VAULT

VIRGINIA ULTRASOUND

Regional Anesthesia + Vascular Access Training

SOUND PRINCIPLES

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Introduction

- The incorporation of ultrasound into anesthetic procedures has become commonplace in recent years. Numerous studies have shown that when used correctly, ultrasound reduces the incidence of complications, as well as decrease patient recovery times and improve overall outcomes.

Objectives

- Review the physics and principles of sound
- Describe how an sound wave is generated
- Discuss the interaction between an ultrasound wave and different tissue media
- Explain how an ultrasound image is created
- Understand how Doppler ultrasound can be used to clarify an ultrasound image
- State how commonly seen artifacts impact an ultrasound image

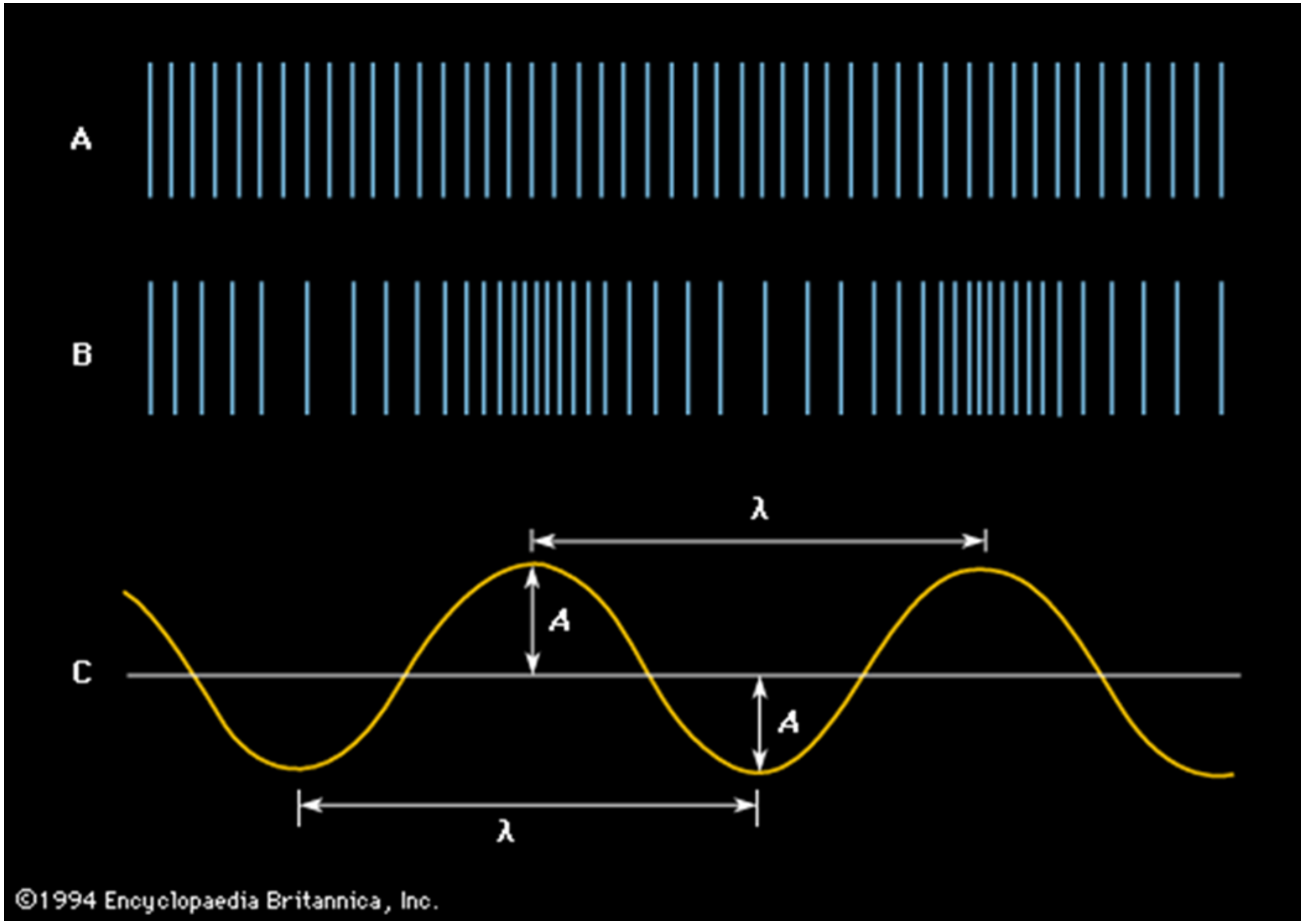
What is sound?

- Sound is a form of mechanical energy.
- Sound travels at **<u>different speeds through different substances, or media</u>**.
- As sound travels through media, it can be **reflected**, **refracted**, **scattered, reverberated** and ultimately **attenuated**, providing information about its make-up.
- Ultrasound used in in diagnostic imaging involves frequencies greater than 1MHz.

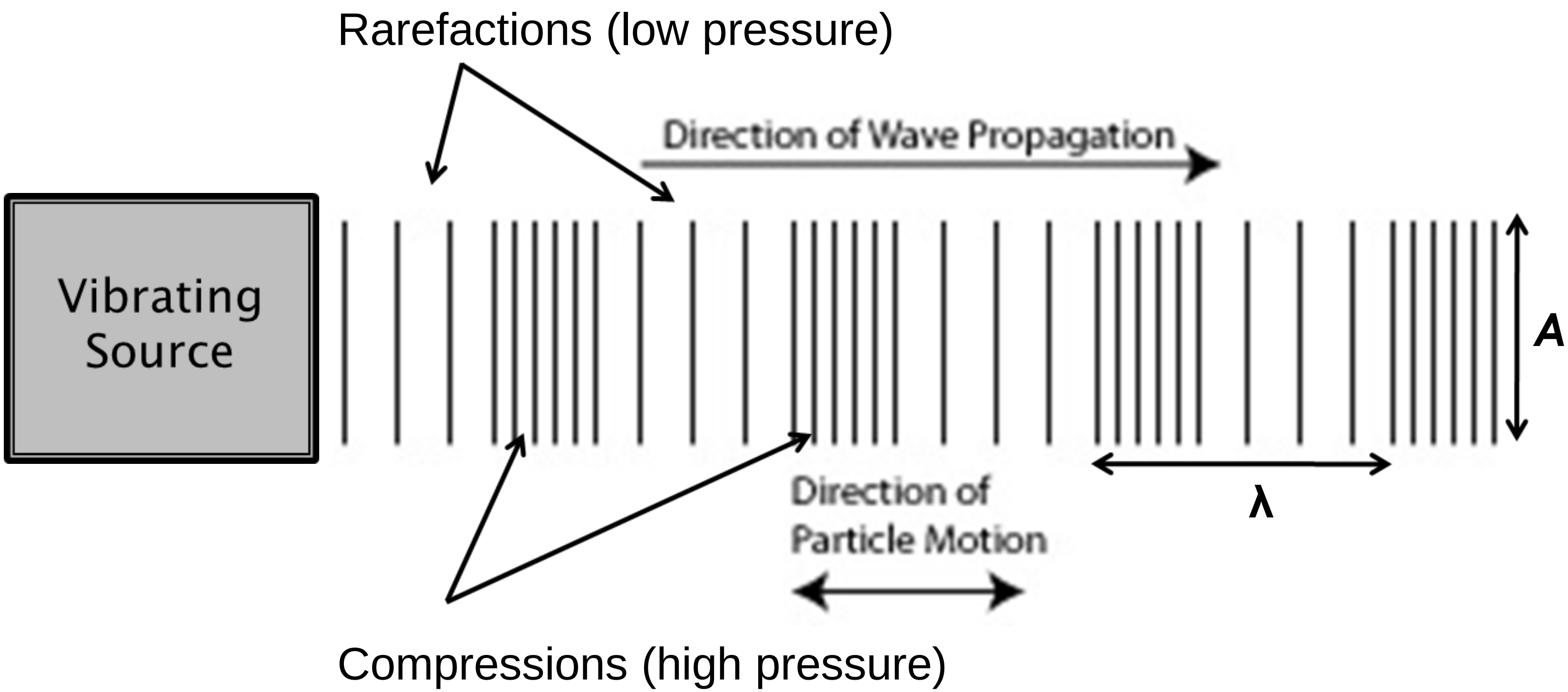
Propagation velocity

Medium	Velocity
Air	331 m/s
Brain	1,541 m/s
Kidney	1,561 m/s
Liver	1,549 m/s
Muscle	1,585 m/s
Fat	1,450 m/s
Soft Tissue (average)	1,540 m/s
Bone (different densities)	3,000 to 5,000 m/s

What is sound?



What is sound?



Sound waves

- Frequency is determined by the number of cycles (compressions and rarefactions) that occur in a second
- Wavelength is inverse to the frequency (i.e. the higher the frequency the shorter the wavelength)
- Amplitude describes the energy of the wave, and is not related to frequency

Thoughts on frequency…

High frequency

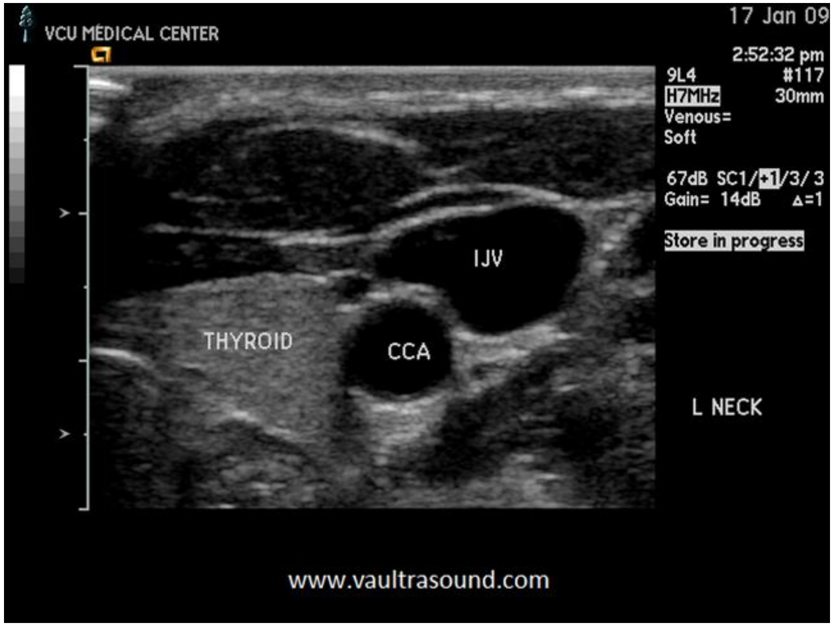
- More cycles occur per second
- Images are higher resolution
- Greater attenuation of the sound waves limits the depth at which tissue can be imaged

Low frequency

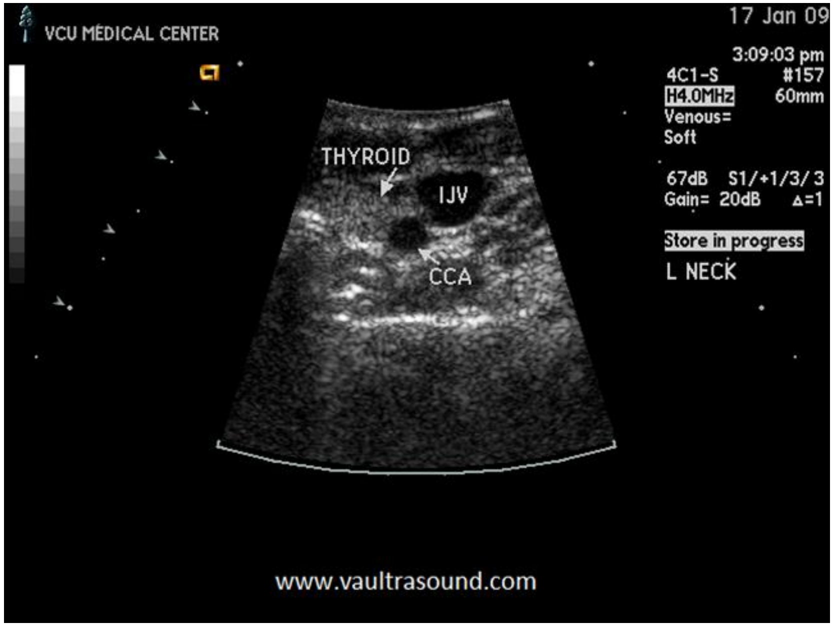
- Fewer cycles occur per second
- Greater tissue penetration but lower resolution
- Less attenuation allows for imaging of deeper structures

