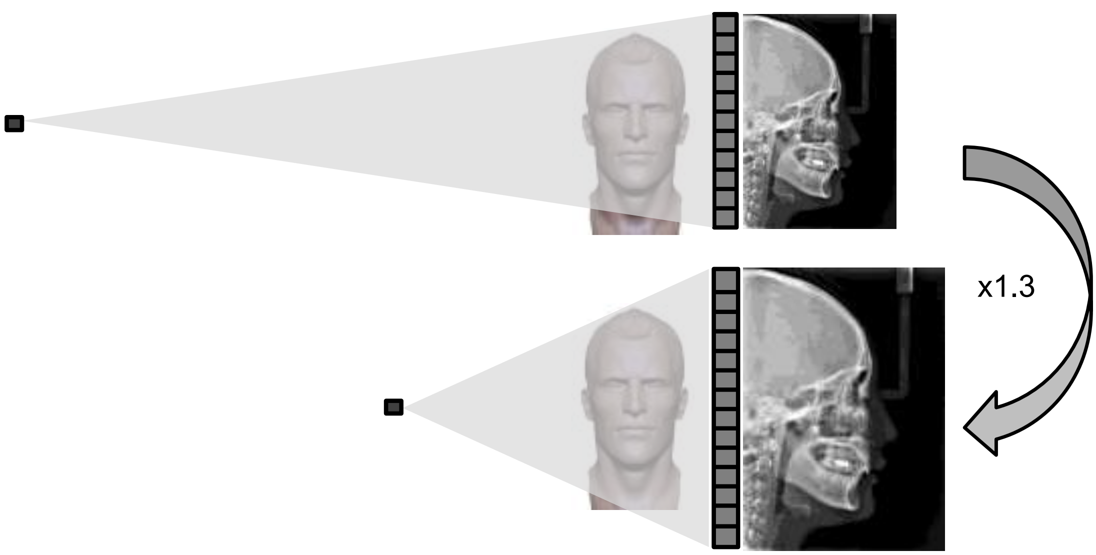
Conical projection

- In some situations it may be necessary to enlarge the image to identify more details, a result obtained by reducing the distance between the tube and the screen - **macroradiography**. In this case, the object is at a distance of about 40 cm from the detector, and the X-ray tube is close to the object.
- This technique can be used in various situations such as dacryocystography (radiography of the nasolacrimal canal with contrast agents), fractures of the carpal bones, etc.



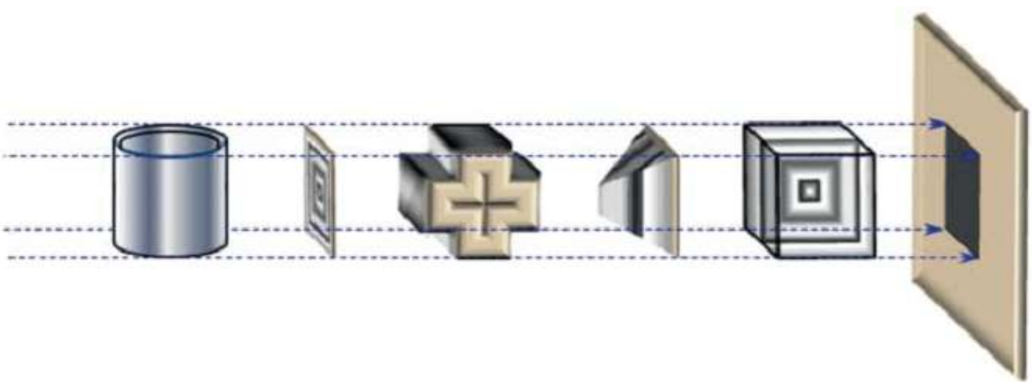
Conical projection

Geometric magnification is higher at a shorter SOD (source-object distance)



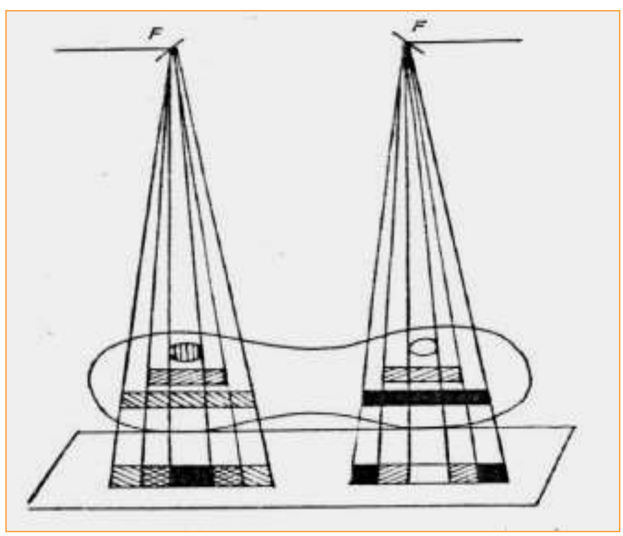
Addition and subtraction

- **Addition** of planes results from the fact that a radiological image is a two-dimensional image of a three-dimensional object.
- Thus, objects of various shapes can have similar projections on the radiological film or the detector screen.



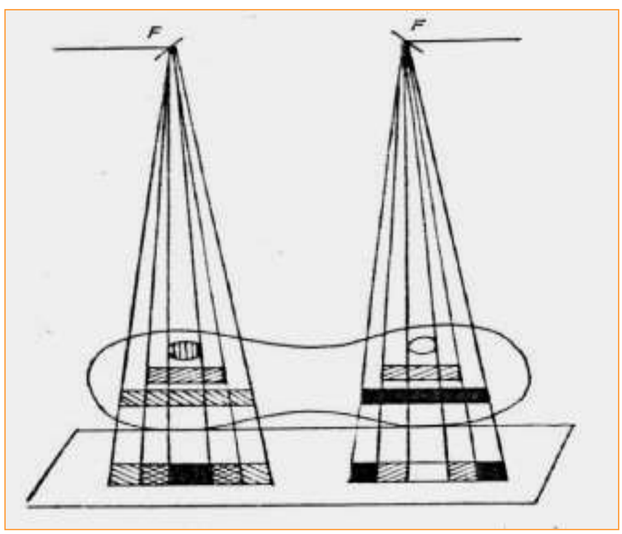
Addition and subtraction

- Penetrating the human body, the X-ray beam passes through a lot of structures, whose images are projected on the screen in a single plane, overlapping each other (like shadows), and the final appearance be the sum, representing the addition of all images with different spatial location and different density.

