Introduction to Radiological Imaging

Dr. Tamara Muayad
Radiologist
General terms...

- **Radiograph** :- An image of a patient’s anatomic part(s), as produced by the action of *x-rays* on an image receptor...

- If the radiograph is produced with the use of traditional film-screen (analog technology) the image is captured and displayed on film..

- If the radiograph is produced via (digital technology), the image is viewed and stored on display monitors.
Radiographic positioning :-

refers to the study of patient positioning performed for radiographic visualization of specific body parts on image receptor ...
This is the traditional method that is often referred to as film-based radiography.

The need for processing chemicals, the use of a dark room, the need for human resources, as well as the difficulty to maintain high quality images are all factors that limit the wide-scale use of this method.
Analog technology ...
digital (computed) imaging technology...

- This technology eliminates the need for dark-room and chemical processing of the film, since **reusable phosphor plates** are used as image receptors and are scanned by CR reader (digitizer with laser scanner).

- The laser scanner (CR-reader) converts the stored information into digital images. The image receptor then erased prior to the next use.
Digital technology...
- **Radiography** :- The process and procedures of producing a radiograph.

- **Image receptor (IR)** :- a device that changes the x-ray beam that pass through patient's body into a visible image. An image receptor may be a radiographic **film and cassette** or a special **detector** placed in a table...
Look to the detector...

Projectional radiography

X-ray generator

Object

X-ray detector

Radiograph
Look to the cassette & film...

- X-ray machine
- X-rays (invisible)
- X-ray cassette holds the x-ray film

X-rays passing through hard tissue like bone (more dense) meet more resistance and leave a lighter image on the film.

X-rays passing through soft tissue like skin and muscle meet little resistance (less dense) and leave a darker image on the film.
Central ray (CR) :– refers to the centermost portion of the x-ray beam emitted from the x-ray tube (the portion of the x-ray beam that has the least divergence).
A radiologic technologist is shown positioning a patient for a routine chest examination as shown in the figure below.
A radiographic examination involves 5 general functions:–

1. Positioning of body part and alignment with the IR and CR
2. Application of radiation protection measures and devices
3. Selection of exposure factors.
4. Instructions to the patient related to breathing and initiation of the x-ray exposure
5. Processing of the IR

- **Film-based** >>> chemical processing (analog technology)
- **Computer based** >>> digital processing (digital technology)
The anatomic position: –

is a reference position that defines specific surfaces and planes of the body.

The anatomic position is an upright position with arms abducted slightly (down), hands by side with palms forward, head and feet together and directed straight ahead ...
Anatomic position
Positioning terms that describe Central ray angles or relationships between body parts often are related to imaginary planes that pass through the body in the anatomic position.

The study of CT, MRI and sonography emphasizes sectional anatomy, which also involves the primary body planes and sections as described subsequently.
Plane ...

- It is a straight line connecting two points.
- Four common planes as used in medical imaging are:
  1. Sagittal >>> green color
  2. Coronal >>> purple color
  3. Axial (horizontal) >>> light blue color
  4. Oblique >>> orange color
planes...

- **A sagittal plane** is any longitudinal plane that divides the body into right and left parts..

- **Coronal Plane** is any longitudinal plane that divides the body into anterior and posterior parts...

- **Horizontal (Axial) Plane** is any transverse plane that passes through the body at right angles (90 degree) to longitudinal plane, dividing the body into superior and inferior portions..

- **Oblique Plane** is a longitudinal or transverse plane that is at an angle not parallel to the sagittal, coronal, or horizontal plane.
Body sections are divided by planes

- Sagittal plane (median plane)
- Transverse plane (horizontal plane)
- Coronal plane (frontal plane)
Sections ...

- **Longitudinal Sections**: These sections or images run in the direction of the long axis of the body or any of its parts, regardless of the position of the body (erect or recumbent).

- **Transverse or Axial Sections (Cross-Sections)**: Sectional images are at right angles along any point of the longitudinal axis of the body or its parts (Fig. 1.40).
Body Surfaces...

- Terms of the back and front of the body:
  - **Posterior or Dorsal:**
    - Refers to the back half of the patient, or the part of the body seen when the person is viewed from the back as demonstrated in the anatomic position. (colored purple)

- **Anterior or Ventral:**
  - Refers to the front half of the patient, or the part seen when viewed from the front in the anatomic position. (colored tan)
Terms of surfaces of the feet :-

- **Plantar surface:** refers to the sole or posterior surface of the foot.
- **Dorsal surface:** refers to the dorsum or anterior surface of the foot.
Terms of surfaces of the hand:-

- **Dorsal surface** :- refers to the back or posterior aspect of the hand..

- **Palmar surface** :- refers to the palm of the hand in the anatomic Position..
Radiographic Projections...

- **Projection**: is a positioning term that describes the path of the cr of the x-ray beam as it passes through the patient, projecting an image onto the IR.

- Although the term *position* is used in the clinical setting, the term *projection* is considered to be the most accurate term for describing how the procedure is performed.
Posteroanterior Projection (PA) –

(PA) projection refers to a projection of the CR from posterior to anterior.

Combines these two terms, posterior and anterior, into one word, abbreviated as PA.

The CR enters at the posterior surface and exits at the anterior surface (PA-projection).
Anteroposterior Projection (AP) :-
(AP) projection refers to a projection of CR from anterior to posterior,
Combines these two terms, anterior and posterior, into one word.
Describes the direction of travel of the CR, which enters at an anterior surface and exits at a posterior surface (AP–PROJECTION)...
Specific body positions

- In addition to a general body position, the second way the term position is used in radiography is to refer to a specific body position described by the body part closest to the IR (oblique and lateral) or by the surface on which the patient is lying (decubitus).
Lateral Position:– refers to the side view. A true lateral position is always 90° to a true AP or PA projection. If it is not a true lateral, so, it is an oblique position.