Thoughts on frequency…

High frequency



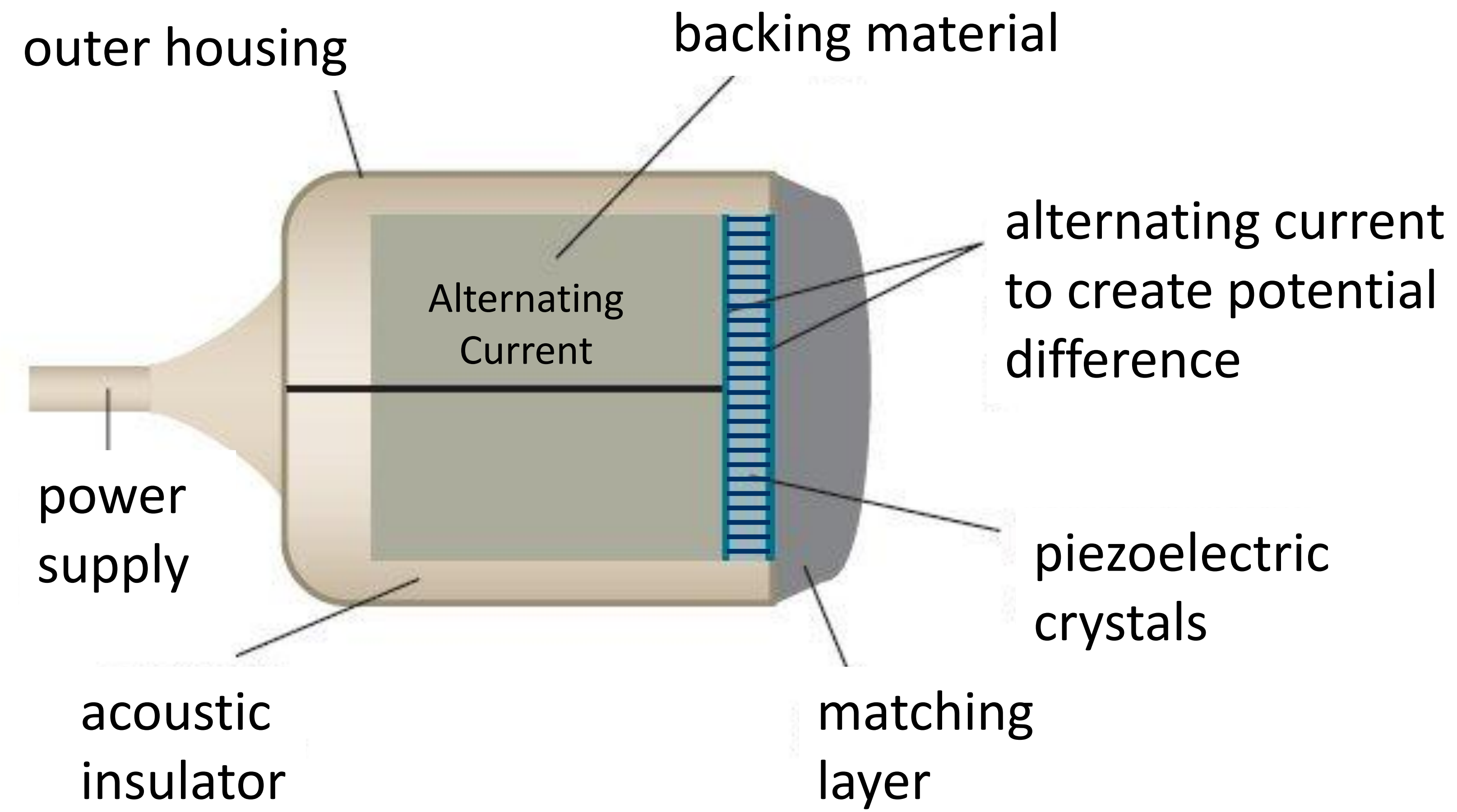
Low frequency



Generation of sound waves

- A wave is generated when an ultrasound system applies an electrical field to crystals located on the transducer
- These crystals convert the electrical energy to mechanical energy; this is known as the **piezoelectric** effect
- The sum of the waves is an ultrasound beam
- These beams are emitted in pulses, with each beam being two to three cycles in length

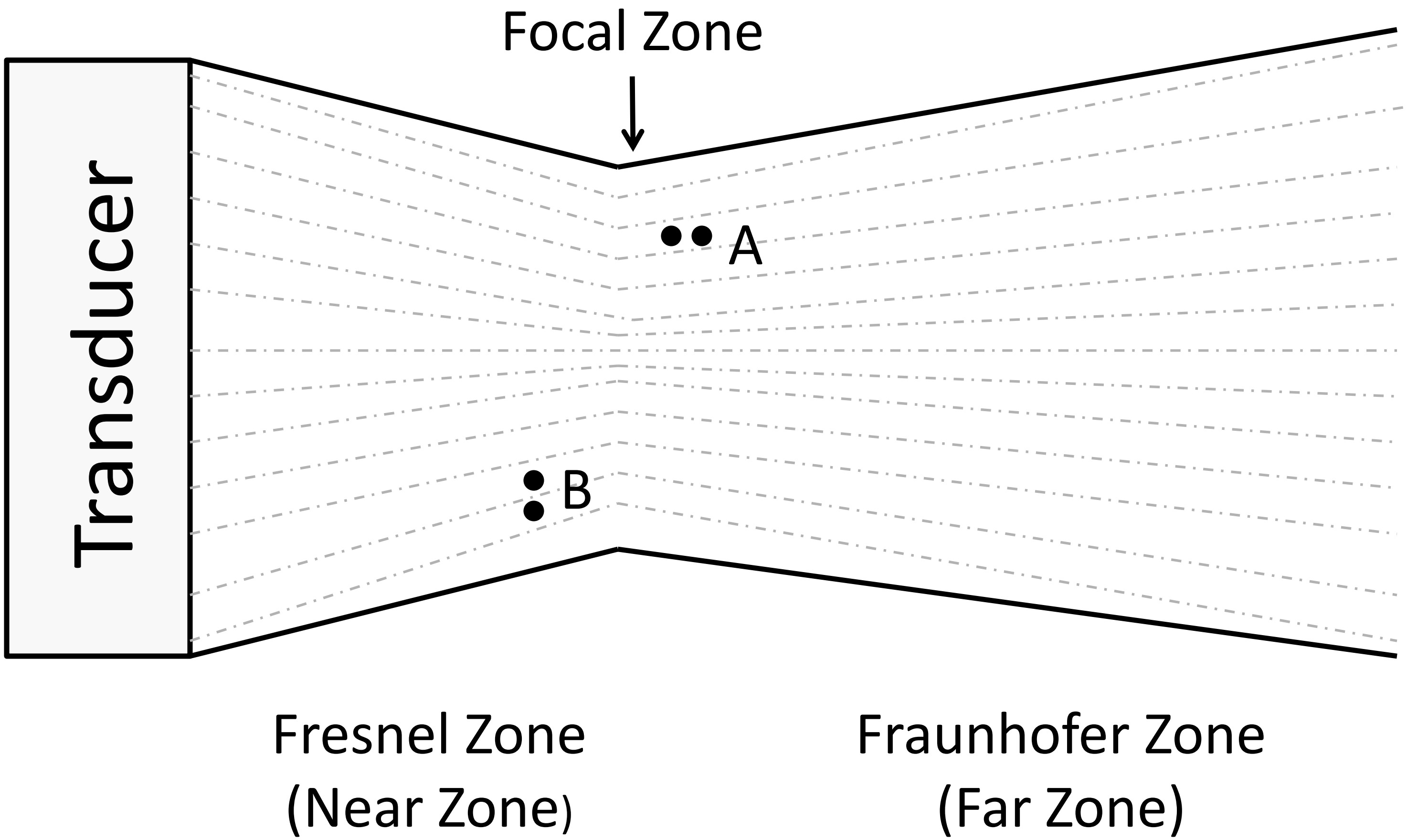
Generation of sound waves



Transducers

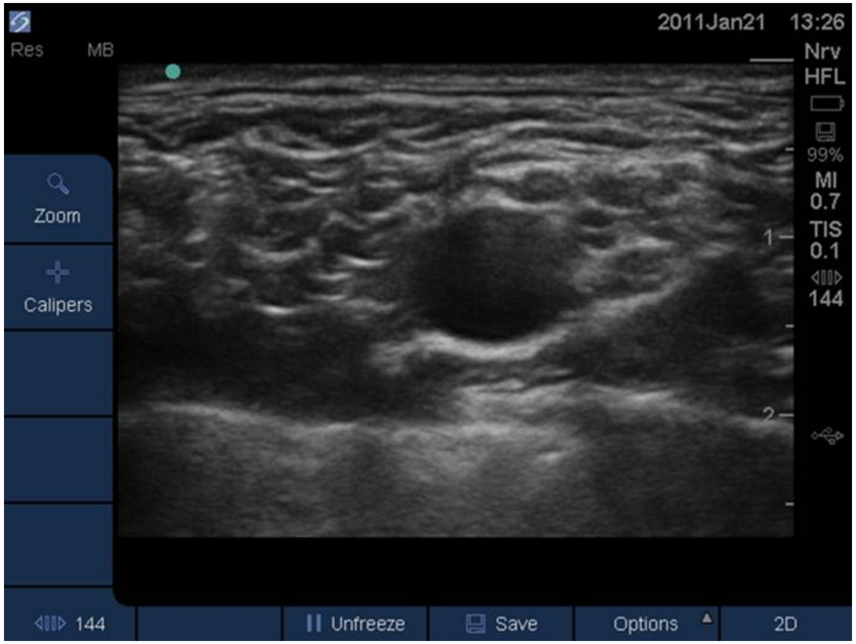
- Transducers are the link between the ultrasound system and the tissue.
- Most transducers used for regional anesthesia are either linear or curved array transducers.
- Transducers use the **piezoelectric effect** to create an image.
- Axial and lateral resolution are determined by the characteristics of the transducer.

