PI Session: 2020.10.12_HAC_ Gross Anatomy_Radiology: Head and Neck Preparatory_Marcus John Julius, M.D.

<u>Objectives</u>: At the end of this session, students will be able to:
1. Discuss the relationship between voltage, electrical current, and exposure time in the creation of radiographs
2. Differentiate the radiographic appearance of five hallmark types of matter
3. Describe the physiologic mechanism essential to the production of a thyroid scan
4. Illustrate the components of an ultrasound transducer
5. Explain the role of reflection of sound waves in ultrasound image creation
6. Differentiate high resistance and low resistance arterial wave patterns (on Doppler imaging)
7. Discuss the four hallmark features of a simple cyst
8. Distinguish between neck vasculature, thyroid parenchyma, and trachea on neck sonography

General radiology

PHYSICS

-*Voltage*

-Measured in kVp (*peak* kilovolts)

-Determines the maximum energy of x-rays produced

-*Mean* energy of x-ray beam is approximately one-third its peak value

-100 kVp produces mean energy of 33-40 keV

-Increasing voltage:

-Increases x-ray energy (increases photon frequency and decreases photon wavelength)

-Increases x-ray penetration (thereby decreasing skin dose)

-Decreased contrast (more on this later…)

-Increases the x-ray tube output (proportional to the *square* of the voltage)

-*Electrical current*

-Current flowing through x-ray tube

-Number of electrons flowing per second

-1 ampere (A) is 6.25 x 10^{15} electrons/second

-X-ray currents are expressed in milliamperes (mA)

-The higher the current, the higher the x-ray production (i.e. *linear* relationship)

-Doubling current, doubles the number of x-rays produced

-*Electron volt*

-Kinetic energy gained by an electron when it is accelerated across an electric potential of 1 volt (V)

-Example

-An electron gains 1000 eV (or 1 keV) when it is accelerated across an electric potential of 1000 V (1 kV).

-*Exposure time*

-Along with kVp (*voltage*) and mA (*current*), *exposure time* helps determine x-ray tube output

-Product of tube current (*mA*) and exposure time (*s,* in seconds) is known as ***mAs***

-Shorter exposure times lessen the chance for patient motion (i.e. lessen blurring on the image)

NORMAL ANATOMY

-Based on geometric principles, *two imaging planes, obtained orthogonal/perpendicular to one another, define three dimensions.*

-<u>*AP (anterior-posterior) projection*</u> is an image exposed from an anterior x-ray source with image detector positioned posterior the body part

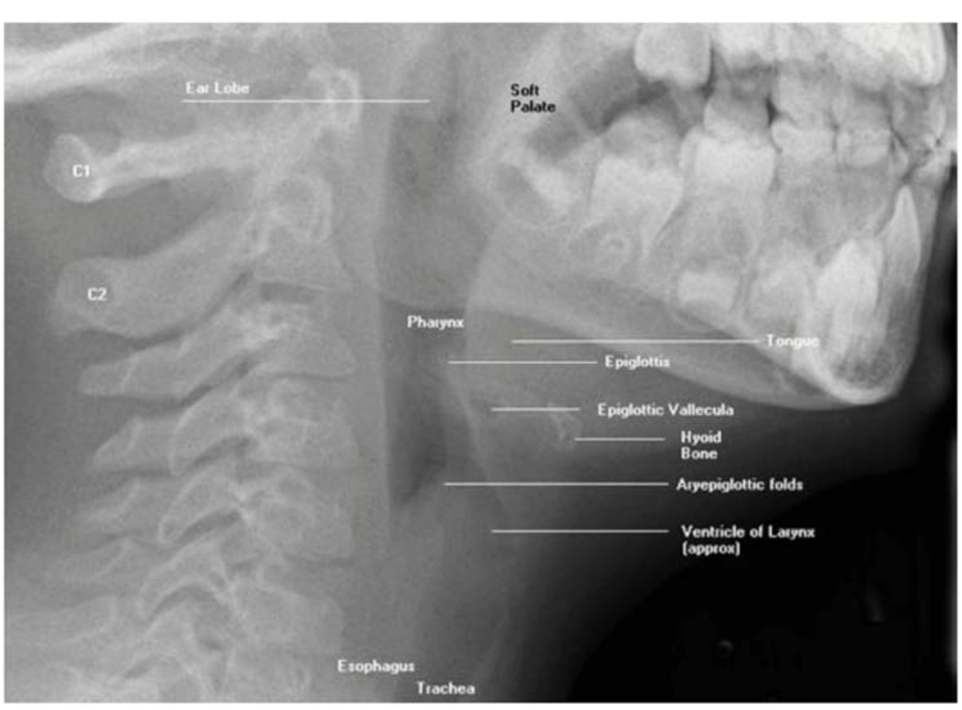
-***The film is labelled and interpreted as if the patient is facing you.***