Specific lateral positions:– described by the part closest to the image receptor (IR)...

- A right lateral position is shown
- with the right side of the body
- closest to the image receptor (IR)
- in the erect position..
The position is named according to the surface on which the patient is lying (dorsal or ventral) and by the side closest to the IR (right or left).

The projection is named according to the pathway of the CR.
Introduction to Radiology

Radiology is the use of radiation for different types of “imaging”. Creating an image of the inner configuration of a dense object, such as parts of human body, with the use of radiant energy.
Imaging(techniques) includes:

- X-ray
- Ultrasound (U/S or US)
- Computed Tomography (CT) scan
- Magnetic Resonance Imaging (MRI)
X-Ray
Ocular Ultrasound
CT scan
MRI
A radiologist reads an image to detect abnormalities such as tumors, in order to achieve an accurate diagnosis. Medical facilities that do not have a radiologist must send the image out for interpretation and await the findings.

Obtaining high quality images can be difficult when a patient is in pain or ill, so a radiologist or imaging technician must have an excellent bedside manner.
The radiologist must to comfort the patient, keeping him calm, and explain radiology procedures to reduce the patient's anxiety, also insure that X-rays or other imaging techniques are not risky for a patient, for example, a pregnant woman. A technician must also protect himself and the patient from the dangers associated with radiation.
The accurate detection and localization of intraocular foreign body is critical component in preoperative ophthalmological treatment and surgical planning.

Cataract or intraocular hemorrhage prevent adequate direct ophthalmological evaluation, and the ophthalmologic surgeon must rely on available imaging techniques for the detection of intraocular foreign bodies.
X–Ray Properties

- X–rays are invisible electromagnetic radiations composed of small packets of energy called photons.
- X–rays travel at speed of light and in straight lines.
- They are highly penetrating.
- They blacken radiographic films
How does X-ray imaging work?

To obtain an x-ray image, the part of the patient to be X-rayed is placed between the X-ray source and the image receptor to produce a shadow of the internal structure of that particular part of the body.
Projectional radiography

- X-ray generator
- Object
- X-ray detector
- Radiograph
How does X-ray imaging work?

- The interpretation of an x-ray film requires sound anatomical knowledge, and an understanding that different tissue types absorb x-rays to varying degrees:
  - Air: this will appear black because the X-rays can easily penetrate air.
  - Fat: fat will not be completely penetrated and will appear faintly on film.
  - Soft tissues: this medium will appear more white than fats on X-rays due to its increased density.
  - Bone (calcium): bony/calcified structures show up the most clearly on X-rays (bright white!) because the X-rays have difficulty penetrating these structures.
Densities on x-ray

1. Air
2. Fat
3. Water (Organ/Soft tissue)
4. Calcium (Bone)
5. Metal
THANK YOU
STANDARD ORBITAL VIEWS

Dr. Tamara Muayad
Radiologist
RADIOLOGIC PRINCIPLES

• Radiology: is a medical specialty that uses imaging to diagnose and treat diseases seen within the body, by a variety of imaging techniques such as X-ray, ultrasound, computed tomography (CT), nuclear medicine including positron emission tomography (PET), and magnetic resonance imaging (MRI).
• Because the orbit is close proximity to the larger bones of the skull, multiple shadows overlap one another and obscure some radiographic details.

• Numerous radiographic projections have been developed to evaluate the bony structures of orbit and face.
RADIOLOGIC PRINCIPLES

• These various projections attempt to eliminate overlapping shadows and allow for better details of the bony orbit.
• For maximal image clarity, the distance from the object to the x-ray cassette should be minimized and the distance between the subject and the x-ray beam maximized.
• In any projection, the image detail is maximized using the minimal distance from the subject and the x-ray cassette.
RADIOLOGIC PRINCIPLES

• A. anterior to posterior projection demonstrating decreased clarity and definition of anterior structures.
• B. posterior to anterior projection showing improved clarity of the anterior structures, such as the orbital rim and frontal sinus.
Anterior to posterior projection
Posterior to anterior projection
STANDARD ORBITAL PROJECTIONS/VIEWS

A standard radiographic study of the orbit and paranasal sinuses consists of the following views:
1- waters projection (occipitomental OM).
2- caldwell projection (occipitofrontal OF).
3- lateral projection.
4- basal projection (submento-vertex).
5- oblique apical projections (Rhese view or optic foramen).
WATERS (occipitomental) PROJECTION

• This view was used to improve the visualization of the maxillary and ethmoidal sinuses, that eliminated the overlapping shadows of the dense petrous ridge of the temporal bone which lies below the maxillary sinus.
WATERS PROJECTION

Waters projection is created by:

1- placing the chin of the patient on the cassette.
2- the canthomeatal line at 37-45 degrees.
3- patients nose is 0.5-1.5 cm above the x-ray plate.

as if the patient raises the chin up to sip water.
WATERS PROJECTION

[Diagram of a skull showing the Waters Projection with angles and lines indicating the C.R. and Mentomeatal line.]
WATERS PROJECTION

Waters projection is created by placing the chin of the patient on the x-ray cassette with the canthomeatal line (CM) or orbitomeatal line (OML) (the line that connects the lateral canthus and the external auditory meatus) at 37 degrees to 45 degrees.