Sound wave properties



Generation of sound waves

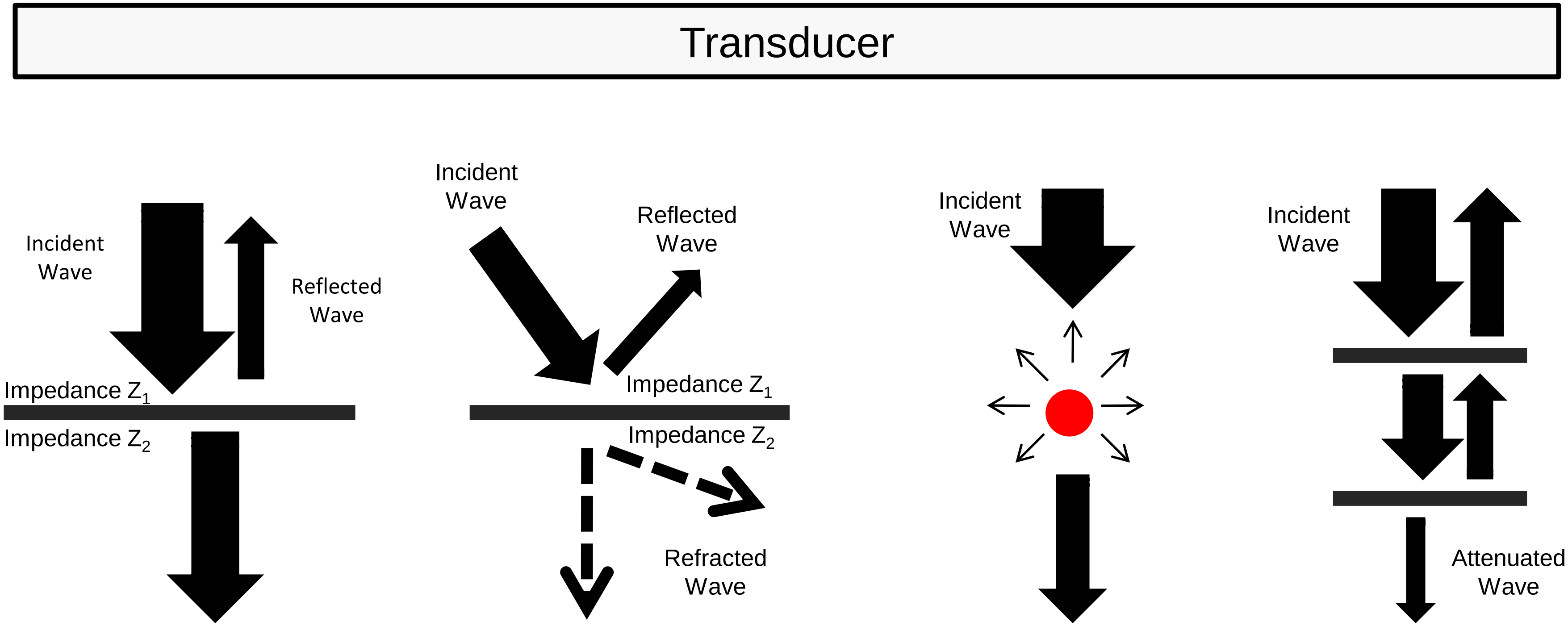
- The echoes interpreted by ultrasound result from the different acoustic impedances of tissues
- The amount of reflection, refraction, scattering, and attenuation is dependent on the degree of difference



Acoustic impedance

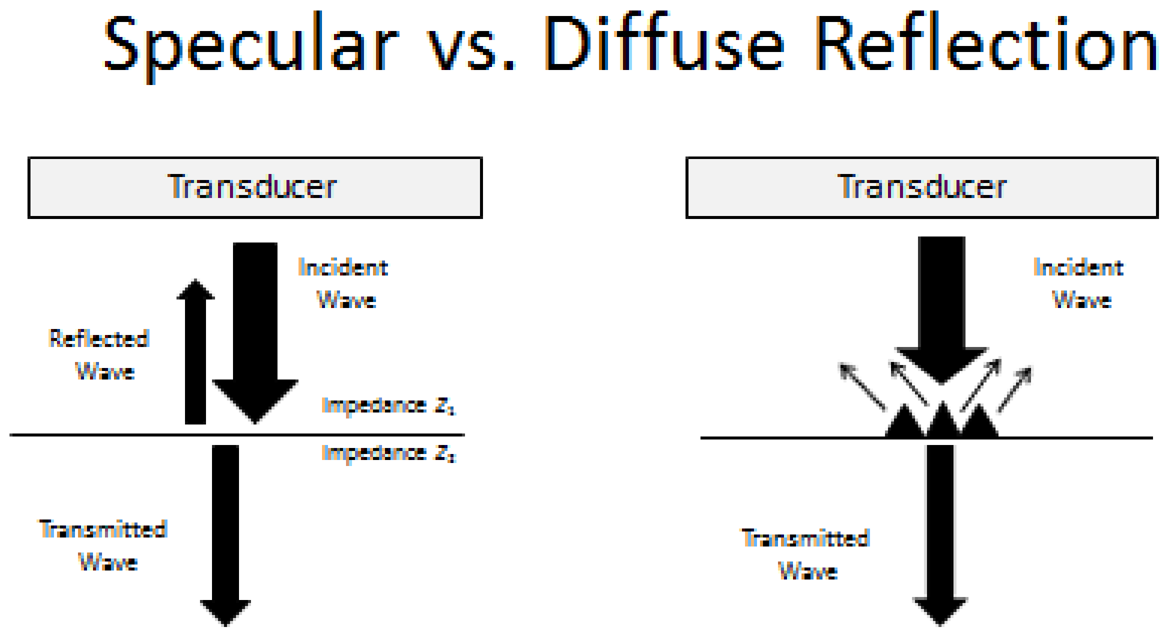
Body Tissue	Acoustic Impedance (10^6 Rayls)
Air	0.0004
Lung	0.18
Fat	1.34
Liver	1.65
Blood	1.65
Kidney	1.63
Muscle	1.71
Bone	7.8

Sound/Tissue interaction



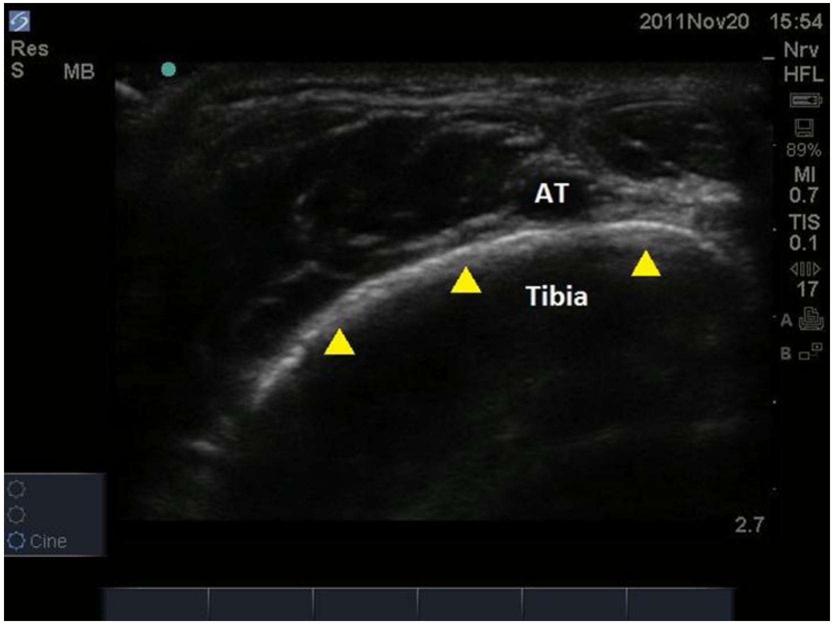
Reflection **Refraction** **Scattering** **Attenuation**

Reflection

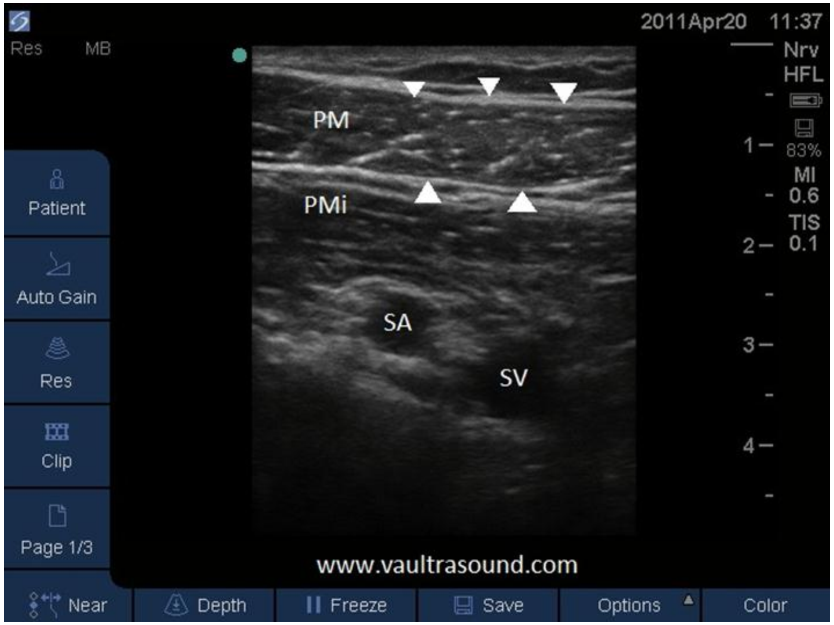

Specular vs. Diffuse Reflection
Transducer
Incident Wave
Reflected Wave
Impedance Z_1
Impedance Z_2
Transmitted Wave
Transducer
Incident Wave
Transmitted Wave

Reflection

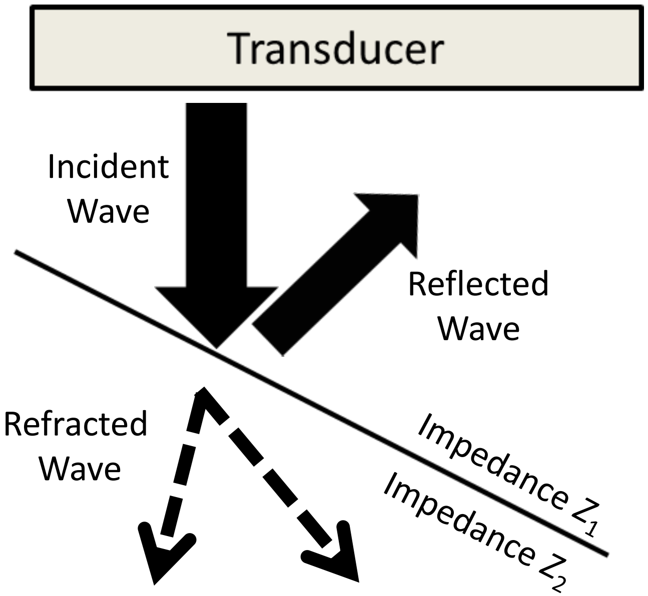
Specular



Diffuse



Refraction


Transducer
Incident Wave
Reflected Wave
Refracted Wave
Impedance Z_1
Impedance Z_2


TEST 2
2009Feb20 13:50
Gen
S MB
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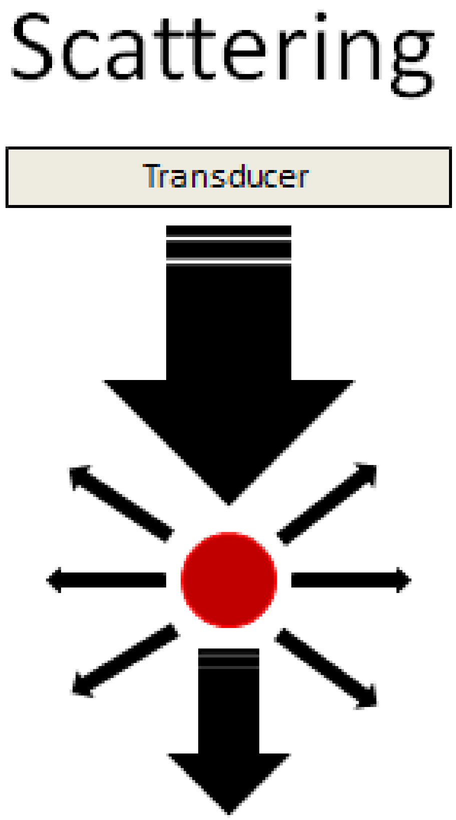
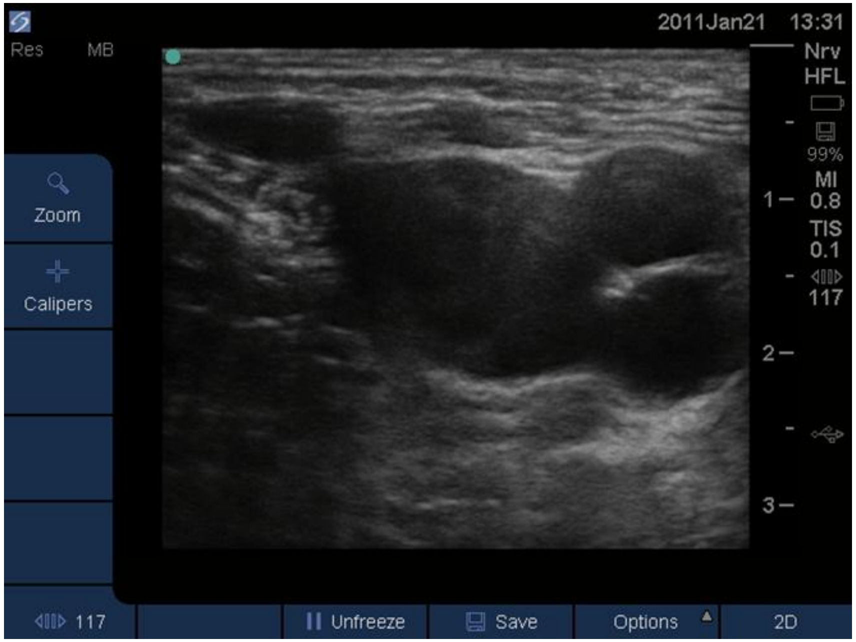
Dual
Page 1/2

Rayleigh scattering



- Rayleigh scattering occurs at interfaces involving structures of small dimensions (such as a red blood cell).
- This creates a <u>relatively uniform average amplitude in all directions.</u>

Rayleigh scattering



- Who/What is Mickey?