-<u>*Lateral projection*</u> is an image exposed from a source on one side of the body part with the image detector positioned on the opposite side of the body part

-***AP and lateral views are orthogonal to one another (and allow us to assess the body part in 3-dimensions)***

Superior

Posterior

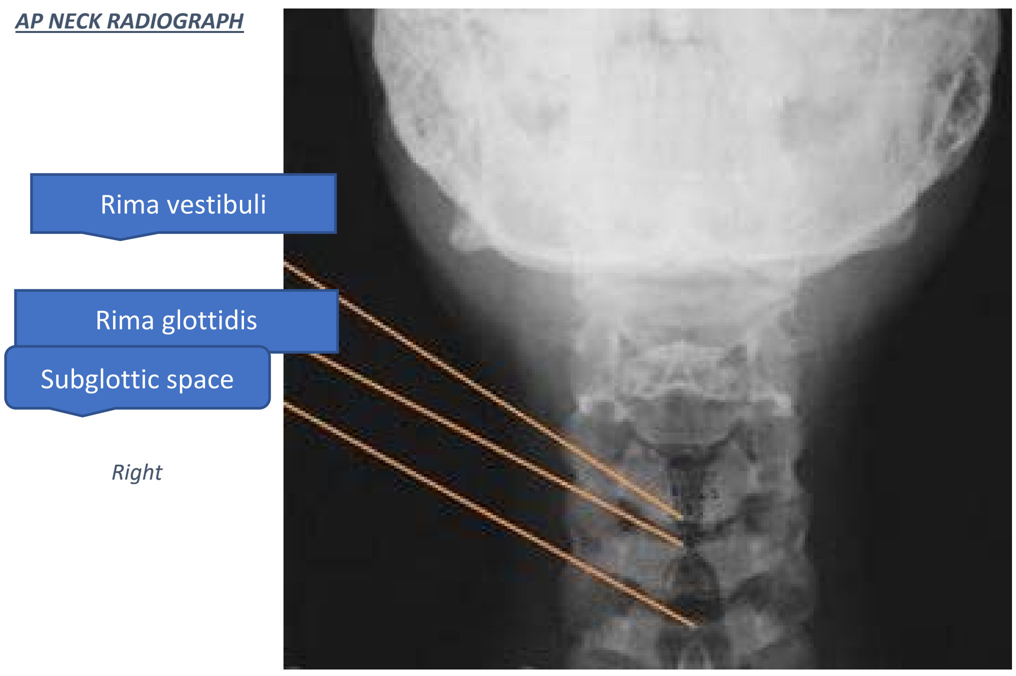


Anterior

<u>LATERAL NECK RADIOGRAPH</u>

Inferior

AP NECK RADIOGRAPH



Nuclear Medicine

INTERACTION WITH MATTER (NUCLEAR MEDICINE)

-**Physiologic mechanisms of radiopharmaceuticals**

-*Active transport*: I^{123} (thyroid scan)

-T ½ 13.2 hours (28 keV and 159 keV gamma rays)