- a: frontal sinus
- b: medial orbital wall
- c: innominate line
- d: inferior orbital rim
- e: orbital floor
- f: maxillary antrum
- g: superior orbital fissure
- h: zygomatic-frontal suture
- i: zygomatic arch
WATERS PROJECTION

- Waters view provides the best image of the maxillary antrum(sinus) and good images of the orbital rim, orbital floor, zygomatic bones and arches, lesser wing of sphenoid, and infraorbital foramen.
- Waters view is useful in assessment of orbital floor and maxillary sinus, soft tissue swelling in the roof of maxillary sinus.
Caldwell Projection

- Both the nose and forehead on the x-ray cassette.
- X-ray beam is directed downwards 15-23 degrees to the canthomeatal line.
- The petrous bones inferior to the orbit, thus, avoiding obscuring orbital structures.
- Caldwell view is a PA projection.
The PA projection (Caldwell) is designed to provide a clear view of the frontal and ethmoid sinuses without loss of definition by superimposition of portions of the sphenoidal bone.
CALDWELL PROJECTION
CALDWELL PROJECTION

a: frontal sinus
b: innominate line
c: inferior orbital rim
d: posterior orbital floor
e: superior orbital fissure
f: greater wing of sphenoid
g: ethmoid sinus
h: medial orbital wall
i: petrous ridge
j: zygomatic-frontal suture
k: foramen rotundum
CALDWELL PROJECTION

• Is an excellent view of:

1- frontal and ethmoid sinuses.
2- orbital rims and medial orbital wall.
3- greater and lesser sphenoid wings.
4- lacrimal gland fossa.
5- superior and inferior orbital fissures.
6- The innominate line (a depression on the sphenoid bone formed at the medial wall of the temporal fossa or lateral wall of the orbit).
CALDWELL PROJECTION

OF / PA VIEW
1. Nasal Septum
2. Frontal Sinus
3. Maxillary Sinus
4. Ethmoid Sinus
5. Inferior Turbinate
6. Superior orbital fissure
7. Sagittal suture
8. Coronal suture
9. Sphenoid ridge
10. Mastoid process
11. Hard palate
12. Innominate line
Note that in this projection:

* Petrous ridge is positioned at the orbital floor (the lower 1/3 of the orbits)
LATERAL PROJECTION

• The patients head is placed against the x-ray cassette.
• The cassette is centered on the lateral canthus.
• The x-ray beam is directed perpendicularly to the midpoint of the cassette and enters the patients head at the lateral canthus remote from the cassette.
• Lateral projection provides a view of the sagittal plane of the skull.
• Because of the overlapping skeletal structures, interpretation of unilateral disease processes is difficult.
LATERAL PROJECTION

a: orbital roof
b: frontal sinus
c: ethmoid sinus
d: anterior clinoid process
e: sella turcica
f: planum sphenoidale
The structures that can be identified and best evaluated include:

1- the sphenoid, frontal, ethmoid, and maxillary sinuses.

2- sella turcica.

3- anterior and posterior processes.

4- the cribriform plate.
LATERAL PROJECTION

• The best evaluated orbital structure is the orbital roof.
• The orbital floor is visible but difficult to be evaluated.
• The lateral projection gives information concerning air-fluid levels in traumatized patients, when only a horizontal projection is possible.
BASAL PROJECTION
(SUBMENTO-VERTEX)

• Used for evaluation of sphenoid sinus and skull base.
• The patients neck extended either in supine or upright position.
• The top of the head is placed so that the infraorbitomeatal line is parallel with the x-ray cassette.
• X-ray beam is directed perpendicular to the infraorbitomeatal line.
BASAL PROJECTION
BASAL PROJECTION

- a: zygomatic arch
- b: orbit
- c: lateral orbital wall
- d: posterior wall of maxillary sinus
- e: pterygoid plate
- f: sphenoid sinus
BASAL PROJECTION

• This view shows the lateral walls of the orbit and maxillary sinuses well.
• The nasopharynx, pterygoid plates, pterygopalatine fossa, and the sphenoid and ethmoid sinuses may also be inspected.
• Because of the extreme head position, any history of neck injury is contraindicated to this projection.
OBLIQUE APICAL PROJECTION
RHESE POSITION (OPTIC FORAMEN)

- The oblique apical projections of the optic canals are additional views available if there is clinical evidence of posterior orbital pathology, such as traumatic orbital neuropathy or optic nerve tumors.
- Used for evaluation of the ethmoid sinuses and the optic foramen.
RHESE POSITION

)OPTIC FORAMEN(

• Zygoma, nose, and chin should touch the cassette.
• X-ray beam is directed PA at 40 degrees the midsagittal plane.
• Optic canal is the inferolateral quadrant of the orbit and oriented perpendicular to the x-ray.
• Assessment of the orbital apex (optic foramen, optic strut, and upper ethmoid sinus).
• Landmark for finding the foramen is to find the planum sphenoidale, the optic foramen lies at its lateral end.
• Optic canal may be evaluated for expansion or compression by disease processes, such as optic nerve tumors and trauma.
• CT and MRI show much better details, therefore; have replaced the use of plain films for evaluation of the optic canal.
RHESE POSITION

a: right optic canal
b: optic strut
c: superior orbital fissure
d: ethmoid sinus
e: planum sphenoidale
f: greater wing of sphenoid
RADIOGRAPHIC CHANGES WITH ORBITAL PATHOLOGY

Dr. TAMARA MUAYAD/ RADIOLOGIST
• Plain film provide excellent images of the bony structures of the orbit and face.

• As mentioned previously, the orbital roof consists of the orbital plate of the frontal bone and the lesser wing of the sphenoid.

• The lateral projection gives the best view of the roof.

• Pathology in the frontal sinus, is located between the orbits anteriorly, and roof of the orbit and even cause bone displacement of the eye.

