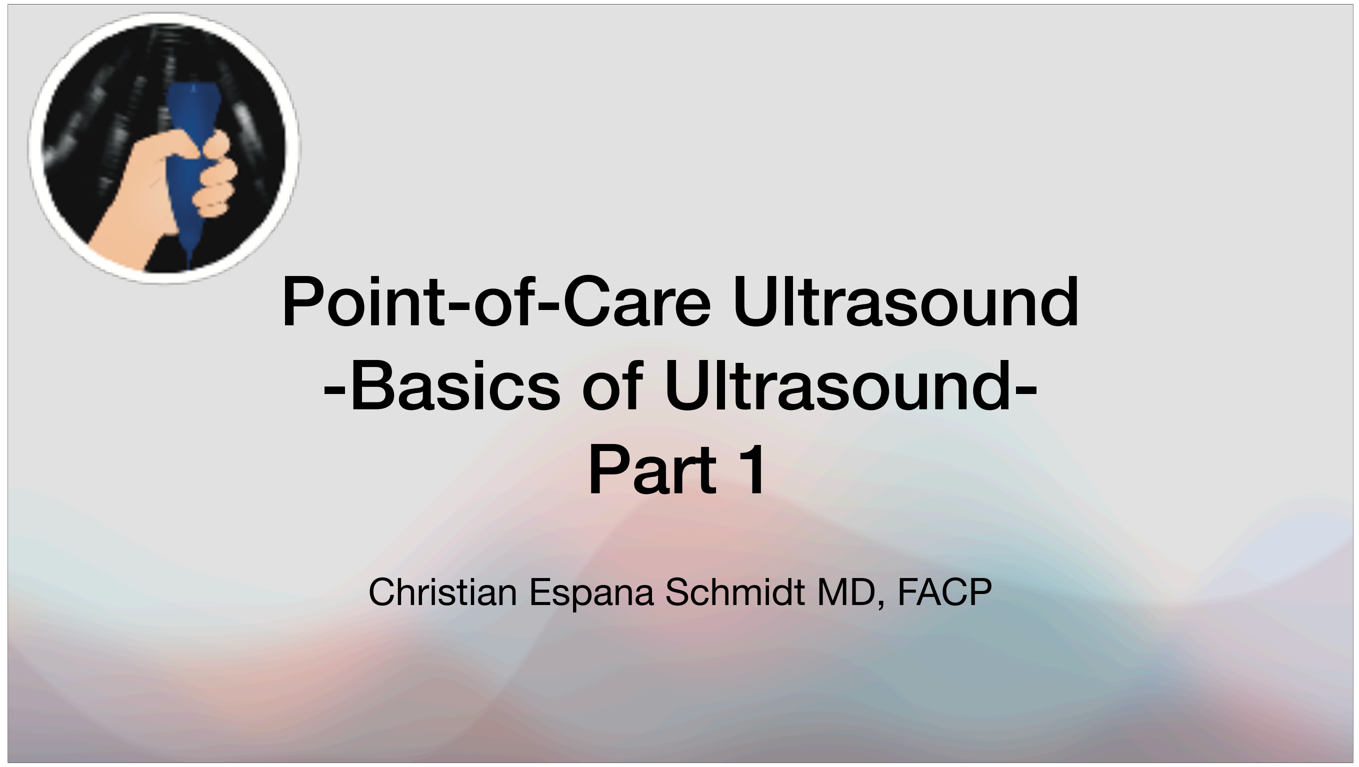