-Oral (P.O.) administration of I^{123} is followed 24 hours later by:

-*Uptake*: Assessment of the percentage of administered radioactivity taken up by the thyroid gland

-Corrected for radioactive decay and background activity

-Normal range: 10%-30%

-*Imaging*: AP, right anterior oblique (RAO), and left anterior oblique (LAO) images

-Superior, mid, and inferior thyroid lobes

-Thyroid isthmus

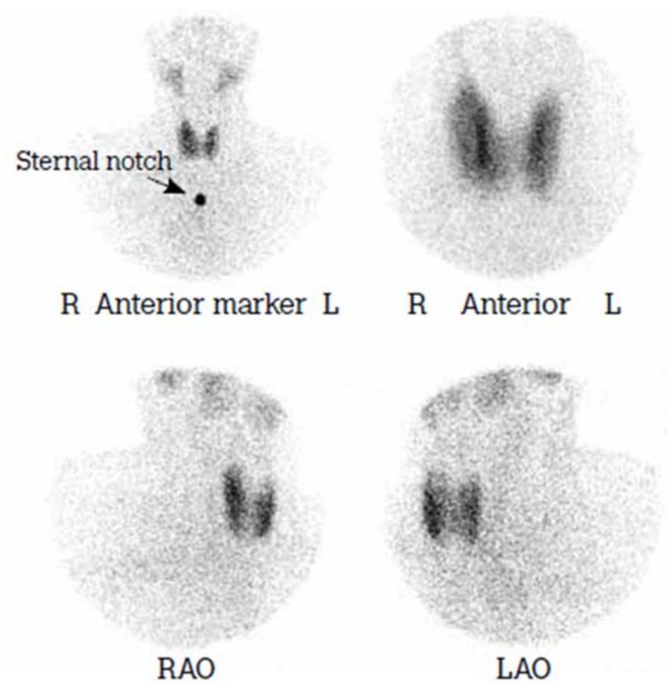
- *Active transport*: I^{131}

--T ½ of I^{131} is 8.02 day

-beta minus (606 keV) and gamma (364 keV) emissions

-Utilized in radioactive iodine therapy (RAI) for treatment of hyperthyroidism and thyroid neoplasia

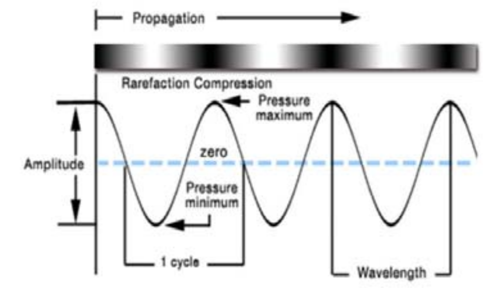
NORMAL ANATOMY (THYROID SCAN)



Ultrasonography

-**PHYSICS**

Ultrasound waves



-Mechanical disturbance traveling through a medium

-*Wavelength*: distance between successive waves

-*Frequency*: number of oscillations per second (in hertz, Hz)

-Ultrasound frequency is higher than audible sound

-Audible sound frequencies: 15Hz-20,000Hz

-Ultrasound frequencies: greater than 20,000Hz

-*Velocity* of sound (in medium) = Frequency x wavelength

-Average velocity of sound in soft tissues: 1540 m/s

-Velocity of sound in air: 330 m/s

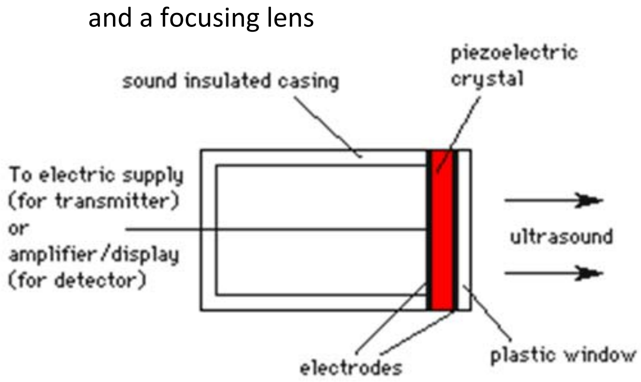
-Velocity of sound in bone: 3,300 m/s

-Velocity of sound in metal: >4,000m/s

Production of ultrasound

-*Transducer*: device that converts one form of energy to another form of energy

-*Ultrasound transducer* (**see below**) is comprised of high-quality crystals, a backing material, electrode wires, and a focusing lens