• Isolated orbital roof fractures in adults are uncommon, comprising 12-19% of all orbital wall fractures. Most roof fractures are associated with other orbital fractures and result from significant head trauma, as a high degree of force is required to fracture this portion of the orbit.
• The orbital floor consists of the maxillary, zygomatic, and palatine bones.
• **Waters view** is best image of the anterior and middle portion of the floor, because extension of the neck brings the floor into a position that is tangential to the x-ray beam.

• The floor is represented by the most inferior radiopaque line, whereas the orbital rim will be the line above it. The vertical distance between these lines should be approximately 1 cm. This relationship between the floor and the orbital rim should be symmetric between the two orbits. Any asymmetry should suggest a fracture of the orbital rim or floor.
Figure 1 (a & b) Blowout fracture (a traumatic deformity of the orbital floor or medial wall). Muscles/fats herniate down into the maxillary sinus. Results in a ‘teardrop’ of soft tissue in the roof of the maxillary sinus.
Figure 2 Blowout fracture on the left side compared to normal orbital floor with Waters view (occipitomental (OM))
• **Waters projection** also gives the best information on the anterior medial wall because of the more superior location of the anterior structures, whereas the posterior wall is obscured by the overlying nasal bones.

• Opacification of the ethmoid and maxillary sinuses, as in sinusitis prevents reliable assessment of the bony detail of this wall because of loss of contrast.
Figure 3 (a) A ten month old infant with complete opacification of the right maxillary sinus and partial opacification of the left maxillary and ethmoid sinus cavities.

Figure 3 (b) After therapy, all sinus cavities are clear.
The Caldwell view of the floor gives the best information concerning the posterior orbital floor, this is because the posterior floor is more tangential to the x-ray beam.

The orbital floor and maxillary sinus can be adequately evaluated by using both the Waters and Caldwell views.
Figure 4 a motor vehicle accident, sustained a right orbital floor fracture. Soft tissue density (arrow) located in the roof of the maxillary sinus. Disruption of the orbital floor is seen at the fracture site (Caldwell view).
• Fractures of the lateral orbital wall can occur from blunt trauma to the malar prominence.

• The zygomatic complex fracture (tripod) results from separation of the zygomatic-frontal, zygomatic-temporal, and the zygomatic-maxillary sutures. These fractures are associated with an inferior displacement of the malar prominence and a rounded lateral canthus.

• Caldwell projection provides a detailed image of the posterior medial orbital wall. This wall is thin but the air cells of the ethmoid sinus provide a clear contrast, and, therefore, a distinct image of the posterior portion can be achieved. These air cells hinder the evaluation of the anterior medial wall because of superimposition.
Figure 5 A tripod fracture (zygomatico-maxillary complex fracture). Right zygoma is inferiorly displaced.

a: zygomatic-frontal suture separation
b: orbital rim disruption
c: opacification of maxillary sinus
• **Orbital emphysema** may result from disruption of an orbital wall that is adjacent to the paranasal sinuses. The detection of air in the orbit is increased if the patient's radiologic studies are performed in the upright position.

• Orbital emphysema may be seen in 45% of cases of medial wall fractures and 35% of floor fractures. Loss of vision can occur if this air is forced into the orbit because of sneezing or vomiting and is unable to escape.
Figure 6 Air density around the left superior orbital margin, suggestive of orbital emphysema (Caldwell view)
• **Intraocular calcification** is seen with tumors such as retinoblastoma or with degenerative changes of the lens, choroid, or vitreous (figures 7 & 8).
Figure 7 Caldwell projection of a hemangioma of the left orbit with partial calcification (arrows).
Figure 8 A well defined smooth rim calcified area within the left orbital cavity representing globe calcification. Lens calcification also noted within the calcified globe.
• **Bony destruction** usually results from a rapidly growing process such as a tumor of the lacrimal gland or paranasal sinuses (Figure 9).

• Sinusitis or a mucocele can cause bone destruction or dehiscence of the orbital bones. Mucoceles originate in the frontal and ethmoid sinuses, and destruction of bone is noted radiographically in 70% of cases (Figure 10).
Figure 9 Caldwell projection of a patient with a rhabdomyosarcoma. The superior orbital rim (arrow) with erosion of bone that disrupts the continuity of the orbital margin.
Figure 10 Frontal sinus mucocele to the right orbit. The orbital extension was responsible for downward displacement of the globe in this patient.
• **Hyperostosis of the orbital bones.** The most common causes are meningioma of the sphenoid bone (figure 11), fibrous dysplasia, osteoblastic metastatic disease, or Paget's disease.
Figure 11 Caldwell projection of an optic nerve sheath meningioma of the left orbit. The increased radiodensity is caused by the calcium content of the meningioma.
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Foreign body localization by plain X-ray film
• Foreign bodies of the eye or orbit can be detected with plain films. Although standard radiography should theoretically be able to visualize metallic fragments as small as 0.1 mm by 0.1 mm by 0.1.

• In patients with a high clinical suspicion for an orbital or ocular foreign body, plain radiographs showed a 90% sensitivity for metallic foreign bodies, 71% sensitivity for glass, and lower sensitivities for wood and other materials. Metallic foreign bodies in the cornea showed a particularly high false-negative rate.
CT is regarded as the imaging method of choice to identify suspected foreign bodies in the globe or orbit. A plain films clearly visualized iron, graphite, and glass (containing trace lead) but could NOT distinguish between the three.

CT, not only was able to distinguish between iron, graphite, and glass but was significantly more sensitive to wood and plastic.

Echography and CT have diminished the need for plain film techniques for localization of foreign bodies, but the latter can be used when other imaging modalities are unavailable. Frontal and lateral projections are standard views in these studies (Figure 12).
Figure 12 Foreign body localization using a frontal and lateral projection. A. Caldwell projection of a patient with a gunshot injury to the left orbit. B. Lateral projection with a large metal fragment (arrow) in the orbital apex.
• Localization of a foreign body within the globe is possible with bone-free examination using dental film or by ocular rotation to study localizes the foreign body to either the anterior or posterior segment of the eye.