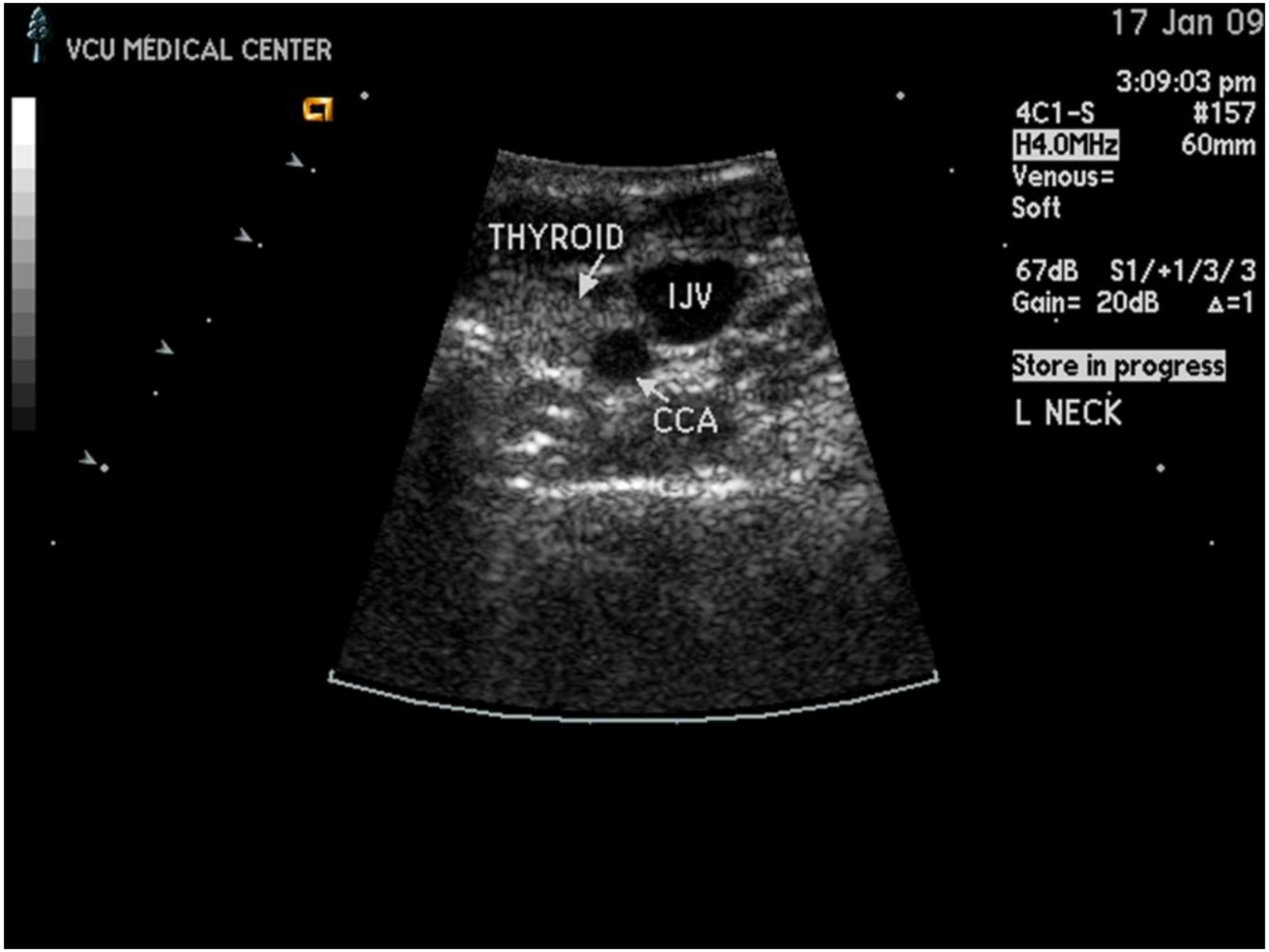
Attenuation

- The decreasing intensity of a sound wave as it passes through tissue
- In medical ultrasound, attenuation is the result of the interaction of sound with tissue
- The attenuation coefficient is the relation of attenuation to distance, and is dependent on the tissue traversed and the frequency of the ultrasound wave
- Higher frequency waves are attenuated to a higher extent than lower frequency waves

Attenuation coefficients

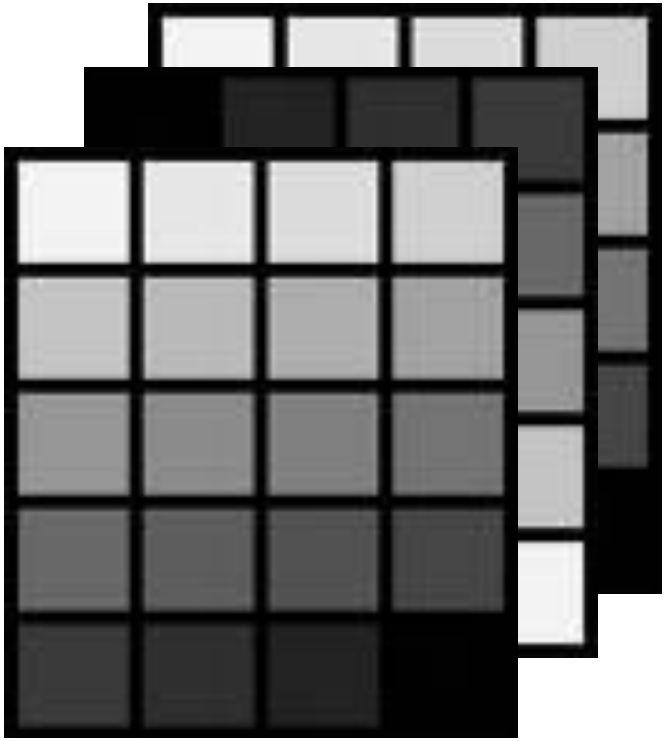
Body Tissue	Attenuation Coefficient (dB/cm at 1MHz)
Water	0.002
Blood	0.18
Fat	0.63
Liver	0.5-0.94
Kidney	1.0
Muscle	1.3-3.3
Bone	5

Attenuation



What creates my picture?

- It's all in the math!!!
- The computer assigns a color in a grey scale based on the strength of returning echoes to form the image.
- This process repeats itself hundreds of times a second resulting in real-time imaging.

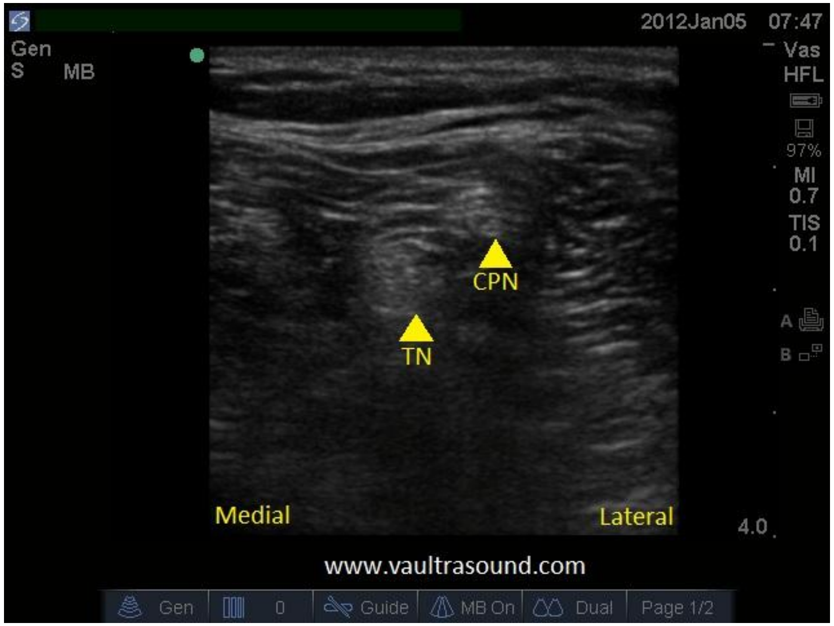


What do tissues look like?

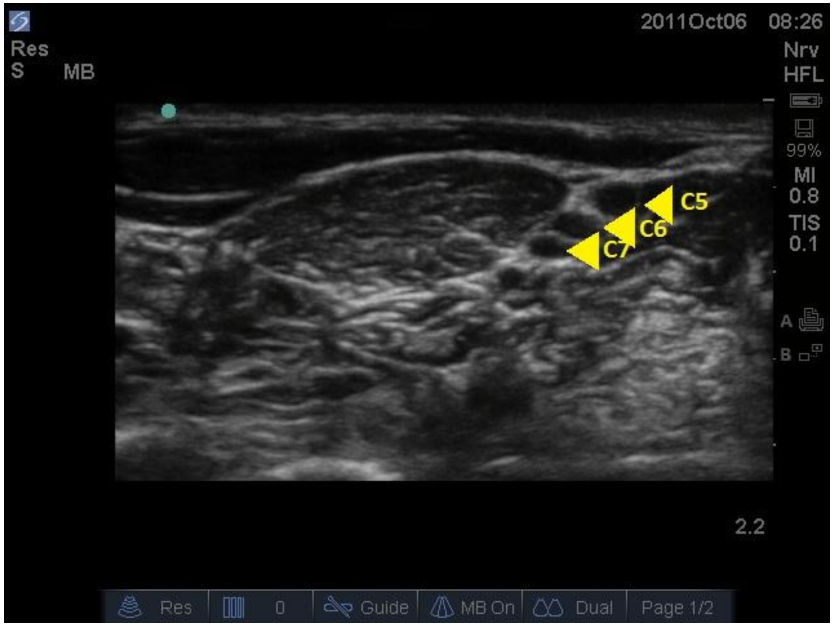
- **Nerves** – in cross section appear as round “honeycomb” structures
- **Tendons** – appear similar to nerves, but become flat and disappear when followed proximally along an extremity
- **Vascular Structures** – typically appear as anechoic circular structures in cross-section. Will appear tubular in longitudinal view
- **Fat** – appears hypoechoic with streaks of irregular hyperechoic lines
- **Fascia** – appears linear hyperechoic structures marking tissue boundries
- **Muscle** – appears feather-like in longitudinal view; appears as a “starry night in cross-section, more hypoechoic than nerves
- **Pleura and Air** – pleura appears hyperechoic, with the lung appearing hypoechoic underneath
- **Cysts** – similar appearance to vascular structures, cysts will also appear as hypoechoic in longitudinal view
- **Bone** – appear as hyperechoic linear structures with hypoechoic regions underneath (shadowing)