-Converts electrical energy into ultrasound waves (and vice versa) via the 'piezoelectric (i.e. 'pressure electricity') effect

-High frequency voltage oscillations cause a high-quality crystal to change shape, which alters the pressure in front of the transducer (producing ultrasound waves)

-Electricity…to…pressure (as a '*transmitter'*)

-Returning echoes (i.e. reflected sound) subject the crystal to changes in its shape. These pressure changes are then converted to electrical signals (and ultimately an image)

-Pressure…to…electricity (as a '*receiver'*)

-Transducer resonant frequency is determined by crystal thickness and acoustic velocity of crystal elements

-*Crystal thickness is usually manufactured to ½ wavelength*

-Based on crystal thickness (and, therefore, wavelength) as well as acoustic velocity of crystal, frequency can be calculated

-Higher frequency transducers are thinner

-Lower frequency transducers are thicker

ULTRASOUND INTERACTION WITH MATTER

-*Reflection*

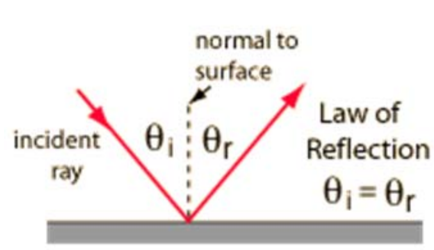
-Sound *reflected* at a tissue interface forms an echo, which is used to create an image

-Degree of reflection is based on both *angle of incidence* and *acoustic impedance* of tissues

-Angle of incidence equals angle of reflection

-As angle of incidence increases, reflected sound waves are less and less likely to reach the transducer

-At angles of incidence greater than 3 degrees from perpendicular to an interface, no appreciable reflected echoes are detected



-*Acoustic impedance* = density of medium x velocity of sound in medium

Material	Speed of sound (m s⁻¹)	Density (kg m⁻³) x 10⁻³	Acoustic Imp Z (kg m⁻² s⁻¹) x 10⁻⁶
Air	330	1.2	0.0004
Water	1480	1000	1.48
Steel	5000	7800	39.0
Blood	1575	1057	1.62
Fat	1459	952	1.38
Muscle	1580	1080	1.70
Bone	4080	1912	7.8

-Air has the lowest acoustic impedance

-Soft tissues have intermediate acoustic impedance

-Bone and metal have the highest acoustic impedances

-*The greater the degree of acoustic impedance difference at a tissue-tissue boundary, the greater the degree of wave reflection*

-*The overall amount of reflected and transmitted waves must equal 1*

Reflection

Interface	Reflection co-efficient (%)
Soft Tissue - Air	99
Soft Tissue - Bone	66
Fat - Muscle	1.08
Muscle - Liver	1.5

-The greater the degree of reflection, the lesser the degree of transmission

-This leaves less useful sound waves to image deeper tissues

-*'Posterior acoustic shadowing'*

-The lesser the degree of reflection, the greater the degree of transmission

-This leaves more useful sound waves to image deeper tissues

-*'Posterior acoustic enhancement'*

-This explains the need to use gel material to 'couple' the probe to the patient's skin (eliminating intervening air)

-This explains the difficulty in visualizing through/deep to both aerated lung and bone

-**Note**: Additional ultrasound interactions with matter (i.e. scatter, absorption, and refraction) will be described in 'Radiology: Thorax' lecture in CPR.

-*Doppler principle*

-*Doppler effect*: An increase (or decrease) in the frequency of a wave as the source and observer move toward (or away from) one another.