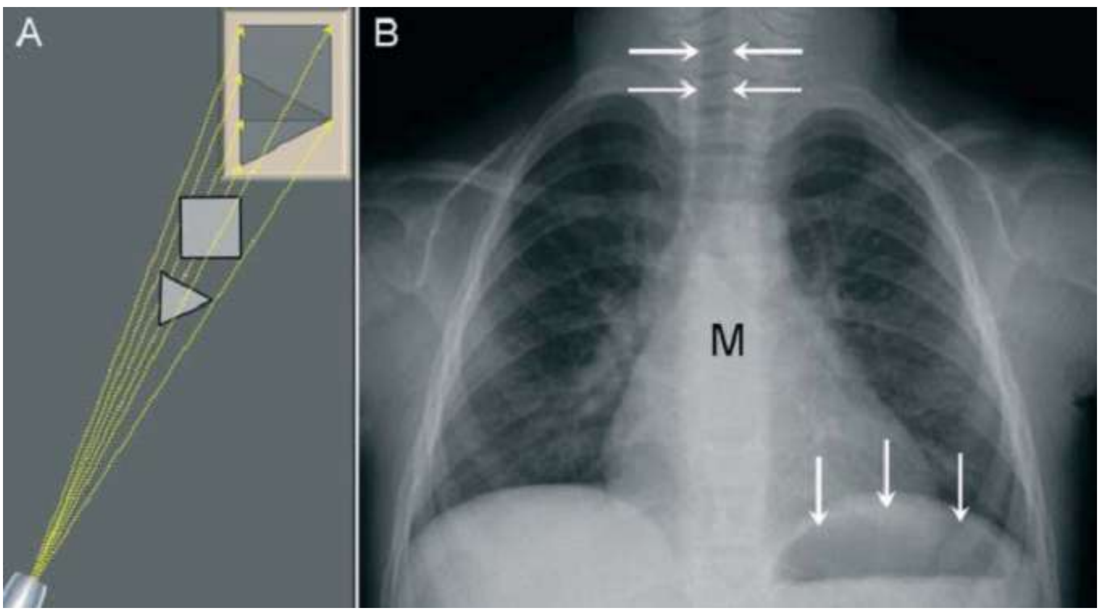


Addition and subtraction

- The contribution of each structure to the addition of the plans is usually expressed by increased opacity in the image (in case of high-dense structures).
- A variant of the addition is the **subtraction** effect in case of low-dense structures, as they involve less X-ray attenuation compared to adjacent tissues, expressed by decreased opacity or lucency.



The addition of plans in the radiographic image. A profile radiograph shows a metallic structure in the skull projection, but its exact location cannot be determined. On the postero-anterior radiograph it becomes clear that the structure is located extracranialy, in the projection of the upper edge of the left outer ear (it is a hearing aid).

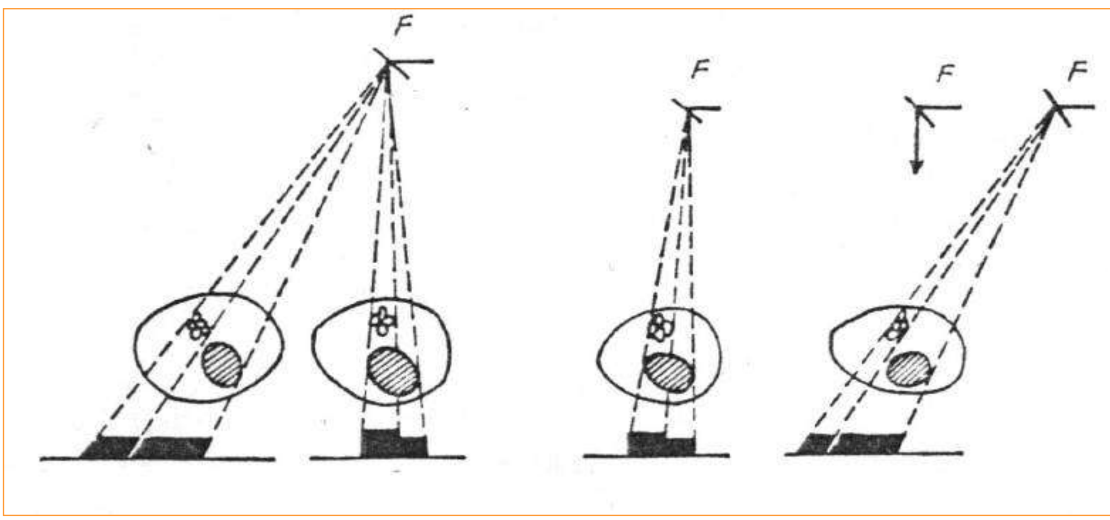


A. – schematic representation of the addition of the planes, the projection of each object being expressed by increasing the opacity on the detector device.

B. – the mediastinal shadow (M) on the chest radiograph is due to the addition effect, while the projection of the trachea (horizontal arrows) and the gas content of the stomach (vertical arrows) can serve as examples of the subtraction effect.

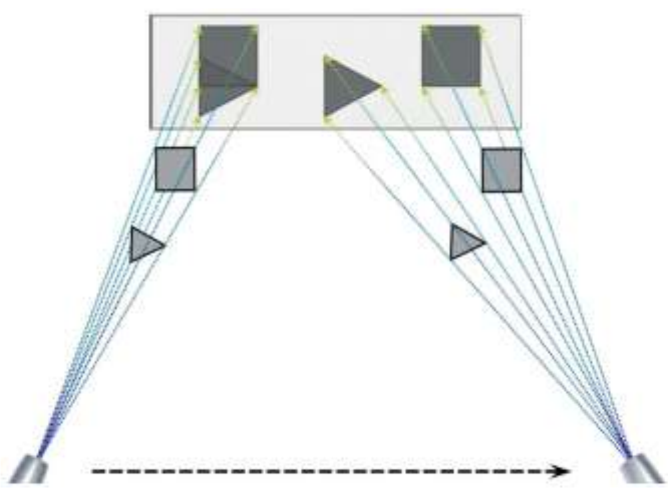
Parallax effect

Parallax is an apparent exaggeration of the relative position of two objects when viewed along two different lines of sight. Given the two-dimensional nature of radiographs, parallax is an important principle in localizing objects within the body. On the basis of a single frontal view, it is impossible to tell the anteroposterior location of an abnormality. However, a second view from a different perspective can be used to localize the object.



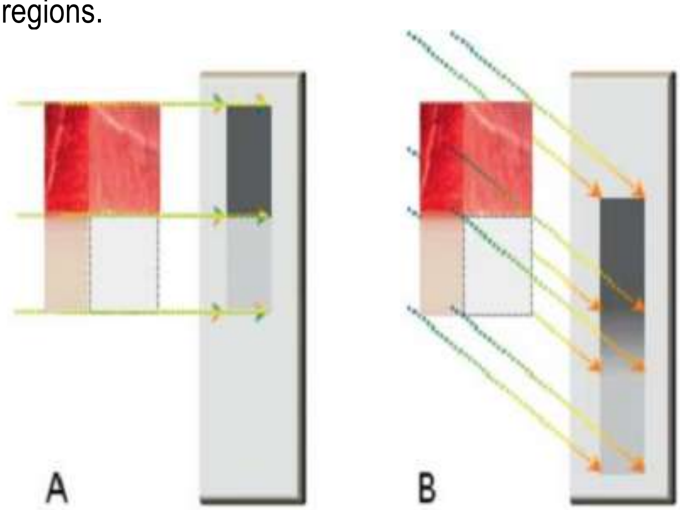
Parallax effect

- The parallax effect allows the separation of the components (overlaid due to addition) in radiographic image and is based on the use of oblique projections.
- In order to separate two overlapping structures located in different planes it is necessary to change the incidence of the X-ray beam through the respective region. This goal can be achieved by two methods: moving the X-ray tube or repositioning the patient.