• If the foreign body is anterior, the object will rotate in the same direction as the eye. The object will move in an opposite direction to eye movement if its location is in the posterior segment of the eye (Figure 13).
Figure 13 Foreign body using the ocular rotation technique. The patient look up, as in A, shows the foreign body moving in the direction of upgaze.
B. Foreign body is seen in an inferior location after the patient looked down. This foreign body was located in the anterior segment of the eye.
Ultrasound

Dr. Tamara Muayad Abdullah/ Radiologist
ALNOOR UNIVERSITY COLLEGE
RADIOLOGY DEPARTMENT
Definition of Ultrasound

- **Ultra** = means beyond in space
- **Sound** = is the sound wave
- **Ultrasound** = beyond the hearing level of sound waves
- Each sound wave has a frequency, humans' ear can hear sounds with frequency ranging from 20 Hz -20,000 Hz so, below 20 Hz is infrasonic and beyond 20K Hz is ultrasonic.
- Medical diagnostic ultrasound waves has a frequency start from 2 Mega Hz to 20 MHz
Sound waves are mechanical longitudinal waves

- **Longitudinal Sound Waves** - A longitudinal wave is a wave in which the motion of the medium’s particles is parallel to the direction of the energy transport. If you push a slinky back and forth, the coils move in a parallel fashion (back and forth).

- **Mechanical Sound Waves** - A sound wave moves through air by displacing air particles in a chain reaction. As one particle is displaced from its equilibrium position, it pushes or pulls on neighboring molecules, causing them to be displaced from their equilibrium. As particles continue to displace one another with mechanical vibrations, the disturbance is transported throughout the medium. These particle-to-particle, mechanical vibrations of sound conductance qualify sound waves as mechanical waves. Sound energy, or energy associated with the vibrations created by a vibrating source, requires a medium to travel, which makes sound energy a mechanical wave.
Sound travels as a mechanical longitudinal wave in which back-and-forth particle motion is parallel to the direction of wave travel. Ultrasound is high-frequency sound and refers to mechanical vibrations above 20 kHz. Human ears can hear sounds with frequencies between 20 Hz and 20 kHz. Elephants can generate and detect sound with frequencies less than 20 Hz for long-distance communication; bats and dolphins produce sounds in the range of 20 to 100 kHz for precise navigation.
Piezoelectric Effect

- **Piezoelectricity** is the electricity generated because of the application of mechanical stress on certain materials, such as crystals (Quartz), ceramics (Lead Zirconate Titanate).

- When electric current is applied to the crystal it will vibrate and generate sound waves with frequency ranging from 2 – 10 MHz (ultrasound).

- The crystal can do the opposite as well, when the crystal being hit by the reflected ultrasonic waves it will vibrate also and produce electric current and voltage that can be translated to be an image.
• Thousands of piezoelectric crystals are attached to the front of the transducer
• How sound waves generated, propagated and reflected
• Red arrows represent generated waves by the vocal cord vibration
• Blue arrows represents reflected sound waves after hitting an object (echo)
INTERACTIONS OF ULTRASOUND WITH TISSUES

- As the ultrasound wave travels through tissues, it is subject to a number of interactions. The most important features are as follows:

1. **Reflection** similar to optical reflection
2. **Scatter** the redirection of ultrasound in any direction caused by rough surfaces
3. **Absorption** direct conversion of the sound energy into heat

- When ultrasound encounters boundaries between different media, part of the ultrasound is reflected and the other part is transmitted.
• **Speed of Sound Waves**

• The speed of sound wave transmission is affected by the properties of the medium in which it is traveling. Sound waves generally travel more slowly in gas mediums, faster in fluids, and fastest in solid material. Ultrasound waves travel through most human tissue at a speed of 1,540 m/s. Ultrasound instruments use this speed for timing the returning echoes to calculate the depth of tissue and constructing images.
Ultrasound Terms …

- **ANechoic (Black)**
- The term “Anechoic” on ultrasound means no internal echoes are emitted and there is a completely black appearance. This is most commonly seen with fluid-filled structures since ultrasound waves pass through fluid without reflecting any echoes back to the ultrasound machine.
• **HYPERechoic (Bright/White)**

• The term “**Hyperechoic**” on ultrasound means that a specific structure gives off MORE echoes relative to its surrounding structures resulting in a brighter/whiter appearance. Below is an example of the pleural line which is “**Hyperechoic**” (bright/white) compared to the surrounding soft tissue.
• **HYPOechoic (Darker/Grey)**

• The term “Hypoechoic” on ultrasound means that a specific structure gives off fewer echoes relative to its surrounding structures resulting in a darker or more grey appearance.
**Echogenicity**

- Hyperechoic
- Isoechoic
- Hypoechoic
- Anechoic
A – Mode (Amplitude)

- In A mode, the returning echoes are displayed on the monitor as spikes originating from a single vertical or horizontal baseline. The depth of the echo is determined by the position of the spike on the axis, with the top or left side of the monitor being the most superficial and the bottom or right side being farther away. The height of the spike correlates to the amplitude of the echo. This mode is not frequently used other than in ophthalmology.
B – Mode (brightness)

- B-Mode is a two-dimensional ultrasound image display composed of bright dots representing the ultrasound echoes. The brightness of each dot is determined by the amplitude of the returned echo signal.
M – Mode (Motion)

• M-mode is defined as time motion display of the ultrasound wave along a chosen ultrasound line. It provides a monodimensional view of the heart.