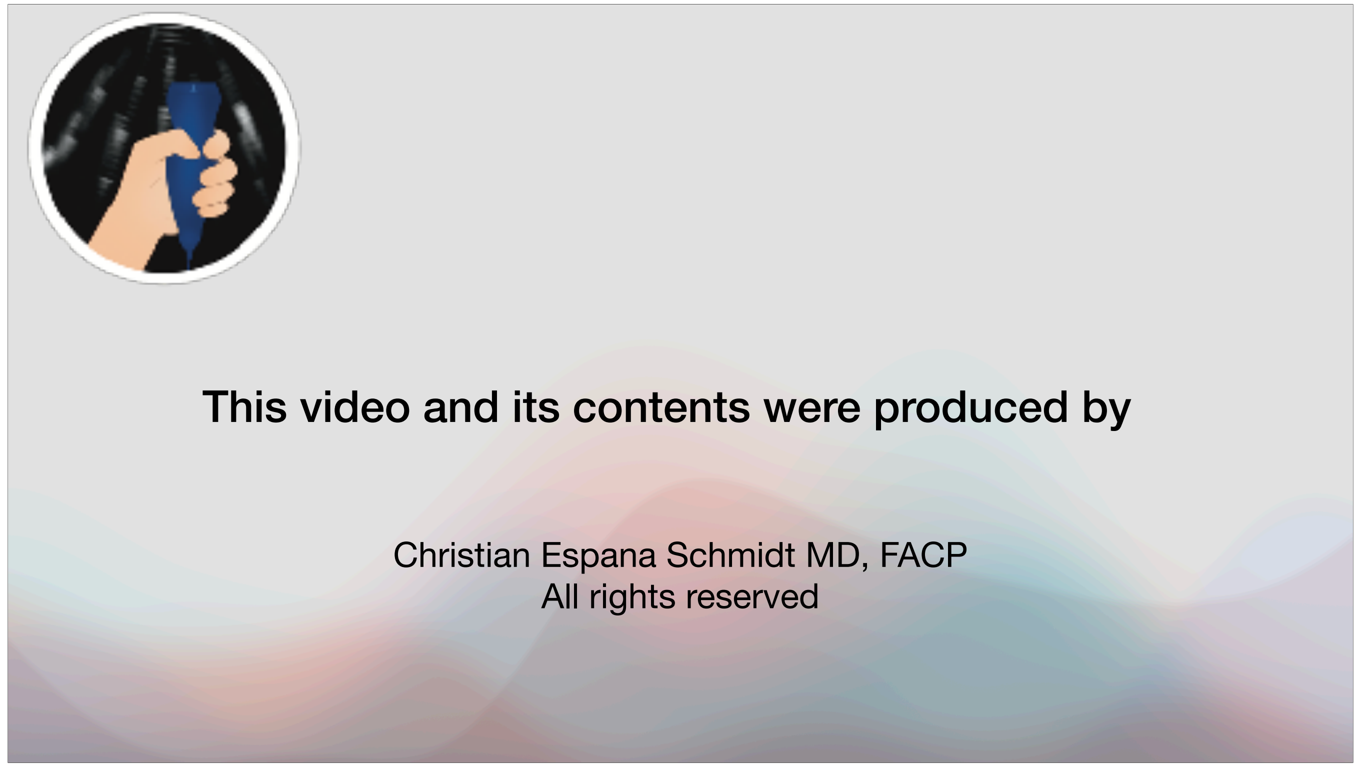