Tangential incidences

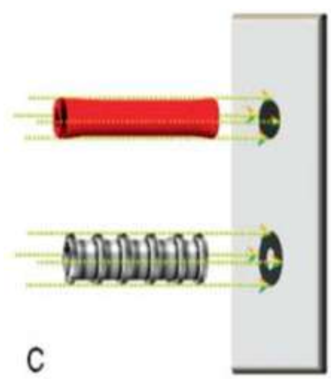
- The angle of incidence of the X-rays on the region separating structures with different attenuation capacity influences the clarity of the visualized details.
- Thus, tangential (parallel) rays to the surface separating two regions with different attenuation coefficients will generate a well-defined contour in the radiological image, while the oblique incidence of X-rays is associated with loss of clarity of the contour of these regions.



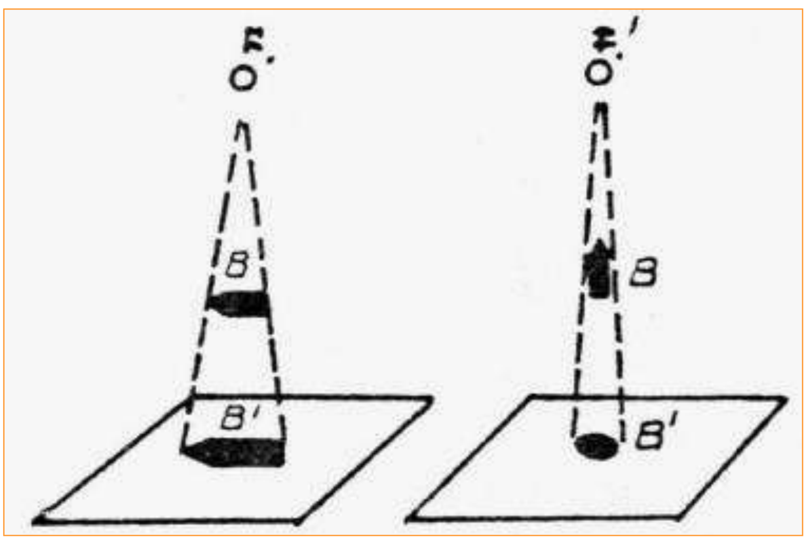
Tangential incidences

- Due to tangential incidences, various anatomical structures can generate various shapes in the radiographic image depending on the angle of incidence of the X-rays.when the X-ray beam is oriented parallel to the long axis of a structure, its projection is called **orthograde** (along the axis).

In the radiographic image, some orthograde oriented vessels may be visualized as round opacities, while bronchi in orthograde projection may appear in the form of lucency or annular (ring-shape) opacities, especially in the case of pathologies associated with peribronchial edema.



Tangential incidences



CONTRAST MEDIUM

- A substance used to enhance the contrast of structures or fluids within the body -**CONTRAST MEDIUM (contrast agent).**
- To make structures of similar density visible, contrast media are introduced into the body to absorb more or less X-rays compared to native anatomical structures.

CONTRAST MEDIUM

(contrast agent)

- **positive media**
- **negative media**

CONTRAST MEDIUM

- ***Positive contrast media*** and the body's soft tissues contain a similar number of atoms per unit volume. Some atoms in the contrast medium (e.g. iodine or barium) have a much higher atomic number than those of the soft tissues (hydrogen, carbon, nitrogen, oxygen). A higher atomic number is generally associated with an increased ability to attenuate X-rays.

CONTRAST MEDIUM

- ***Positive contrast media***
  - ***water insoluble*** contrast media, an aqueous suspension of in soluble crystals of Barium Sulphate
  - ***water soluble*** contrast media, which in clinical practice today means water solutions of organic compounds with iodine covalently bound to an aromatic structure (Isopaque, Urografin, Angiografin, Gastrografin, Omnipaque, Ultravist..)
  - ***oily (fat-soluble)*** contrast medium (Lipiodol)

CONTRAST MEDIUM

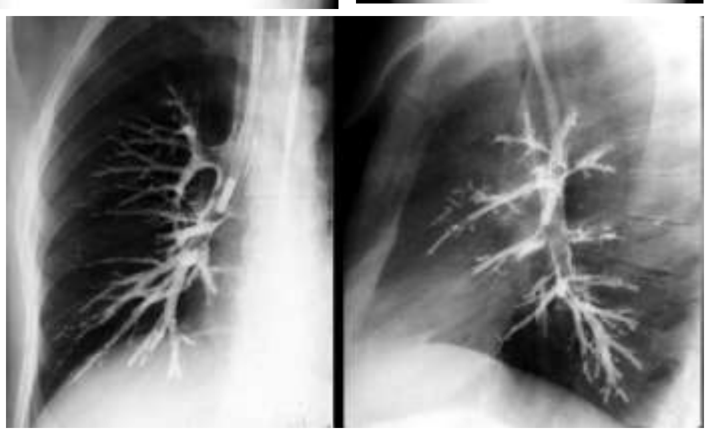
- ***Negative contrast media*** (air, oxygen, nitric oxide (N_2O) or carbon dioxide (CO_2) and other gases) attenuate X-rays less than the soft tissues of the body, because a gas (the negative contrast medium) contains per unit volume a much lower number of radiation attenuating atoms than the patient's soft tissues.

CONTRAST MEDIUM

RADIOLOGICAL METHODS USING CONTRAST MEDIUM

- **Angiography**
- **Bronhography**
- **Colecystography, colangiography**
- **Oral Barium Sulphate, Barium Enema**
- **Limfography**
- **Arthrography**

Bronhography



Pulmonary angiography

Angiography

Barium enema

Double contrast – usage of two different contrasts, radiopositive (Barium Sulphate) and radionegative (air)

CONTRAST MEDIUM

Iodinated contrast media adverse reactions

- **Acute contrast reaction** (within 60 minutes)
  - Mild (nausea, vomiting, flushing, pruritus, mild urticaria, and headache)
  - Moderate (marked urticaria, severe vomiting, bronchospasm, facial edema, laryngeal edema, and vasovagal attacks)
  - Severe (progression of the moderate symptoms and are life-threatening, e.g. respiratory arrest, cardiac arrest, pulmonary edema, convulsions, and hypovolemic shock)
- Treatment depending on symptoms includes administration of antihistamines, epinephrine, beta-2-agonists, corticosteroids.

CONTRAST MEDIUM

Iodinated contrast media adverse reactions

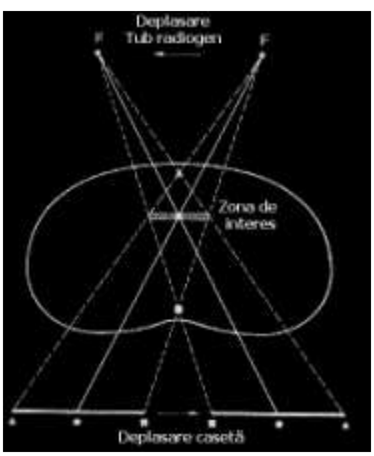
- **Acute contrast reaction** (within 60 minutes after the contrast administration)
  - Mild (nausea, vomiting, flushing, pruritus, mild urticaria, and headache)
  - Moderate (marked urticaria, severe vomiting, bronchospasm, facial edema, laryngeal edema, and vasovagal attacks)
  - Severe (progression of the moderate symptoms and are life-threatening, e.g. respiratory arrest, cardiac arrest, pulmonary edema, convulsions, and hypovolemic shock)
- Treatment depending on symptoms includes administration of antihistamines, epinephrine, beta-2-agonists, corticosteroids.
- Delayed contrast reaction (between one hour to one week after the contrast administration): angioedema, erythema.