• The advantage of the M-mode is its very high sampling rate, which results in a high time resolution so that even very rapid motions can be recorded, displayed, and measured.
**Color – mode (doppler Mode)**

- Done by applying the doppler effect to the B – Mode scan, the main benefit is to visualize and assess the blood flow through the vessels of the scanned area.
Spectral or pulsed wave doppler Mode

The sonogram provides a measure of the changing velocity throughout the cardiac cycle and the distribution of velocities in the sample volume (or gate)
Transducers (probe) ...

• shows three tissue blocks traversed by sound waves that differ only minimally in their transmission velocity (indicated by similar gray values).

• Each interface only reflects a small portion of the original sound waves.

• The right-hand diagram shows a larger impedance mismatch at the interface A between the different tissues (Fig. 6.2b). This increases the proportion of reflected sound waves, in comparison to the tissues shown on the left.

• However, what happens if the sound waves hit air in the stomach or a rib? This causes a so-called "total reflection," as illustrated at interface B (Fig. 6.2b). The transducer does not detect any residual sound waves deep to this structure from which it can generate an image. Instead, the total reflection creates an acoustic shadow (45).
1. Linear

- Linear transducers, as the name suggests, have a linear piezoelectric arrangement. The shape of their beam is rectangular, and they have a better-than-average near-field resolution. Depending on what clinical application you are doing, (Vascular, breast, small parts, etc.),

- With a broadband frequency of 7 MHz – 20 MHz
• Convex

• The convex transducer, also commonly referred to as the curved transducer, has a piezoelectric crystal arrangement that is curvilinear. The beam has a convex shape that makes the transducer ideal for deeper organ imaging examinations.

• with a broadband frequency of roughly 2.5 MHz – 7.5 MHz

• Frequency

• *In addition to transducer shape, frequency also impacts image quality. Frequencies between 2.5 and 7.5 MHz are used for diagnostic ultrasound. High frequency enables a higher image resolution, but depth is reduced (= lower penetration depth). Low frequency reduces resolution, but increases penetration depth.*
• Phased Array

• Another one of the different ultrasound transducer types is the phased array. The phased array transducer is so named because the crystals are arranged in a “stacked” construction, or phased array. Its beam is narrow, near triangular, and has a poorer near-field resolution. This transducer has a small footprint, with a broadband frequency of 2 MHz – 6 MHz. It is used mostly in cardiac, and transcranial examinations.
Endo-cavitary probe

- Unlike transabdominal ultrasounds, a transvaginal ultrasound is an internal examination. The procedure involves the insertion of the transducer into the vagina to produce incredibly detailed images of the organs in the pelvic region.

- It may be necessary to use a transvaginal ultrasound to examine the following internal organs:
  - Vagina, Cervix, Uterus, fallopian tubes, Ovaries, urinary bladder

- Transvaginal ultrasounds are also useful to check for:
  - ovarian cysts or tumors, Fibroids, polyps
Various planes

• A transducer is used to perform transverse and sagittal assessments
• **As a general rule, in the transversal plane**
  • the top of the ultrasound image is the anterior side and the bottom is the posterior side.
  • left on the image is actually right and vice versa.
• As a general rule, in the sagittal plane:
  • the top of the ultrasound image is the anterior side and the bottom is the posterior side.
  • right on the image is towards the feet (= caudal) and left is towards the head (= cranial).
Ultrasound Basics

Orientation

Longitudinal

Transverse

Oblique
**Probe movements**

**Sliding** \(a\) – transducer remains in contact with scanning surface; it is slid in longitudinal or transverse plane

**Rotating** \(b\) – transducer is spun clockwise or counterclockwise; central portion remains fixed to starting site

**Rocking** \(c\) – transducer is moved (rocked) parallel to the scanning plane

**Tilting** \(d\) – transducer is moved perpendicular to the scanning plane
Ultrasound Probe Movements

1 Sliding
2 Tilting/Fanning
3 Rotating
4 Rocking
5 Compression

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• **Gain**

Controls amplification of returning ultrasound waves. This translates to brightness of the ultrasound image.

- Gain can be manually controlled by the sonographer and should be optimized for image clarity.
- If the gain is too high, the image will be bright.
• **Depth**
  
  • Refers to how far sound travels prior to returning to the transducer, typically reported in centimeters.
ULTRASOUND OF EYE

Dr. TAMARA M. ABDULLAH
RADIOLOGIST
A- MODE

[Graph showing various labeled sections: Probe, Cornea, Ant. Lens, Post. Lens, Retina, Sclera, and Orbital Fat.]
B- MODE
B- MODE
B- MODE

- Anterior chamber
- Lens
- Optic nerve
- Retina
- Vitreous
Ocular Ultrasound Indications

- Vision Loss
- Change of Vision
- Acute Eye pain
- Ocular Trauma
- Intraocular Foreign Body
- Suspected Elevation in Intracranial Pressure
Ocular Ultrasound Contraindication

The main contraindication to performing ophthalmic ultrasound is if a patient has a globe rupture. It is advised to refer any of these suspected patients immediately to an ophthalmologist. However, some resources state ocular ultrasound may cautiously be performed if there is a copious amount of gel placed and no pressure is applied to the eye.
Patient Preparation

The patient may be fully supine or head of the bed can be elevated up to 45°

Optional: Place a Tegaderm patch over the closed eye of interest

Apply a generous amount of ultrasound gel on the closed eye or on top of the Tegaderm patch. This ensures the ultrasound probe does not contact or put too much pressure on the patient’s eye
**Transducer**: Linear Ultrasound Probe

**Preset**: Ocular (B scan) or Superficial Preset

**Depth**: Approximately 4 cm

**Ocular Ultrasound Machine Placement**: Place the ultrasound machine on the patient’s right side so you can scan with your right hand and manipulate ultrasound buttons with your left hand.
Step 1: Anchor the Probe

In addition to a generous amount of gel, it is important to anchor your probe to decrease the amount of pressure applied to the patient’s eyes.