Welcome to my point-of-care ultrasound course. In this course, you will learn about point-of-care ultrasound in internal medicine. The use of POCUS medicine is a vast field that should be utilized, depending on the level of expertise of the user in each system. In internal medicine point of care, ultrasound extends to many organs and systems, and it's useful in many conditions, from the simple task of ruling out lobar pneumonia, performing procedures, to evaluating the volume of a status patient, ruling out the presence of abnormal fluid in different cavities, evaluating the heart function and structure. Point-of-care ultrasound for general internal medicine can be used in almost any evaluation.



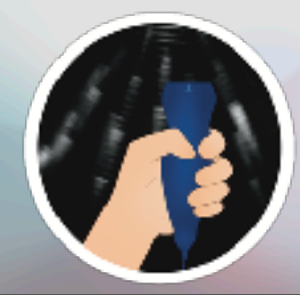
Welcome to my course on point-of-care ultrasound. In this course, you will learn about point-of-care ultrasound in internal medicine. Point-of-care ultrasound and internal medicine are vast fields that should be utilized, depending on the level of expertise of the user in each system. In internal medicine point of care, ultrasound extends to many organs and systems, and it's useful in many conditions, from the simple task of ruling out lobar pneumonia, performing procedures, to evaluating the volume of a status patient, rule out the presence of abnormal fluid in different cavities, and evaluating the heart function and structure. Point of care, ultrasound for the general internal medicine can be used in almost any evaluation.

Conflicts of interest

- No pertinent conflicts to share.

What is POCUS

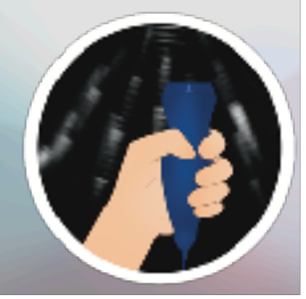
- POCUS is a non comprehensive ultrasonographic study. It is performed at the bedside by the clinician. The goal is to aid the clinician during a procedure or in the diagnosis and treatment of a patient.
  - POCUS enhances physical examination.
    - Improves medical decision.
  - POCUS is of great value to perform procedures.
    - Improves results and decrease complications.



Point-of-care ultrasound is a non-comprehensive ultrasonographic study performed at the patient's bedside to address a specific question. This is by no means a comprehensive anatomical examination; this needs to be understood by both the clinician and the patient. Point-of-care ultrasound can help clinicians answer questions that are not evident in the physical examination. For example, the presence of pleural or pericardial effusion. Confirming the suspicion of pneumonia. Evaluating structures, such as joints, to rule out inflammation and effusion. Point-of-care ultrasound is a valuable tool for performing procedures. Decrease complications and enhance our physical examination.

POCUS is not new

- POCUS has been used for more than 50 years in different places.
  - Adopted by Obstetrics1957
  - Adopted by Cardiology 1970
  - FAST 1990



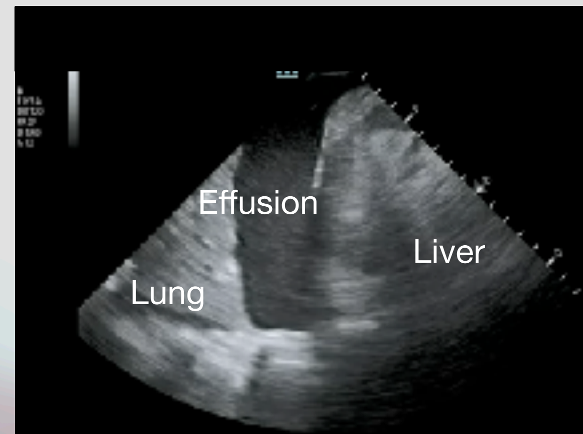
POCUS has been used already for more than 50 years, it was already adopted by the obstetricians in 1957, you can imagine the improvement in evaluation of the heartbeat of a fetus with the aid of ultrasound, things that were not apparent during regular physical examination where now visible in the screen of the ultrasound machine, there are limited ways to evaluate, for example the amount of fluid in the fetal membranes. In the 1970s, ultrasound at the bedside of the cardiologist’s patient was used to rule in or out many cardiac conditions that are elusive to the physical examination and the EKG. Small pericardial effusions are usually not diagnosed with chest x-rays, EKGs, and, furthermore, their hemodynamic impact is very difficult to evaluate clinically.
During the 1990s, the Focused Assessment with Sonography in Trauma (FAST) examination initiated a shift in the approach to patients in the emergency department, particularly those who had sustained trauma.

Is used for the first time to evaluate lungs and other organs

- Daniel Lichtenstein.
- Out of frustration from the little information gather from Chest X rays at the ICU at University Hospital Ambroise-Pare Invented lung ultrasound.