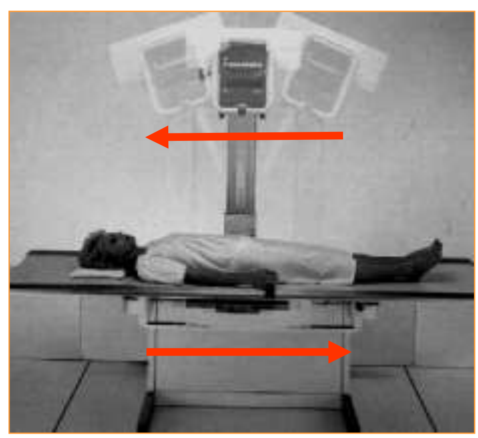
Radiological tomographic modalities

- **The word "tomography" means "the image of a section";**
- **Unlike standard radiography, where all 3 mandatory components (radiogenic tube, patient, detector device) are immobile during the examination, in tomographic methods only the patient remains immobile;**
- **Radiographic tomographic methods include:**
  - **Linear Tomography (plane, conventional)**
  - **Tomosynthesis**
  - **Computed Tomography**

Linear Tomography

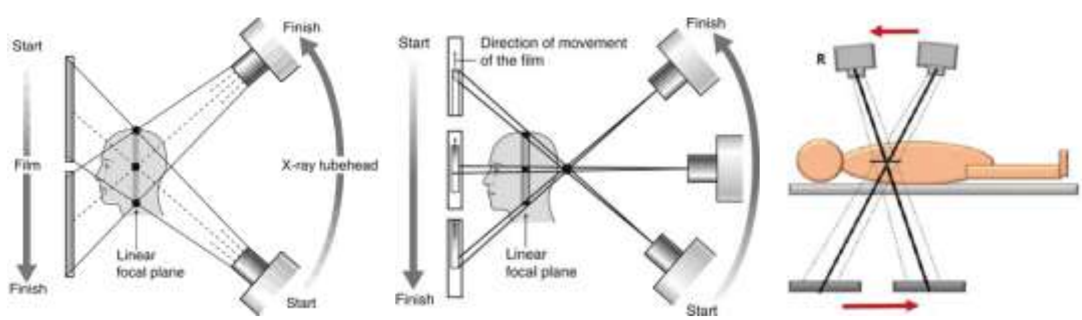
- Allows tissue section radiographs. During the exposure, the X-ray tube and the film move synchronously in opposite directions, pivoting around a fixed point. The chosen pivot point remains stationary during the whole motion.



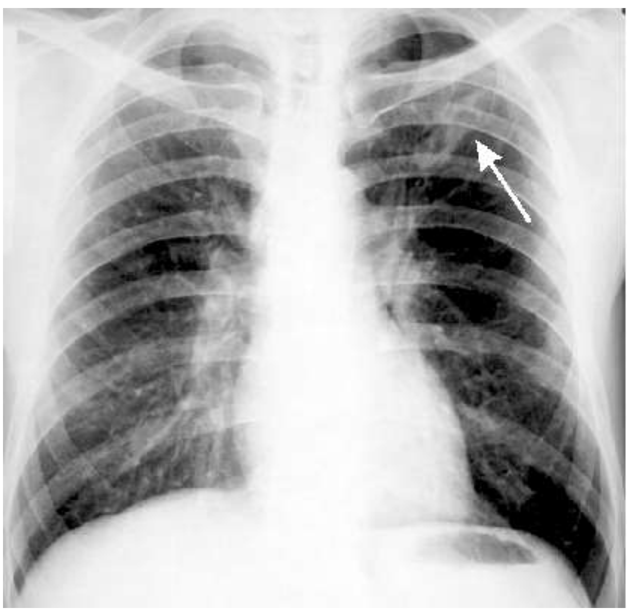


Linear Tomography

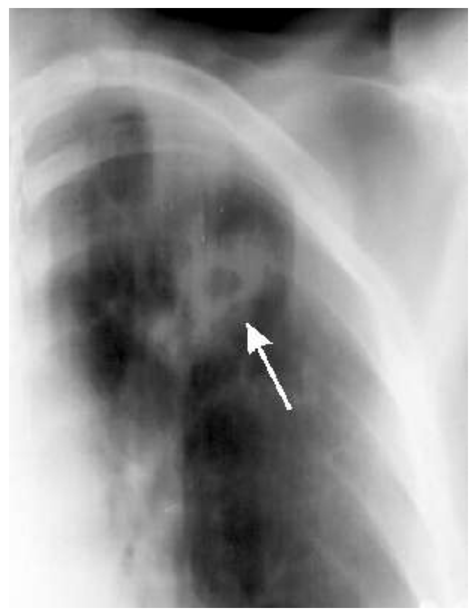
- Thus, only the structures located in the chosen plane will be projected in the same place on the screen, forming an image with a good sharpness, while the structures located in front or behind the chosen plane, will be projected successively in different places of the screen and will form a blurred image.
- Changing the position of the fixed point changes, the section of another plane is obtained.