Grasp the linear probe and anchor your fingers on a bony surface of the patient’s face.

The example below assumes using the right hand to scan the patient.

For the Right eye, anchor your right pinky finger on the patient’s nose.

For the Left eye, anchor your right pinky finger or palm on the zygomatic arch.
Step 2: Obtain Transverse View

Place the probe *lightly* on the gel covering the patient’s eye with the *probe indicator* pointed towards the patient’s right to obtain a *transverse view*. 
Identify the following ocular ultrasound anatomy from anterior to posterior:

- Eyelid
- Anterior Chamber
- Lens
- Iris
- Vitreous Body
- Retina
- Optic Nerve

*Make sure to tilt/fan through the entire eye*
Assess for Extraocular Movements

Next, ask the patient to look left and right to evaluate for extraocular movements. This is important when patients have severe periorbital edema from facial trauma.

In the transverse view, you are looking for MEDIAL and LATERAL (or Left and Right) movements of the eye. Increase the gain slowly to better detect intraocular pathologies such as mobile findings of retinal detachment, posterior vitreous detachment, or vitreous hemorrhage.
Step 3: Obtain Sagittal View

Next, turn the probe 90° clockwise so the indicator points superiorly towards the patient’s head to obtain a sagittal view. Identify the same structures you found in the transverse view.

Then, have the patient look up and down and increase the gain slowly to assess for symmetric extra-ocular movements and to rule out intraocular pathology.

In the sagittal view, you are looking for Superior and Inferior (or Up and Down) movements of the eye.
Step 4: Measure Optic Nerve Sheath Diameter (ONSD)

The Optic Nerve Sheath Diameter (ONSD) is an important measurement that can be used to detect elevated intracranial pressure (ICP).

In the transverse view, **rock the probe** about 10-15° laterally to visualize where the hypoechoic (darkly colored) optic nerve radiates away from the base of the globe (see figure below).

Tip: If you do not see the ocular nerve — immediately, **tilt the probe** up and down until it comes into view.

Once you have a good view, **freeze the image**.
Rock 15° laterally
Probe: Linear
Mode: Ocular
Transverse View

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Optic Nerve
Retinal Detachment
Retinal Detachment
Posterior Vitreous Detachment
Posterior Vitreous Detachment
Vitreous Hemorrhage

Washing Machine Sign
Vitreous Hemorrhage
Vitreous Hemorrhage
Intraocular Mass
Intraocular F.B.
Intraocular F.B.
Globe Rupture

- Flattening of Anterior Chamber
- Buckling of Sclera
- Decreased Globe Size
Globe Rupture
Globe Rupture
Lens Dislocation
Lens Dislocation
Periorbital Edema

Swelling of Eyelid
Periorbital Edema
What is CT – SCAN? In brief

- **Basic Principles of CT**
- **CT scan or CAT scan** = **Computerized Axial Tomography**
- **In arabic** (التصوير المقطعي المحوري المُحَوَسَّبُ)
- The radiographic term tomography is derived from the Greek words tomos, meaning “slice,” and graphein, meaning “to write.”
- CT uses a complex computer and mechanical imaging system to provide sectional anatomic images in the axial, sagittal, and coronal planes.
- CAT scan is not a accurate term because CT images are routinely reconstructed in the sagittal and coronal planes as well as in oblique planes.
CT Scan vs Conventional x ray

- It is simplified as it is imaging of a loaf of bread
- **conventional radiography** captures images of the loaf as a whole (one piece)
- **whereas CT takes** the loaf and images it in slices (also called sections, or cuts), which are viewed independently.
Conventional vs CT-Scan
Evolution of CT scan

- CT scanning introduced in early 1970s
- Basically and in a simplified words CT-scan consist of an x-ray tube and detectors
- The x-ray beam passes through the human body in a thin axial slice.
CT scan generations

- Since introduction it is rapidly developed into 4 generations

- **First generation**: x-ray beam pencil thin and one detector (Fig. A)

- **Second generation**: x-ray beam is small fan beam and 30 detectors (Fig. B)
Third generation: x-ray beam is wide fan beam and hundreds of detectors which are located opposite the x-ray tube and rotate as the tube rotates.
Fourth generation: X-ray beam is wide fan beam with thousands of fixed detectors in a ring inside the gantry. The tube rotates while continuously emitting radiation, but the detectors do not rotate.
Gantry

Patient table

Gantry aperture
All 4 generations in one image

A. Single detector
B. Multiple detectors
C. Multiple detector array
D. Stationary ring of detectors
The development of the multislice CT scanner (also known as multidetector CT or volume CT) significantly reduced scan time.

Multislice CT uses multiple detector rows. In this setting, not just one slice is scanned per rotation, but multiple slices simultaneously.
In conventional CT technique, first a slice is made of the desired area, after which the table moves up a little. In this way the patient is imaged slice by slice (step-by-step). Around 1990, the ‘slip ring’ technique was developed where the x-ray tube and detector ring rotate and continue scanning without interruption. This led to the so-called spiral CT where the scanner table moves with constant speed through the ring with the rotating x-ray tube and detectors. This generates a helix/spiral-shaped pattern.
The significant benefit of spiral CT is the shorter scan time and improving the visualization of small lesions.
The degree of x-ray attenuation depends on the tissue type. These differences are converted into ‘CT numbers’, better known as Hounsfield units (HU).

A spectrum of gray tones is generated, from -1000 to +3000 (note: the upper limit is determined by the scanner type).

Tissues with low attenuation (such as air and fat) have a low HU number.