Doppler equation

$$\Delta F = 2 F_0 V \cos \Theta / C$$

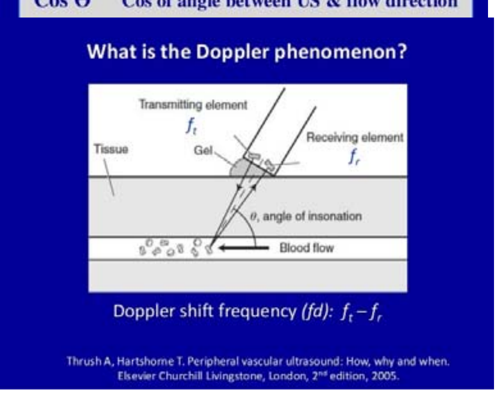
ΔF	Doppler shift frequency (kHz)
F_0	Ultrasound transmission frequency (MHz)
V	Blood cell velocity (cm/sec)
$\cos \Theta$	Cos of angle between US & flow direction

-From the equation, the maximum Doppler shift occurs when blood is flowing directly toward or away from the transducer (0 or 180 degrees). As the scan angle approaches 90 degrees, the frequency shift decreases (i.e. cos 0 degrees=0).

-Practically speaking, it is *not* feasible to scan the vessel at an angle of 0 or 180 degrees.

-It is, therefore, recommended that the Doppler angle be between 40 and 60 degrees.

-Doppler shift may be stated in frequency or velocity (i.e. the aforementioned equation may be solved for *Doppler shift* or *velocity*)



-Doppler waveform

-Tracing displaying the relation between velocity (obtained from the Doppler shift frequency) and time.

-Flow direction

-Above baseline: toward transducer

-Below baseline: away from transducer

-Arterial patterns

-*High-resistance pattern*

-Steep rise to a high systolic peak

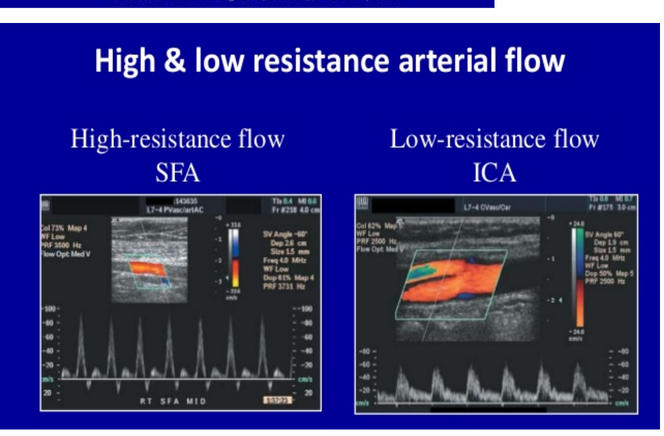
- (Reversal of flow)

-Low diastolic flow

-Examples

--ECA

--Extremity arteries



-*Low-resistance pattern*

-Systolic rise (Biphasic systolic peak)