Not all nerves look the same…

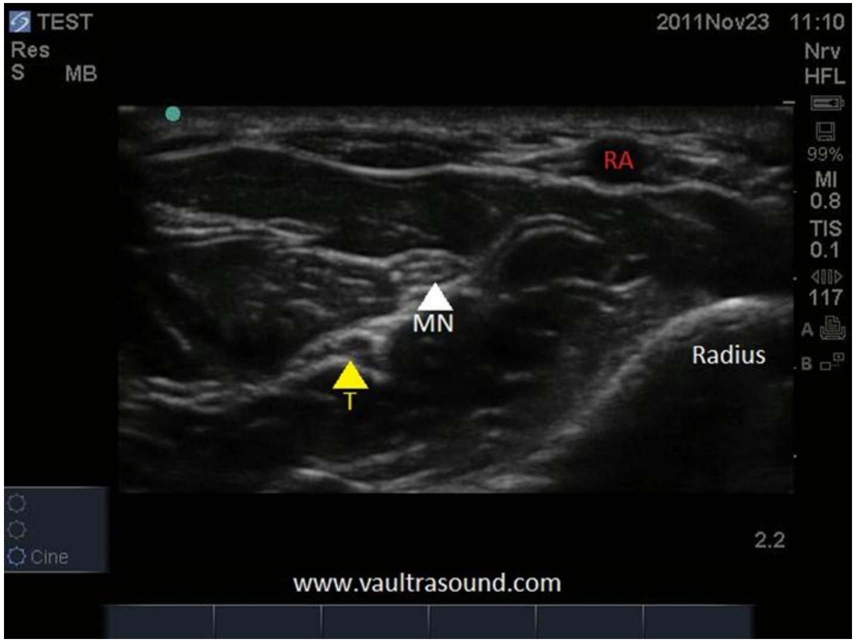
Peripheral Nerves



Roots of the Brachial Plexus



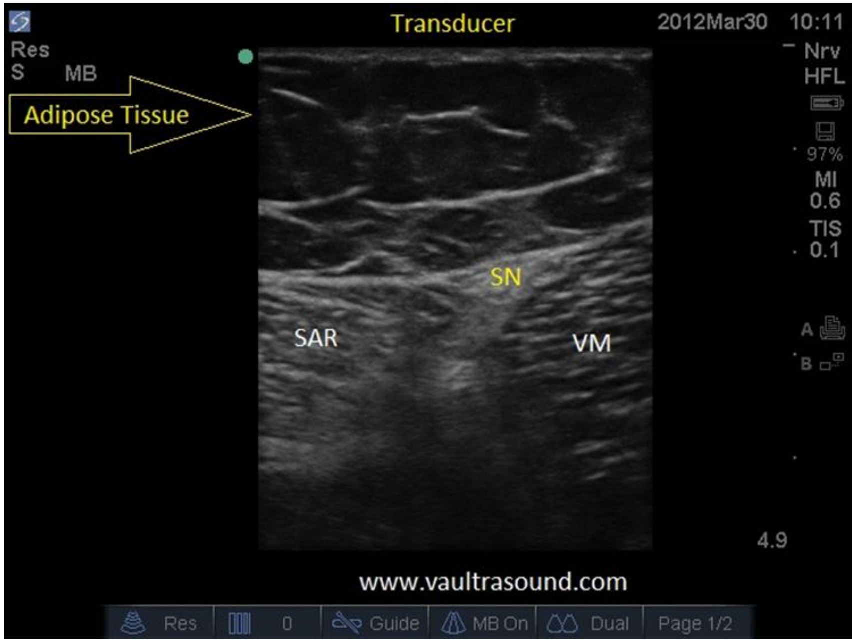
Nerves vs. Tendons



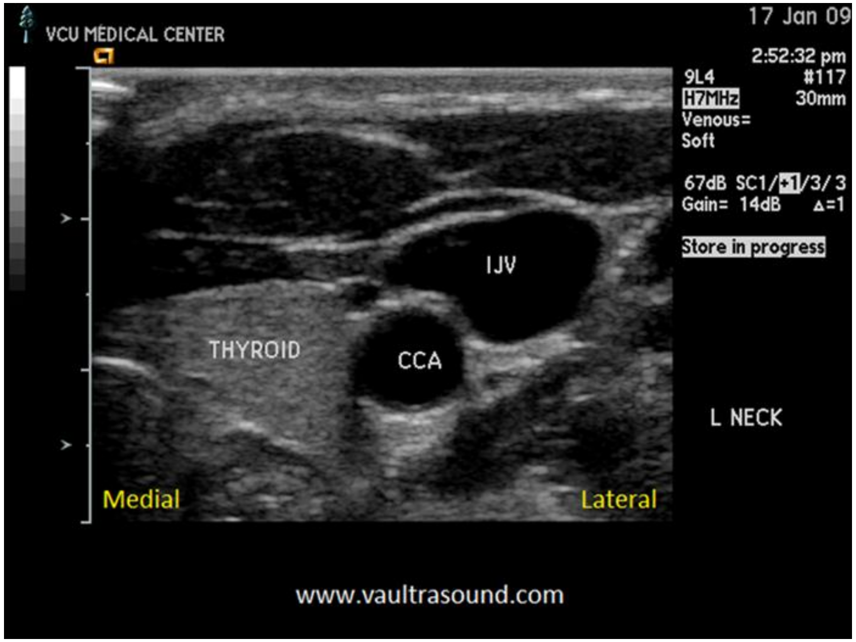
- Nerves and tendons can both appear as hyper-echoic circles in the periphery.
- They can be differentiated by following their course proximally along the extremity

Adipose tissue

- Adipose tissue appears hypoechoic with streaks of irregular hyperechoic lines
- It is the most superficial layer imaged



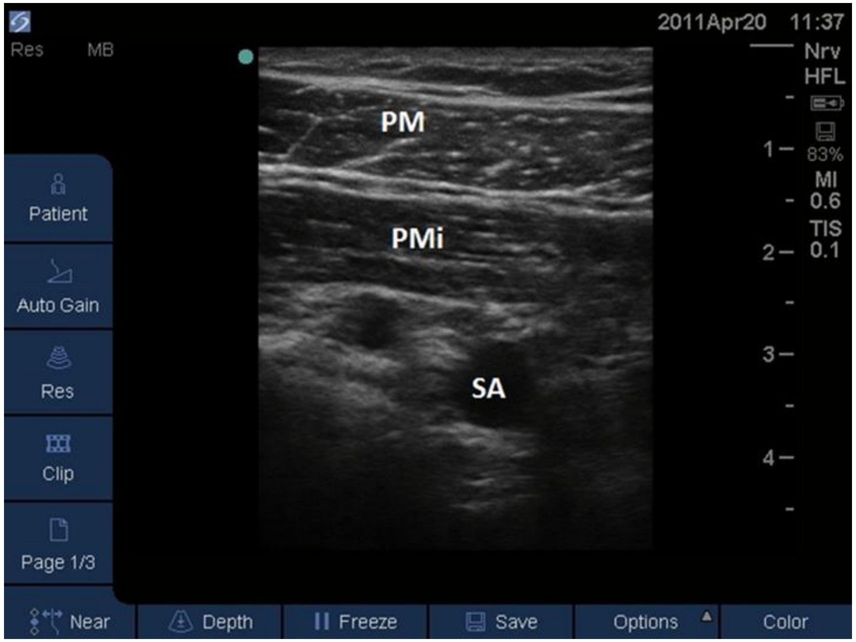
Arteries, veins and cysts



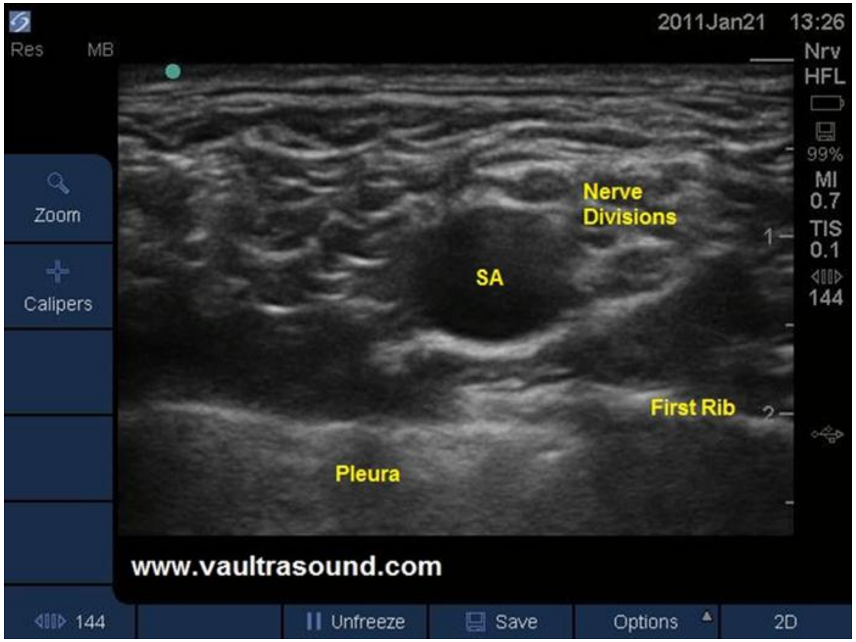
- Arteries, veins, and cysts all appear as anechoic structures
- Arteries are pulsatile, while veins can be easily compressed
- Arteries and veins will appear as tube-like structures in long view, cysts will remain round

Muscle

- Muscle appears heterogeneous on ultrasound because of the varying acoustic impedances between the cell structures, the water content within the cells, and the intertwined fascia



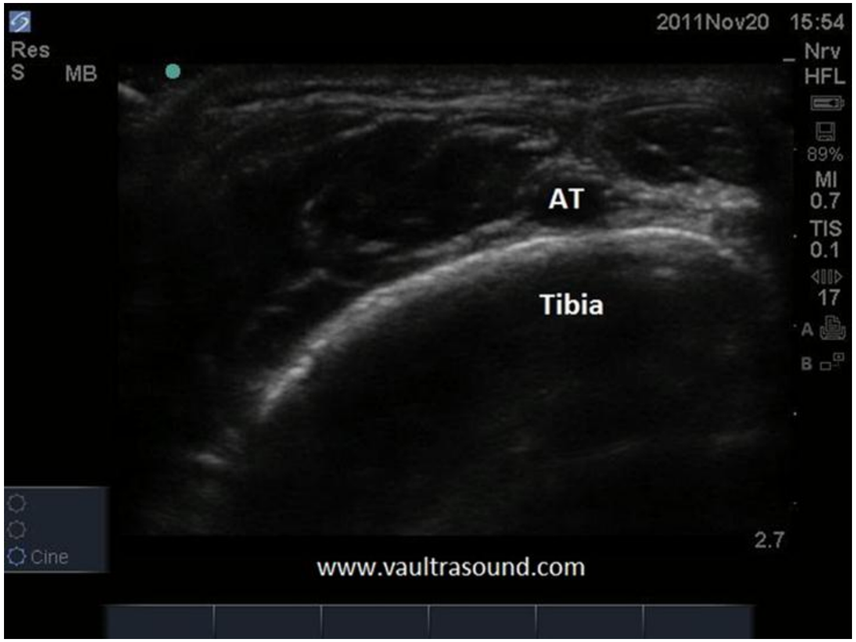
Lung



- Lung tissue appears as a thin hyperechoic line with "tails" (areas of reverberation) beneath it