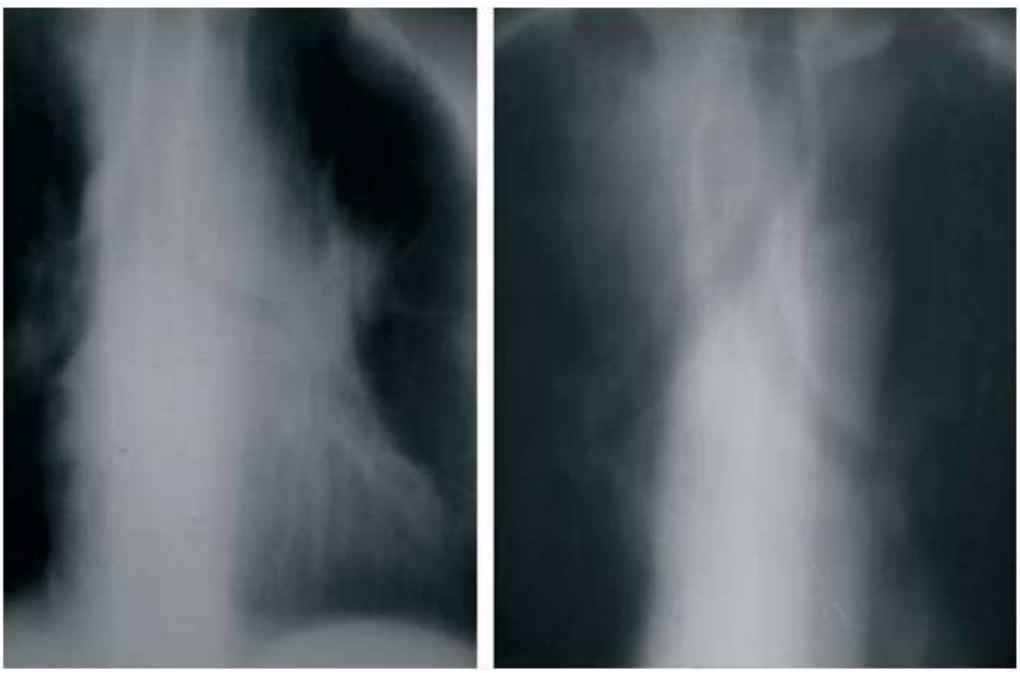
Linear Tomography



Chest radiograph



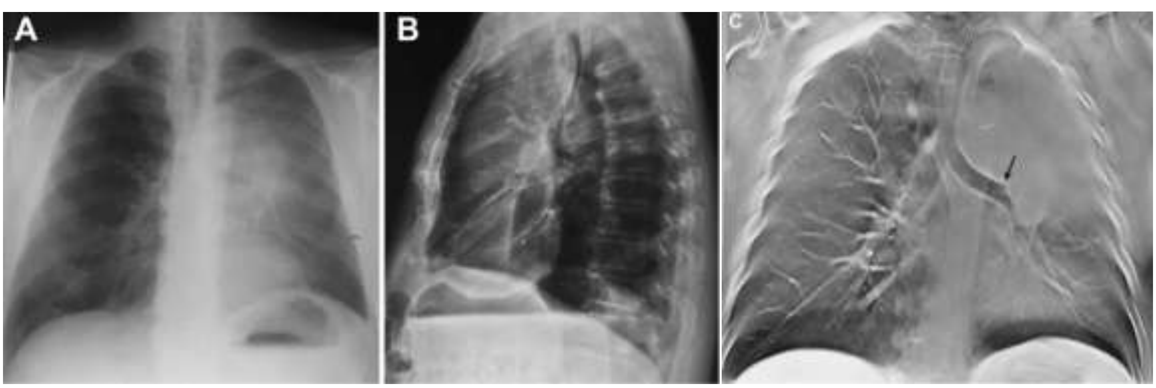
Linear Tomography



Linear Tomography of the mediasinum (different patients). Of all the structures visualized, the satisfactory sharpness is seen only at the level of the trachea.

Tomosynthesis

- At present, linear tomography is almost no longer used, but its principle is the basis of the tomosynthesis method.
- In tomosynthesis, a series of linear tomographies are performed at a predefined depth, with a fixed distance between sections, in a single acquisition.
- The information is digitally processed, creating a high quality final image.

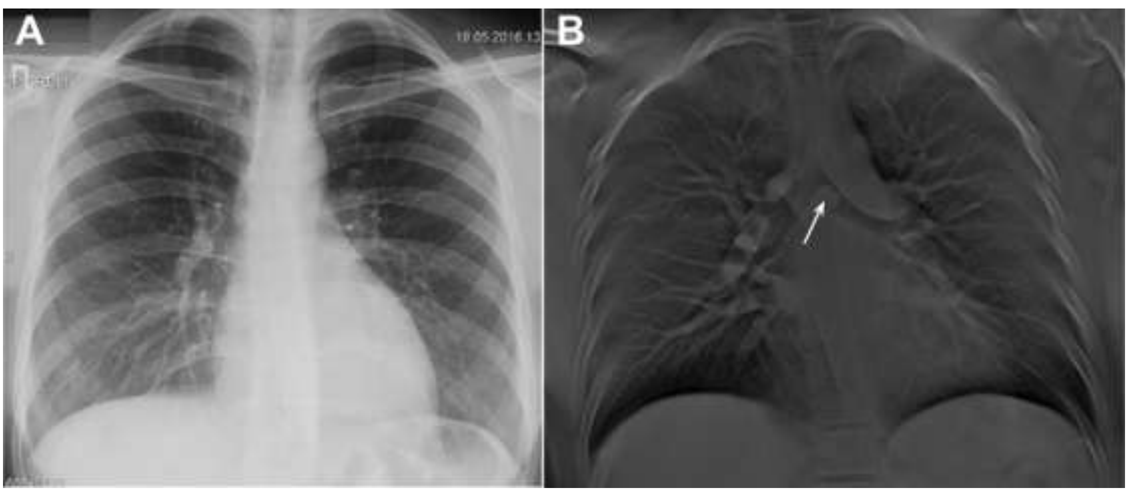


Tomosynthesis

- Tomosynthesis is used to examine different structures:
  - **Chest** (the tracheobronchial tree, detection of pathological lung nodules);
  - **Bones** (bony tumors, vertebral fractures, bony consolidation assessment, bone grafts assessment);
  - **Mammary glands** (especially for tumor detection);
  - In **dental imaging**; etc.

- Compared to computed tomography, in tomosynthesis the radiation doses are much lower, artifacts from metal implants are missing. The resolution is higher in the sagittal and coronal plane, but lower in the axial plane.

Tomosynthesis

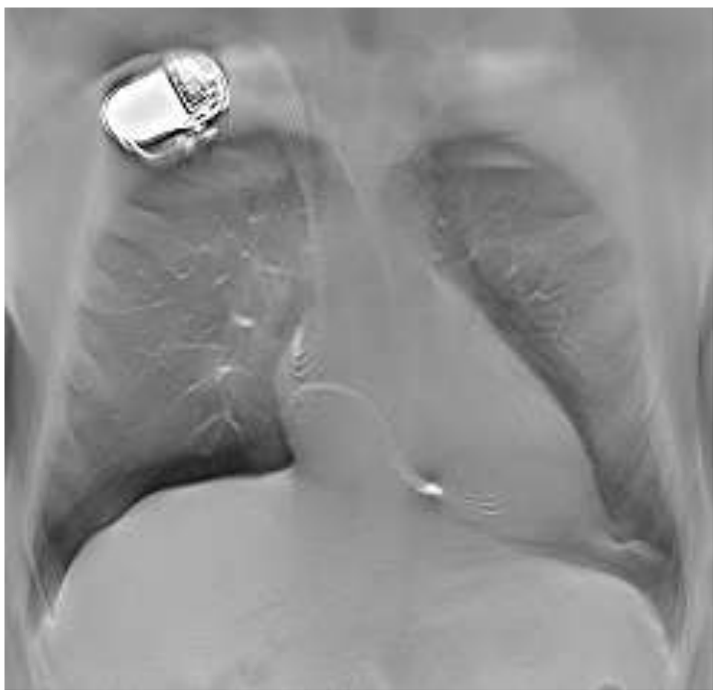


29-year-old patient with dyspnoea. Chest radiography (A) appears relatively normal, while thoracic tomosynthesis (B) reveals a 1.7 cm lesion that obstructs the left main bronchus (arrow).

Tomosynthesis

Reduction of the height of the L2 vertebral body, with its deformation, reduction of the intervertebral space, osteophytes pronounced on the left lateral contour

Tomosynthesis



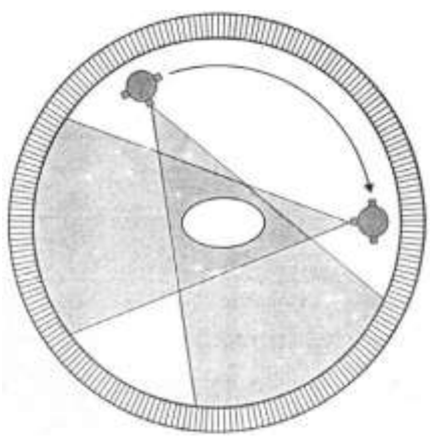
Pacemaker and the absence of metal artifacts

Computed Tomography

- During the examination, the patient lies on his back on the investigation table, which, at the level of the examination region, is placed in a ring, called the gantry, inside which are the tube and the detectors.

Computed Tomography

- The X-ray tube emits a sharply collimated fan beam of X-rays which passes the patient and reaches an array of detectors. The X-ray tube rotates around the patient.