-Relatively high level of flow in diastole

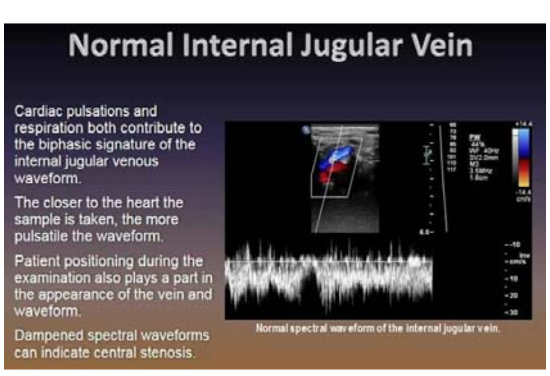
-Examples

--ICA

--Vertebral artery

--Renal artery

--Hepatic artery and splenic artery



-Venous pattern

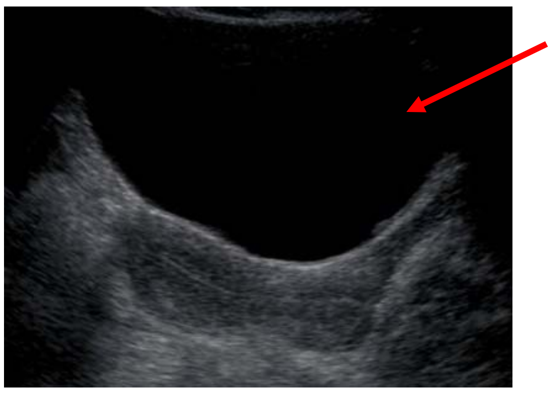
-*Low velocity and low resistance pattern*

TERMINOLOGY

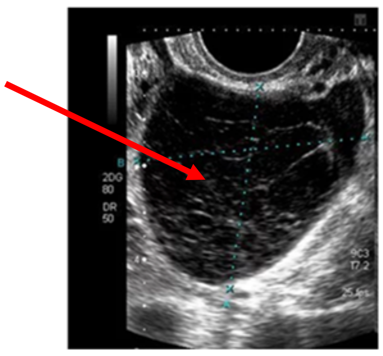
- '*Echoic*': root word
  - -Prefixes describe the underlying echogenicity
    - '*an*', '*hypo*', '*iso*' (better yet, intermediate), and '*hyper*.
- Echogenicities may vary:
  - -Within a given organ
  - -Among different organs
- A normal pattern of echogenicity exists within normal organs
- *Note*: *Comparison of adjacent relative echogenicities may be made*

Anechoic

-Absence of reflected sound waves
-Commonly seen with fluid-filled structures
-'Black' appearance
-Urinary bladder (*arrow at right*)
-Simple cyst (see below)

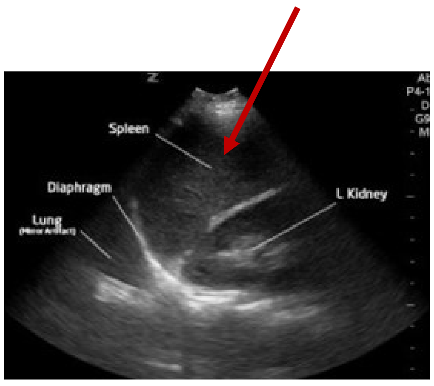


Note: A *simple cyst* is a well-characterized benign entity (arrow at right)
-Anechoic
-Thin, imperceptible wall
-Posterior acoustic enhancement
-Lack of vascularity



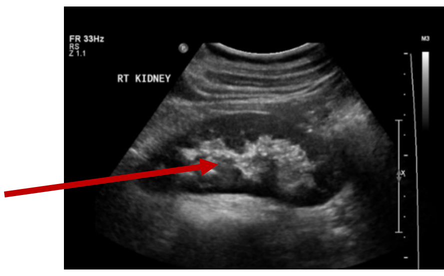
Hypoechoic

-Diminished degree of reflected sound waves
-'Dark' appearance (but not completely devoid of echoes)
-Debris within complicated cyst (*arrow at right*)
-*Note*: The term *hypoechoic* can also be used to compare two different structures



Isoechoic

-Medium degree of reflected sound waves
-Intermediate ('gray') appearance
-Often representative of normal solid organs
-Spleen (*arrow at right*)
-*Note*: The term *isoechoic* can also be used to compare two different structures which appear *similar* sonographically



Hyperechoic

-High degree of reflected sound waves
-Bright ('white') appearance
-Central echogenic complex in renal sinus (*arrow at right*)
-*Note*: The term *hyperechoic* can also be used to compare two different structures