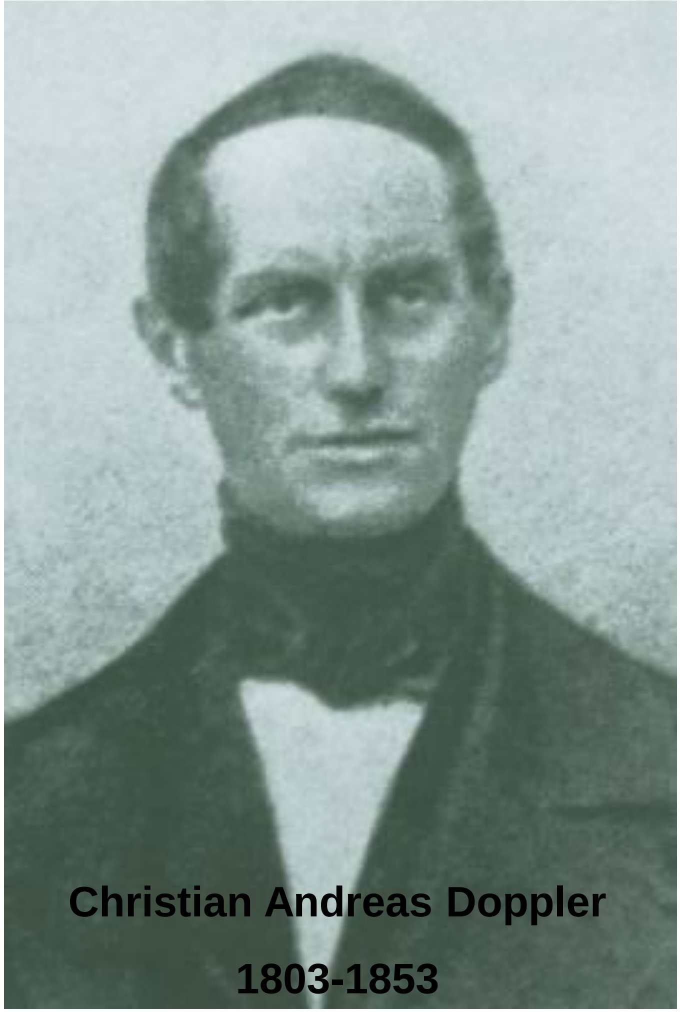
Bone

- Bone is a significant specular reflector, creating a hyperechoic area with shadowing beneath it



The Doppler effect

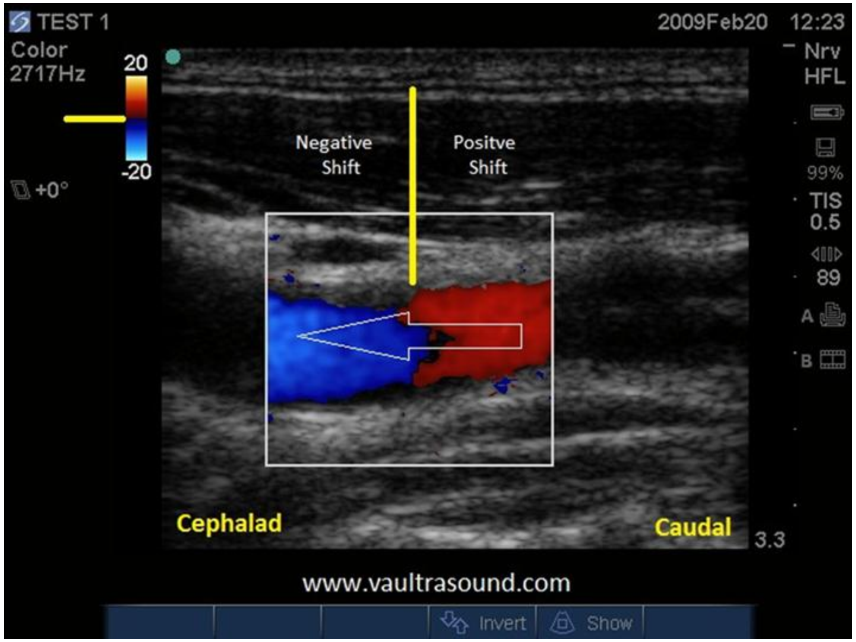
"Über das farbige Licht der Doppelsterne und einige andere Gestirne des Himmels - Versuch einer das Bradleysche Theorem als integrirenden Theil in sich schliessenden allgemeineren Theorie"



Christian Andreas Doppler

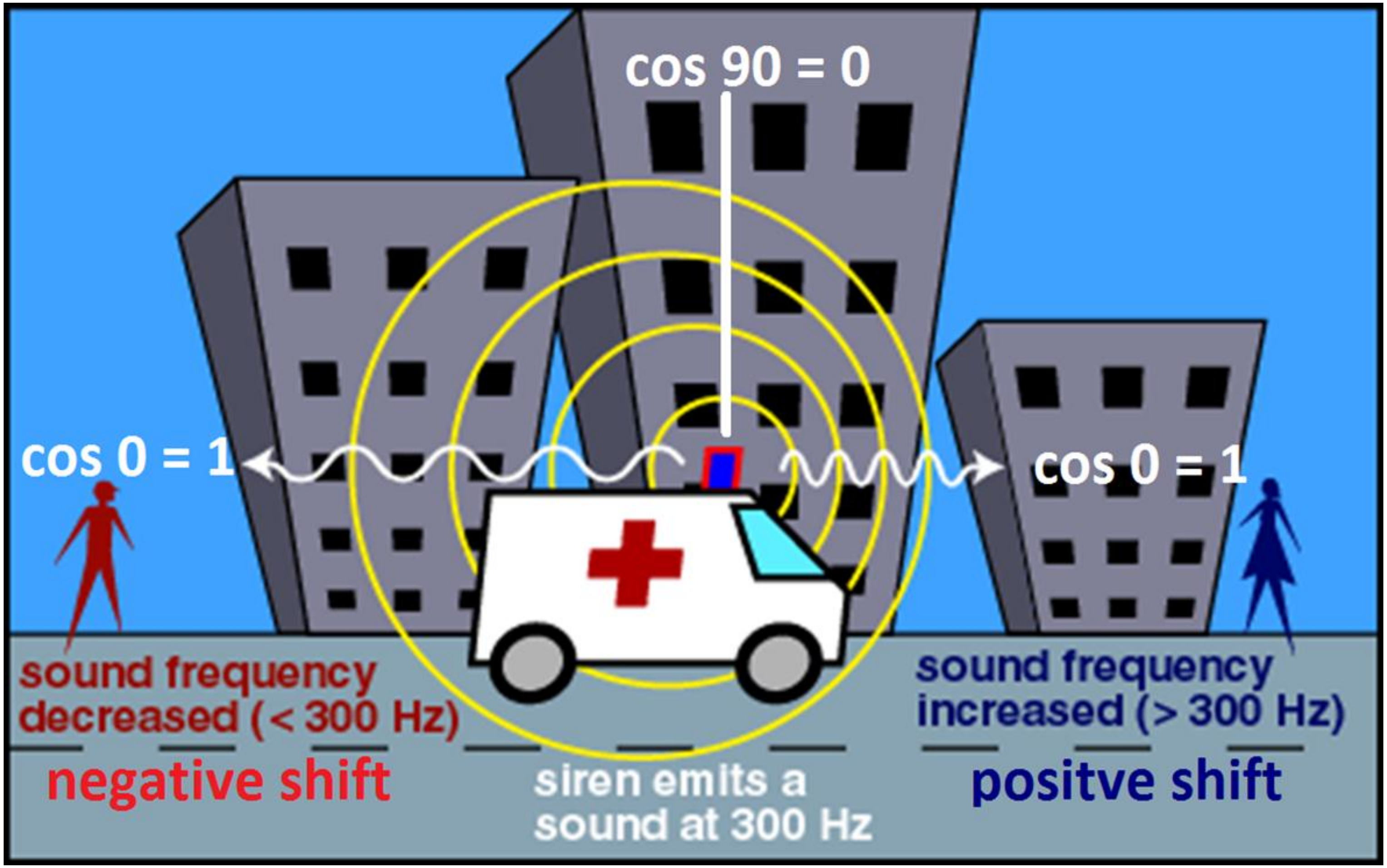
1803-1853

Doppler effect



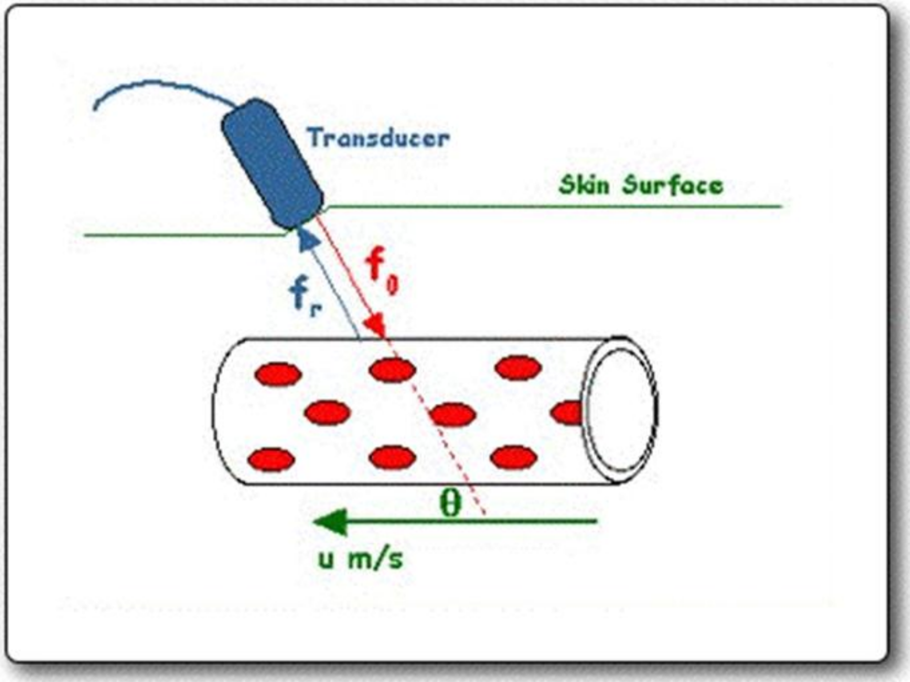
- Animals use Doppler in nature and it has been adapted by man for many purposes
- Doppler is dependent on the angle of insonation
- Either the sender or receiver must be moving
- Doppler is used to create an image

Doppler effect



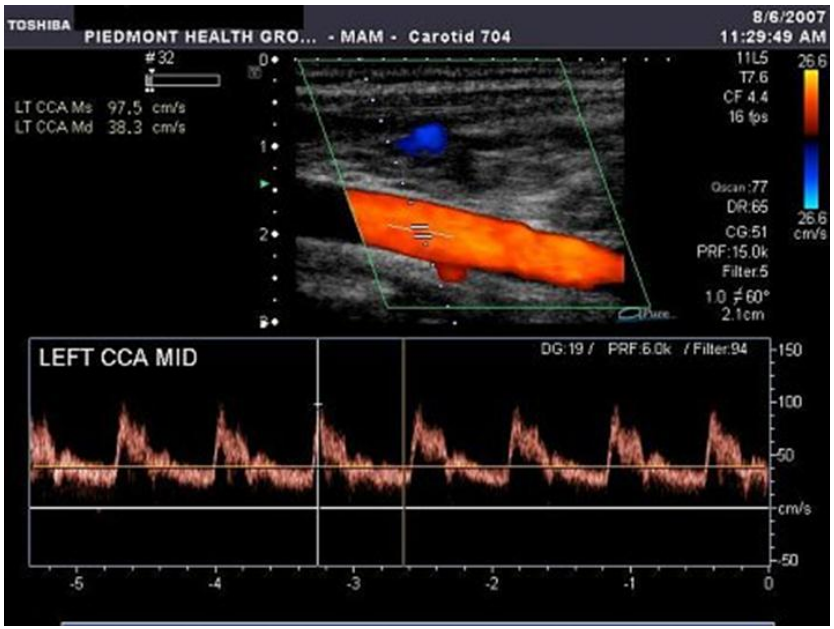
Doppler effect

- The Doppler effect compares the transmitted to the received signal.
- The transducer emits a pulse into tissue. When the pulse comes in contact with a moving object (RBC), it is reflected back to the transducer; the difference between the transmitted and received signals is the Doppler effect.