CT was introduced in 1971 by **Godfrey Hounsfield**

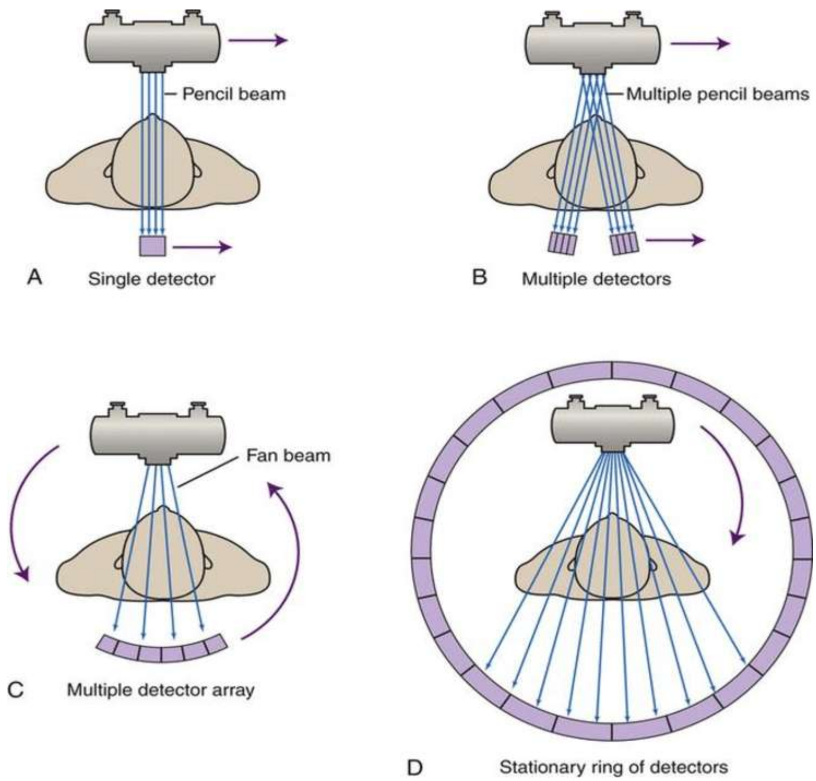
•**First generation**
one detector
tube-detector movements: translate-rotate
duration of scan 25-30 mins

•**Second generation**
multiple detectors
tube-detector movements: translate-rotate
duration of scan less than 90 sec

•**Third generation**
multiple detectors arranged in an arc
tube-detector movements: rotate-rotate
duration of scan approximately 5 sec

•**Fourth generation**
multiple detectors(more than 2000) arranged in an outer ring which is fixed
tube-detector movements: rotate-fixed
duration of scan few seconds

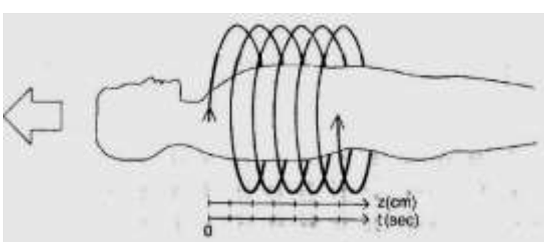
Other CT technologies:
Spiral and **multislice** technologies used in all modern CT machines.
Dual energy CT - uses two separate x-ray energy spectra, distinguishing materials that have different attenuation properties at different energies
Fifth Generation: Scanning Electron Beam

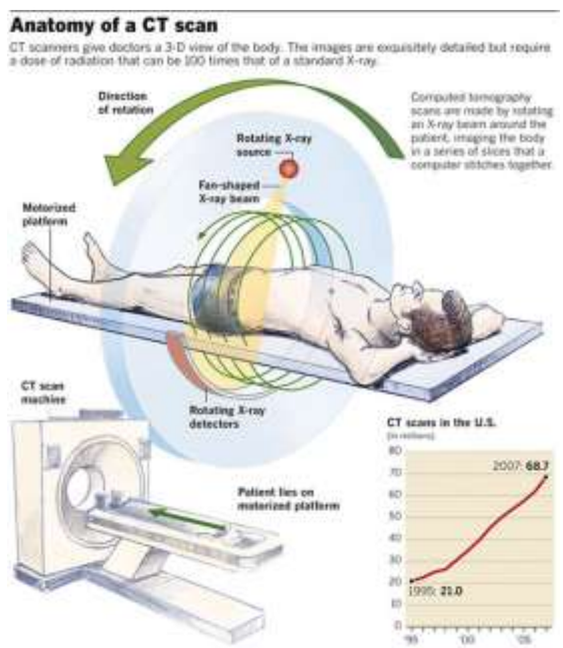


CT generations

Spiral CT

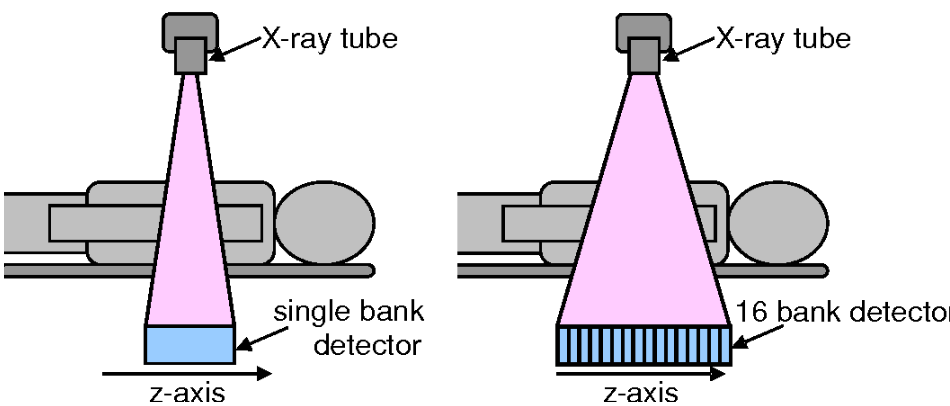
In spiral computed tomography, the X-ray tube in the gantry rotates continuously around the patient, and the table with the patient moves through the X-ray beam plan rotation.

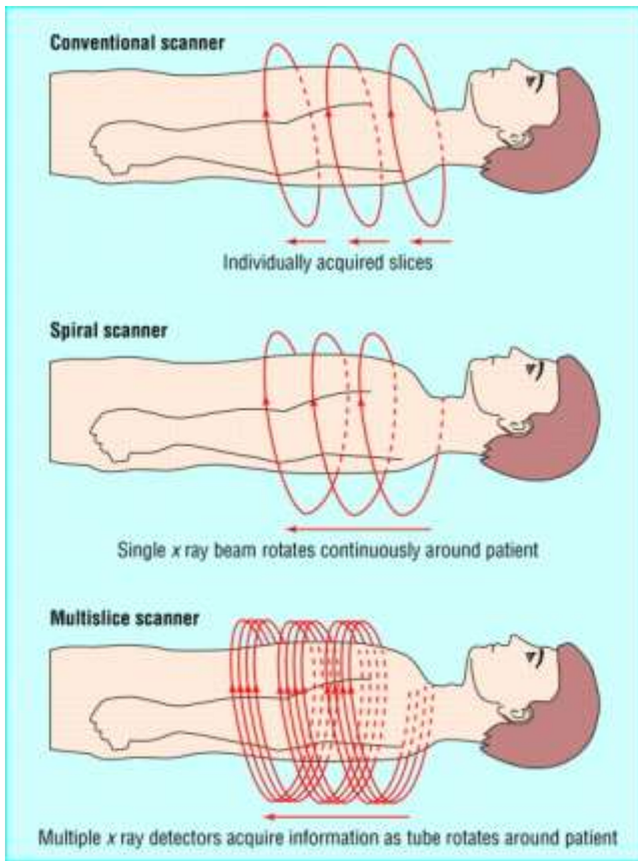




Multislice CT

Multislice or **multidetector** CT scanners, capable of imaging multiple simultaneous, parallel slices in a single rotation.