Tissues with high x-ray attenuation (such as bone and contrast fluid) have a high HU value.

Water has an HU value of 0.
Hounsfield Units

- Bone: +1000
- Fat: -50 - -100
- Soft tissue: +40 - +80
- Lungs: -400 - -600
- Air: -1000
- H20: 0

3000
Planes of imaging
Computed tomography of the orbits (CT Orbits) involves the visualization of bony and soft tissue structures of the orbits. This examination is most commonly performed as a non-contrast scan or reconstructed from other examinations such as a CT head/face. Contrast-enhanced scans are utilized depending on clinical indications, initial assessment, and the radiologist's consultation.
Three views:

1. Axial view
2. Coronal view
3. Sagittal view
Axial
Coronal
Sagittal
Indications:

- A CT orbit exam aims to evaluate the following pathologies:
  - congenital/pediatric orbital anomalies
  - orbital trauma including fractures, penetrating or blunt trauma
  - orbital inflammations or infections
  - orbital neoplasms
  - **orbital mass** or lesions
Purpose:

- CT is considered the optimal form of imaging for evaluating orbital pathologies in a trauma setting. The purpose of a non-contrast orbit CT predominantly includes the evaluation of bony structures for fractures and any blunt or penetrating trauma. Contrast-enhanced CT examinations are generally requested to better evaluate soft tissue structures in emergency imaging and in the circumstance the patient is unable to obtain a magnetic resonance imaging (MRI) scan which is generally preferred.
Technique:

- **patient preparation**
  - remove all radio-opaque jewelry and dental prosthetics

- **patient position**
  - head first
  - supine with arms by their side

- **scout**
  - anterior-posterior and lateral
  - C2 to vertex

- **scan extent**
  - hard palate to frontal sinus

- **scan direction**
  - caudocranial

- **scan geometry**
  - slice thickness: 0.6mm
  - slice increment: 0.6mm

- **respiration**
  - suspended

- **contrast medium**
  - non-ionic iodinated contrast agent as per site’s protocol

- **scan delay**
  - contrast-enhanced CT: scan 70 - 80 sec post injection

- **multiplanar reconstructions**
  - 2mm axial, coronal and sagittal bone reformats
  - 3mm axial, coronal and sagittal soft reformats
Cone beam CT

Although conventional multi-slice CT imaging is the preferred imaging method for visualizing orbits, dose optimization can be achieved through the use of cone beam computed tomography. The tube current (mA) used in cone beam computed tomography is significantly lower in comparison to conventional CT. However, this can compromise image quality as there are fewer x-ray photons and thus contributing to greater noise and less contrast in the resultant image.
Intraorbital Foreign Body
Intraorbital Foreign Bodies
Retro Orbital Hematoma
Retinal Detachment
Vitreous Hemorrhage
Globe Rupture
Retinoblastoma
Thank you
MRI

physical principle
• Imaging Protocol
  • Routine imaging of the orbit should include:
    • Thin section (3 mm or less) axial and coronal T2W images of the orbit.
    • Thin section fat saturated pre and postgadolinium axial and coronal images.
    • The cavernous sinuses should be included
  • in all the sequences
Advantages of MRI

- Excellent soft tissue details
- Entire course of optic nerve well studied
- No exposure to radiation

Disadvantages:

- Less sensitive for detecting bony abn. And
- Calcification.
- Fat saturation artifacts can mimic pathology, C/I in metallic IOFB, longer time
- Contraindication Of MRI
  - Suspected metallic intraocular foreign bodies:
  - Cardiac pacemaker and implanted cardiac defibrillator:
  - MRI incompatible aneurysm clip.
  - Implants: Cochlear, otologic, or ear implant.
  - Lid gold implants and metallic orbital floor implants.
Imaging plane
T2W Axial section with fat suppression through mid orbit
T2W axial scan through sup.orbit
T2W axial scan through inf. orbit
T2W coronal section through ant. orbit
T2w coronal section through globe
T2W coronal section post to globe
MRI in retinoblastoma & cavernous hemangioma
MRI in orbital varix in supine position and prone position
MAGNETIC RESONANCE IMAGING
• Basic Image Sequences
  • \textit{T1-weighted (T1W) images} - Tissues with shorter T1-relaxation times like fat appear brighter than those with longer T1-relaxation like water/vitreous/CSF.
  • \textit{T2-weighted (T2W) images} - Tissues with longer T2-relaxation like water/vitreous/CSF, appear brighter than tissues with shorter T2-relaxation like blood products.
- Fluid attenuation inversion
- recovery (FLAIR)
  - Signal from fluid can be suppressed using the FLAIR sequence.
  - FLAIR is especially useful in demyelinating conditions where the white matter hyperintensities on T2W images are better appreciated when the bright signal from the adjacent CSF in the ventricles is nulled.
• **Postcontrast images**
  • Gadolinium **CAUSES** shortening of T1-relaxation times, which results in brighter areas on T1W images. Therefore postcontrast images are always obtained with T1 weighting.
  • The optic nerve does not normally enhance.
• **Fat-suppressed images**
  
  • Bright signal from intraorbital fat can mask the signal and enhancement of pathology.
  • This problem can be overcome by suppressing the signal of fat by special fat suppression sequences.
• **Heavily T2W images**
  • This sequence helps in better visualization
  • and tracing the course of the cisternal portions of the cranial nerves (useful in cases of suspected 3rd nerve palsy).
- **Magnetic resonance angiography (MRA)**
- the intracranial vessels and aneurysms
- alone can be demonstrated after subtracting the images of the brain parenchyma with or without injecting GADOLINIUM
• **Magnetic resonance venography (MRV):**
  • Similar to MRA, images of the dural venous sinuses can be obtained with or without injecting gadolinium.