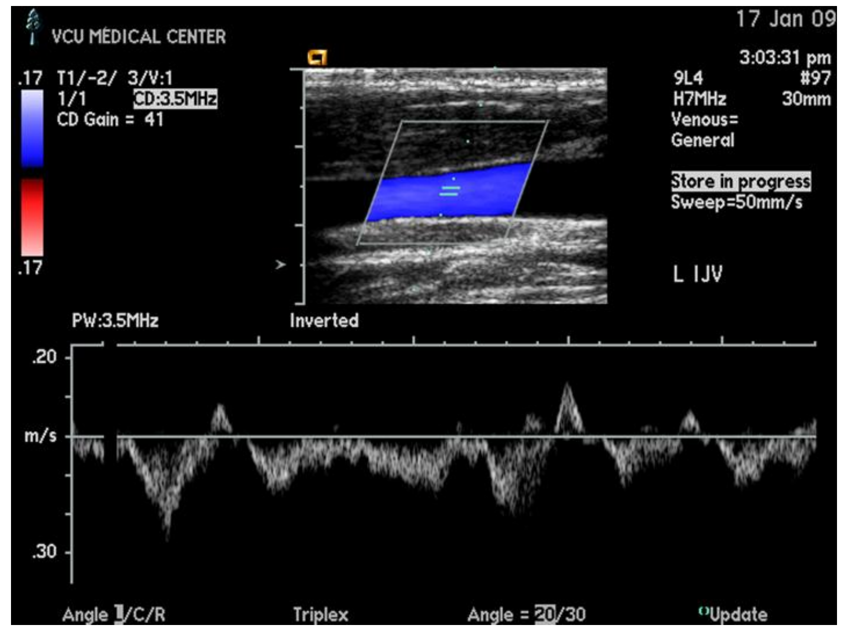


Doppler effect

Arterial

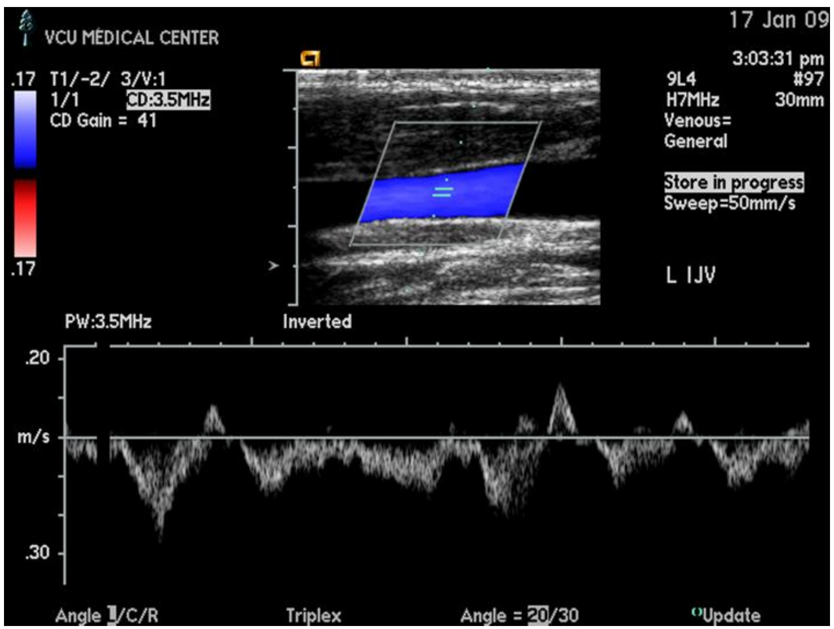


Venous

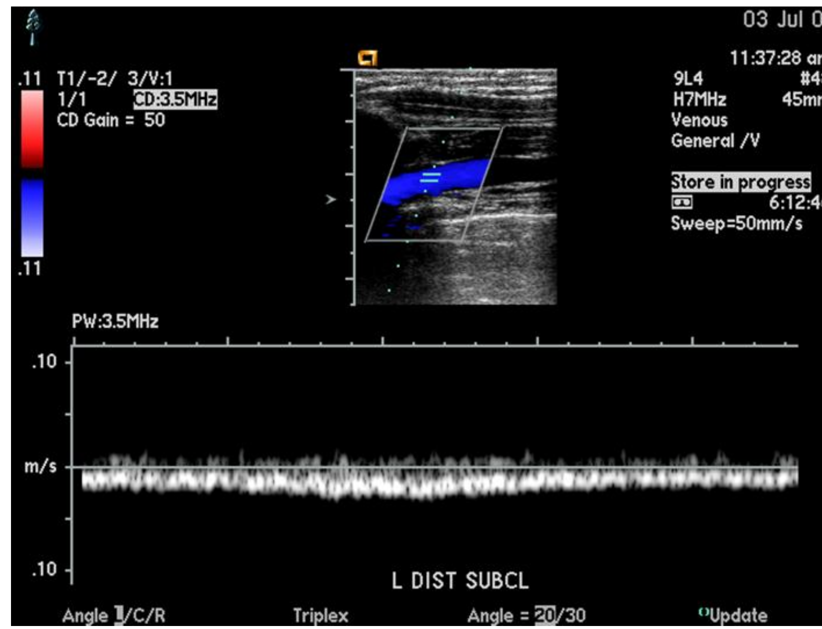


Doppler effect

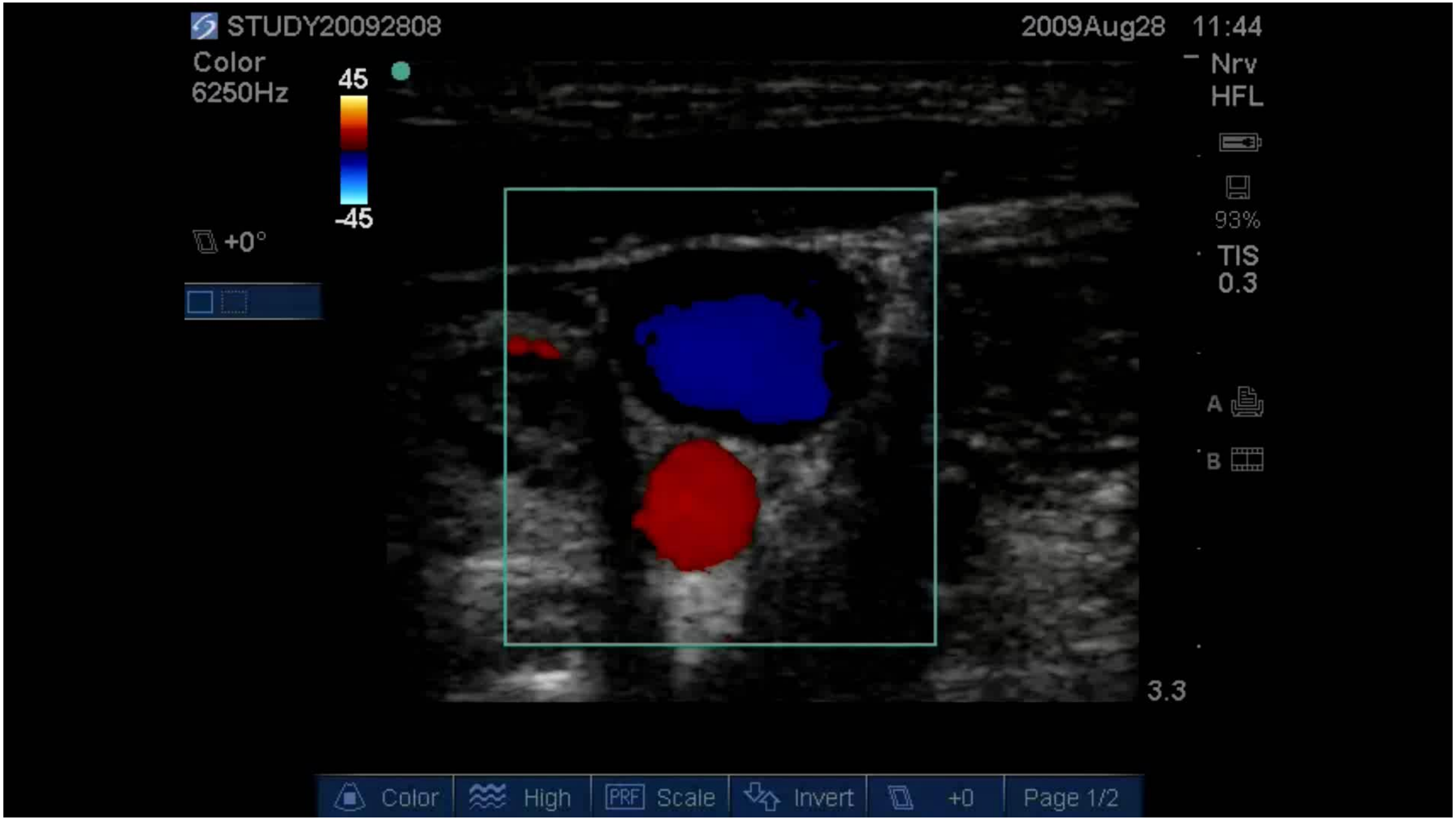
Phasic



Non-phasic

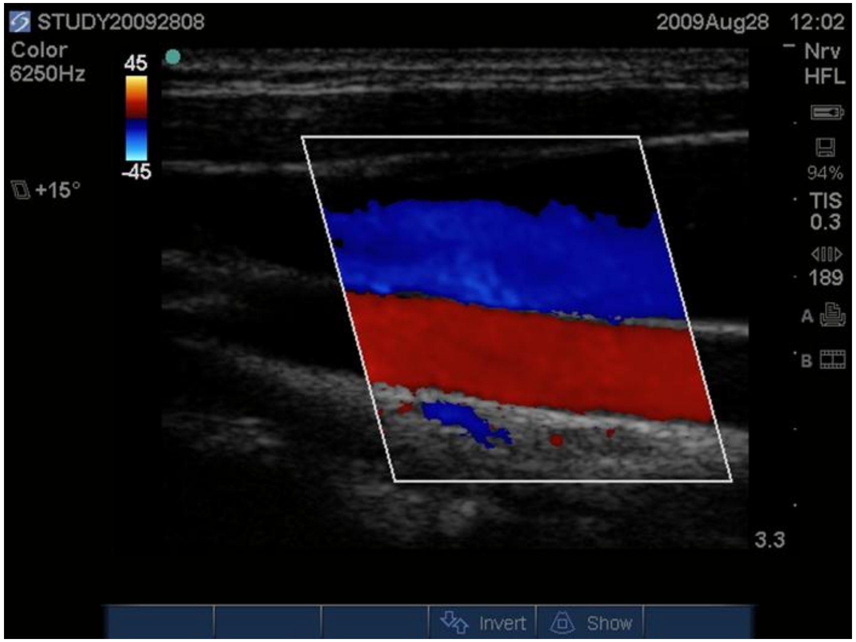


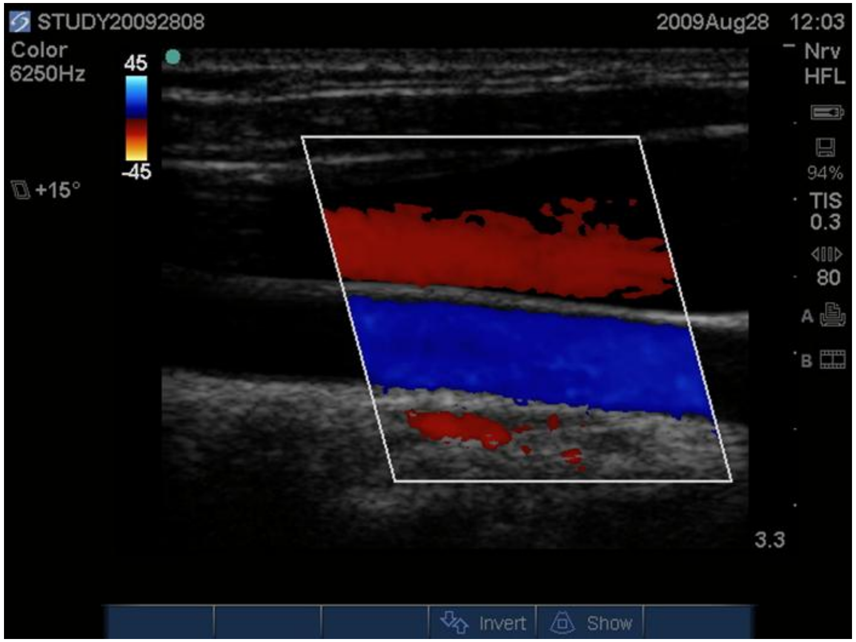
Doppler effect



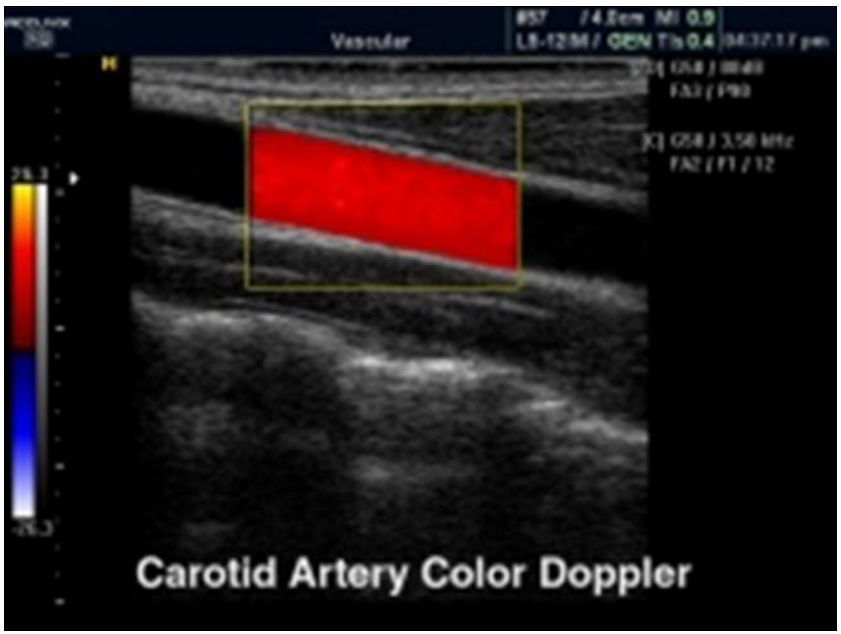
Doppler effect

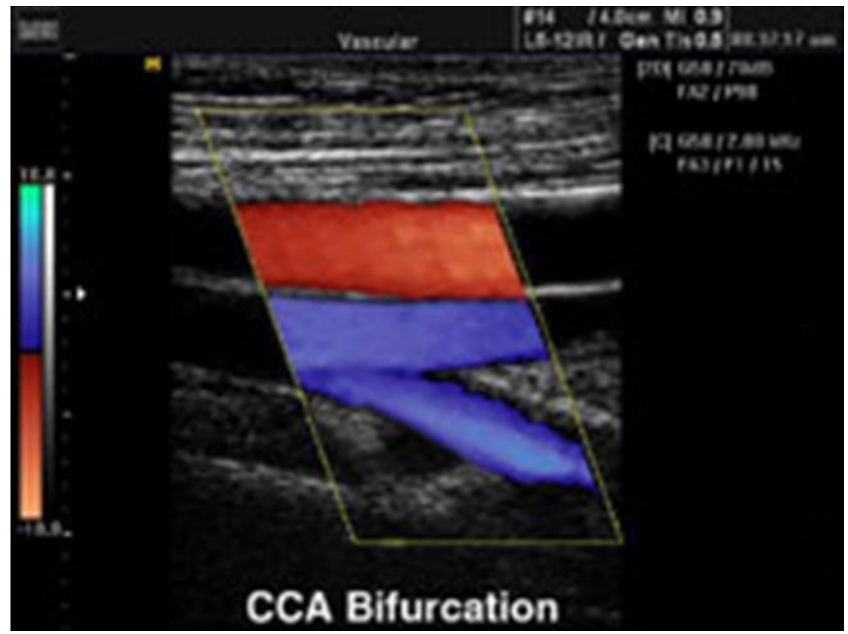
Which picture is correct?





Know you Doppler physics…





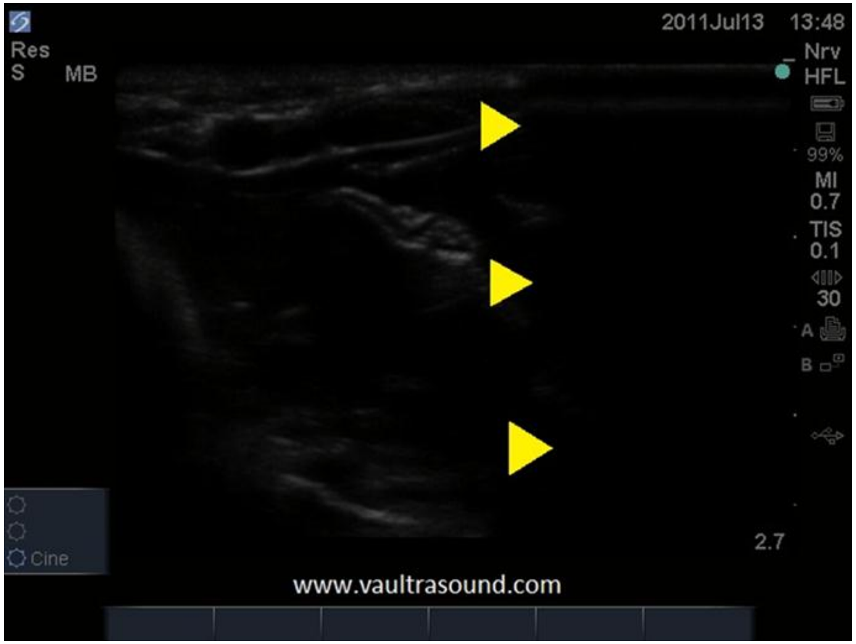
http://www.medison.ru/uzi/eng/all/vessels.htm

Artifacts

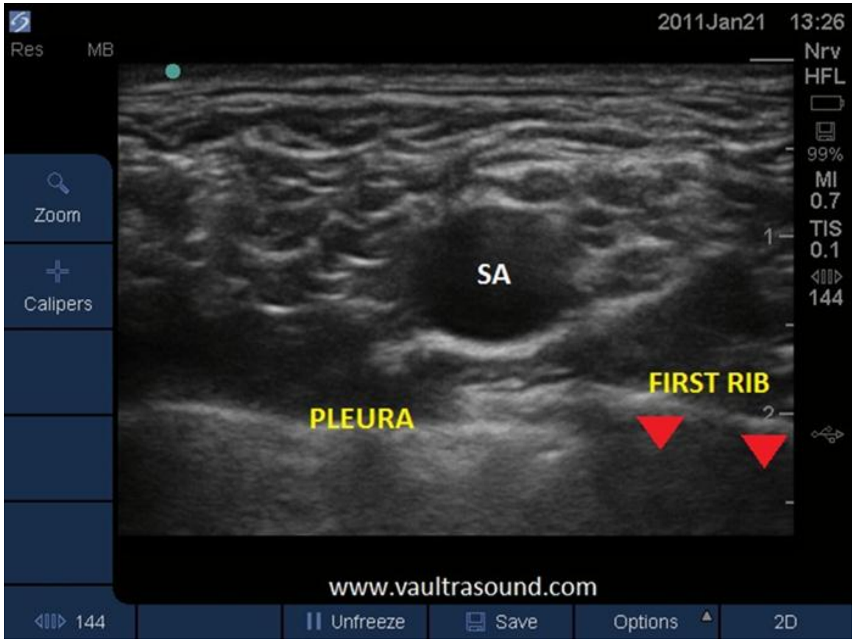
- An artifact is any phenomenon that affects the acquisition or interpretation of an ultrasound image
- Artifacts can occur because of properties within the tissue itself, or created by the anesthetist
- The most commonly seen artifacts are **air artifact**, **shadow artifact**, **acoustic enhancement**, and **reverberation**

Air artifact