Conventional scanner
Individually acquired slices
Spiral scanner
Single x ray beam rotates continuously around patient
Multislice scanner
Multiple x ray detectors acquire information as tube rotates around patient

Computed Tomography

TERMINOLOGY:

- **High dens structures – hyperdense (hyperdensity)**
  - **bones, calcification, metallic foreign bodies**
- **Low dens structures – hypodense (hypodensity)**
  - **air**

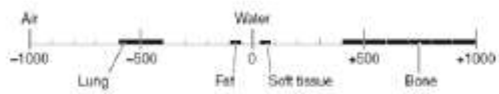
Computed Tomography

- CT shows the density distribution displayed as a digital image
- CT allows the detection of more than 2000 shades of gray (radiodensities);
- Radiodensity is measured in Hounsfield Units (UH) and forms the Hounsfield scale (the radiodensity scale).
- Radiodensity:

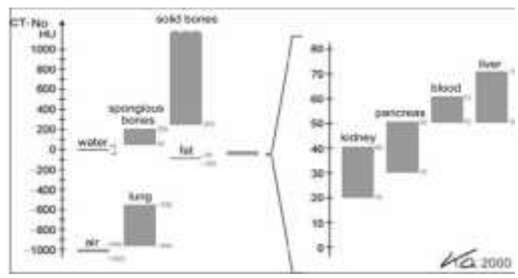
  Water = 0 UH
  Air = -1000 UN
  Bones = +1000.

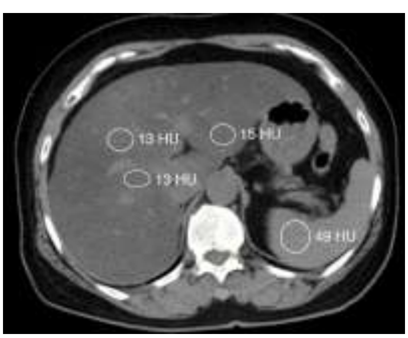
Density of each structure can be assessed quantitatively and expressed in UH.

Hounsfield scale



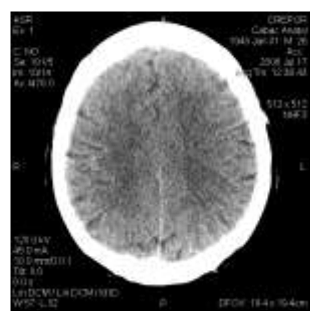
Bone	+400 → +1000
Soft tissue	+40 → +80
Water	0
Fat	−60 → −100
Lung	−400 → −600
Air	−1000