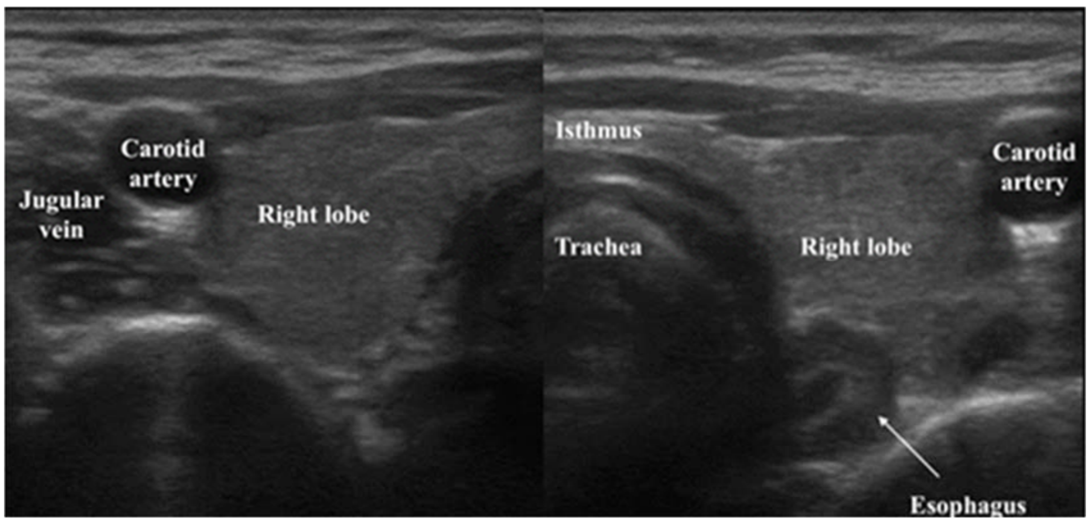
ADVANTAGES OF ULTRASONOGRAPHY

-No ionizing radiation
-Infinite imaging planes
-Dynamic imaging (i.e. vascular assessment; fetal assessment)

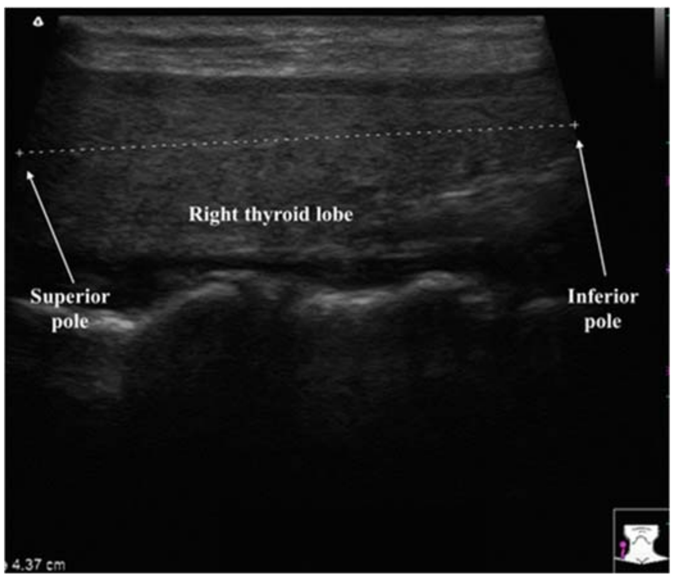
DISADVANTAGES OF ULTRASONOGRAPHY

-User-dependent
-Limited assessment of osseous structures
-Bowel gas often obscures detail

EXAMPLES OF NORMAL ANATOMY



Transverse image of thyroid gland



Sagittal image of thyroid gland

References

-Clinical Radiology: The Essentials. Daffner et al. 4th ed. (Chapters 1, 2, 11, 12).

-Primer of Diagnostic Imaging. Weissleder et al. 4th ed. (Chapter 7).

-Ultrasound Atlas of Vascular Disease. Krebs et al. (Chapters 5, 9, and 10)

Note: Unless otherwise specified, all graphics are from Review of Radiologic Physics. Huda. Fourth edition.

Note: Medical images are from anonymized patient or online archives

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