- Air artifact occurs when the transducer does not fully contact the skin
- This is commonly seen when imaging smaller anatomical structures
- Applying sufficient gel to the transducer and applying even pressure will correct this



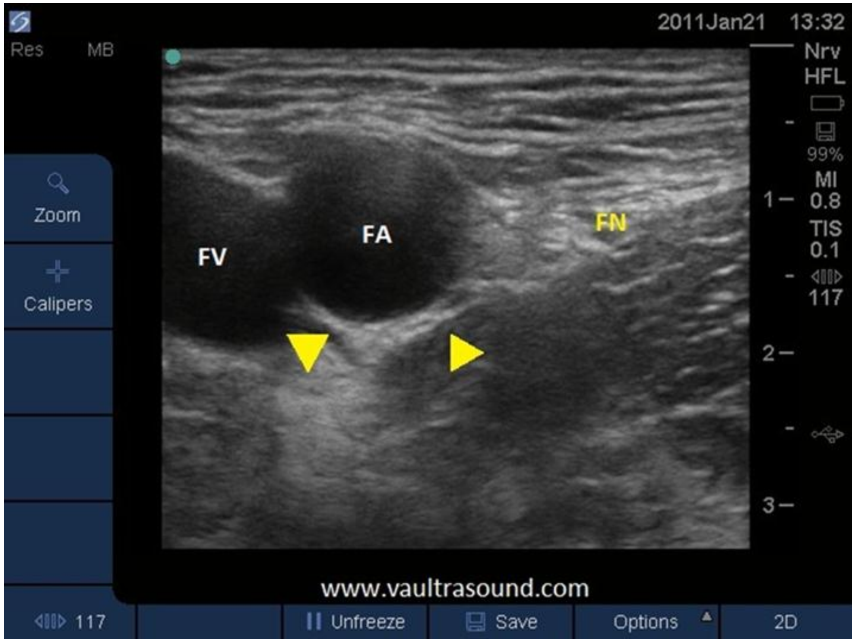
Shadow artifact



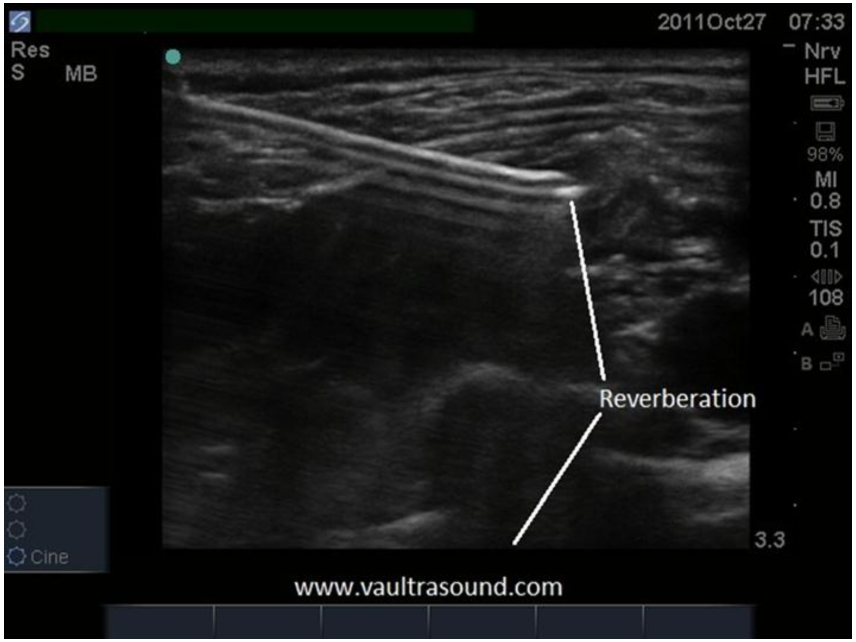
- Shadow artifact (red arrows) results from the severe amount of attenuation when an ultrasound wave comes in contact with bone or other tissue with a high attenuation coefficient

Acoustic enhancement

- Acoustic enhancement occurs when a beam passes through tissue with low acoustic impedance into tissue with a much higher impedance, causing it to look more echogenic than it actually is



Reverberation



- Reverberation occurs sound reflects off of strong specular reflectors such as this block needle creating an illusion there are "multiple" needles below the actual one

Questions?

References

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