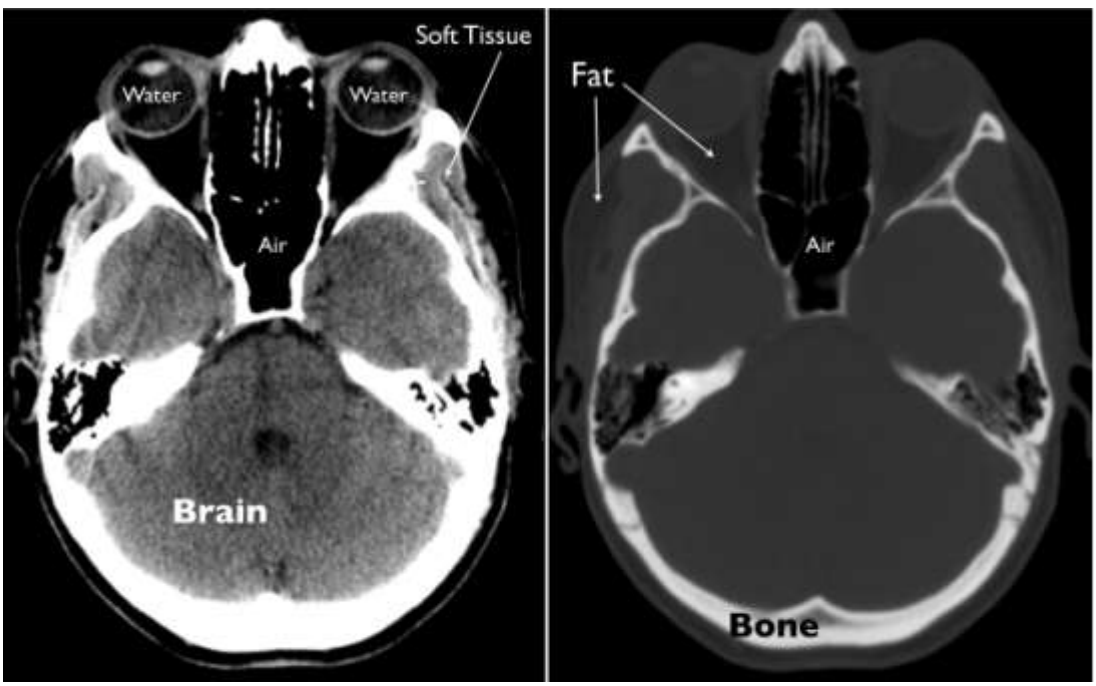


RADIOLOGY

Computed Tomography

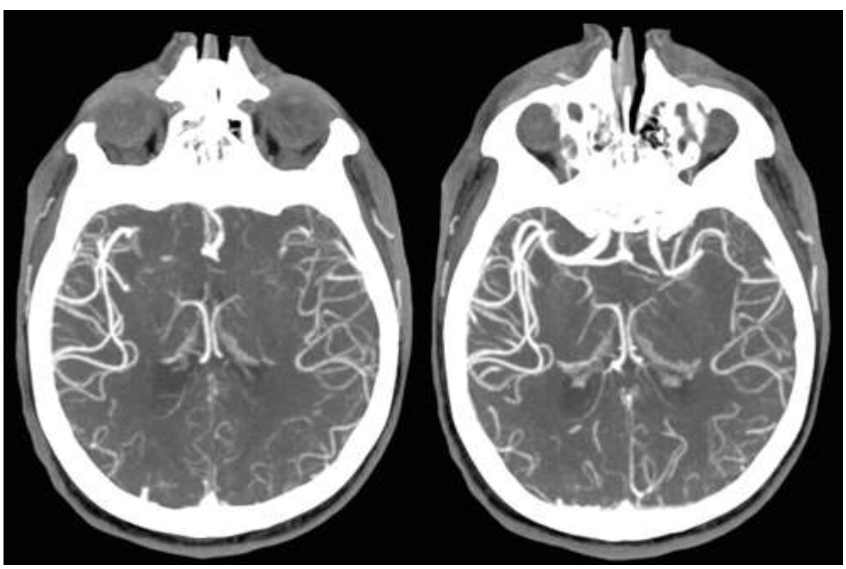


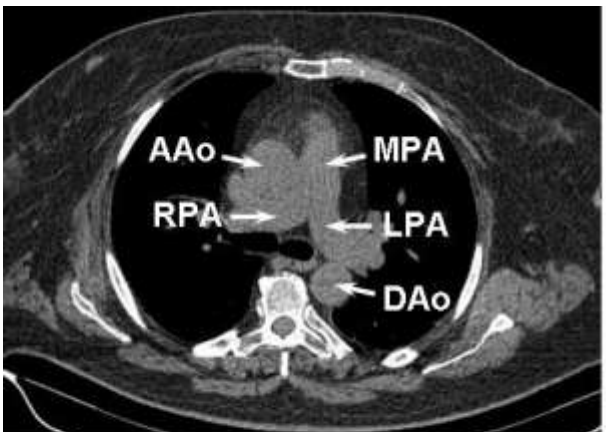
Tomografia computerizată

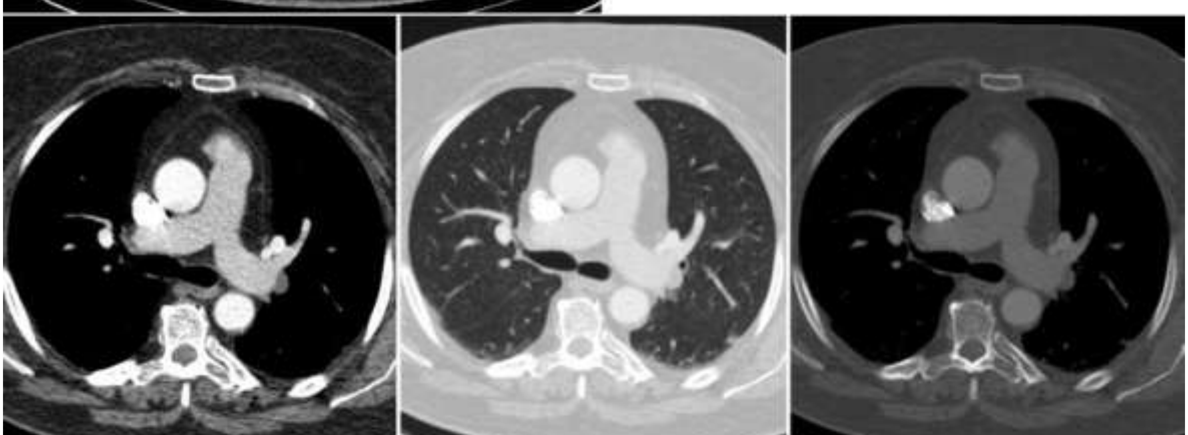


RADIOLOGY

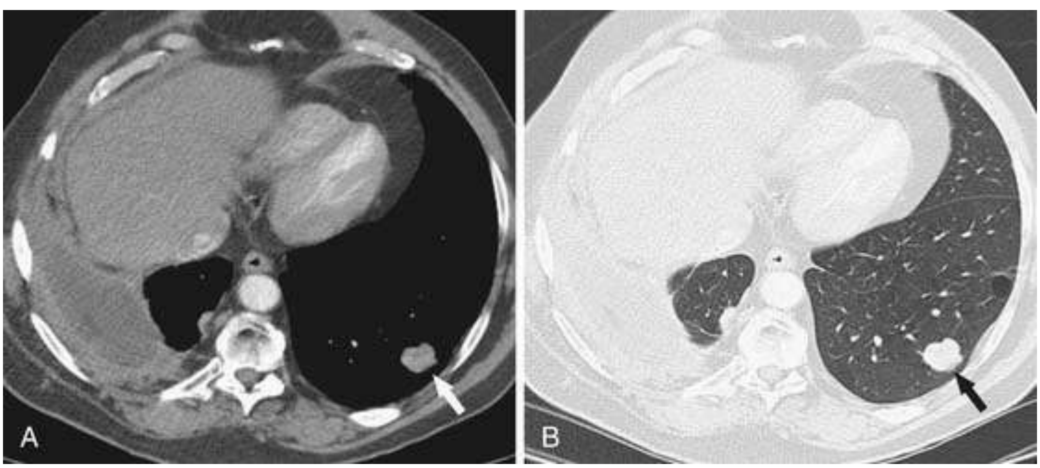
CT-Angiography





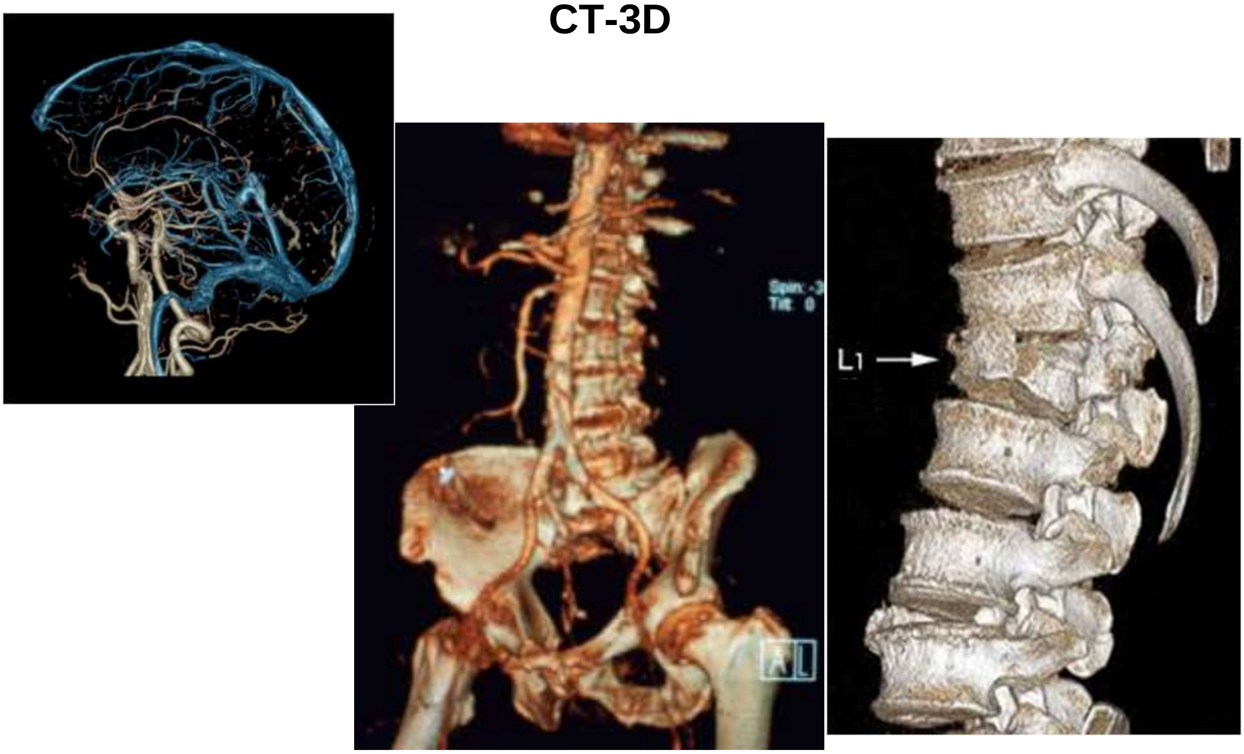


Mediastinal window | Pulmonary window | Bony window


A
B

Computed Tomography

CT-3D



Computed Tomography

CT-3D