In internal medicine, the beginnings of POCUS date to the mid-90s when Dr. Daniel Lichtenstein used a machine that was in his ICU in Belgium, out of frustration with the little information that he was able to obtain from the chest x-rays performed in critically ill patients. He had the idea of evaluating the pleural cavity of a patient who had a hazy X-ray. Soon he realized that the air in the lungs could create many artifacts that we use today in a lung ultrasonography, something that was believed not to be of any use because of the ultrasonographic properties of air.

What he saw first



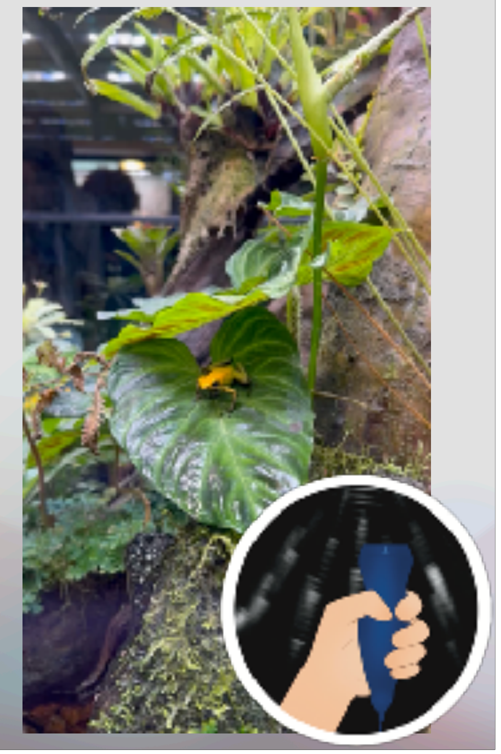
- A pleural effusion.
- He also described A lines, B lines, and many other findings of the lung ultrasound that we have today.

This is an illustration of what Dr. Lichtenstein might have seen in his first patient. In this ultrasonography, we can see a compressed lung, a plural effusion, the diaphragm and the liver from Zone 4 (we will learn about lung ultrasonography in a different lecture). He also described A and B lines, ultrasonography the pleura and many more findings in lung ultrasound. He wrote the book total body ultrasound.

Basic physics

- What is sound?

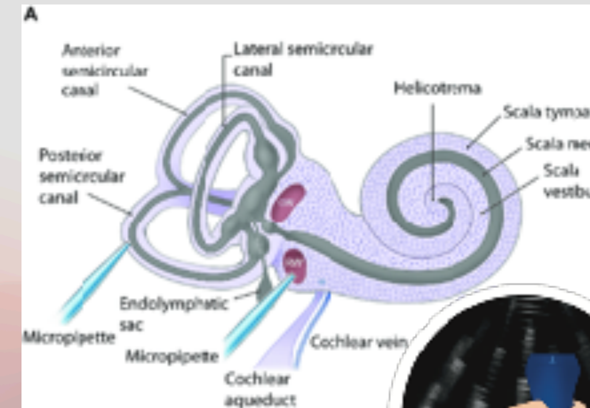
- Sound is a mechanical vibration that propagates as an acoustic wave through a medium.

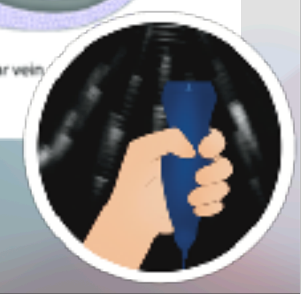


What is sound?
Sound is a mechanical vibration or mechanical force that is repeatedly transmitted through a medium. Sound is usually classified in HERTZ, and one hertz is equal to one cycle or vibration per second. Audible sound usually ranges between 20 Hz and 20,000 Hz. Ultrasound is sound that we cannot hear because it's beyond 20,000 Hz. The ultrasound used in medicine is typically measured in megahertz, which corresponds to a million cycles per second.

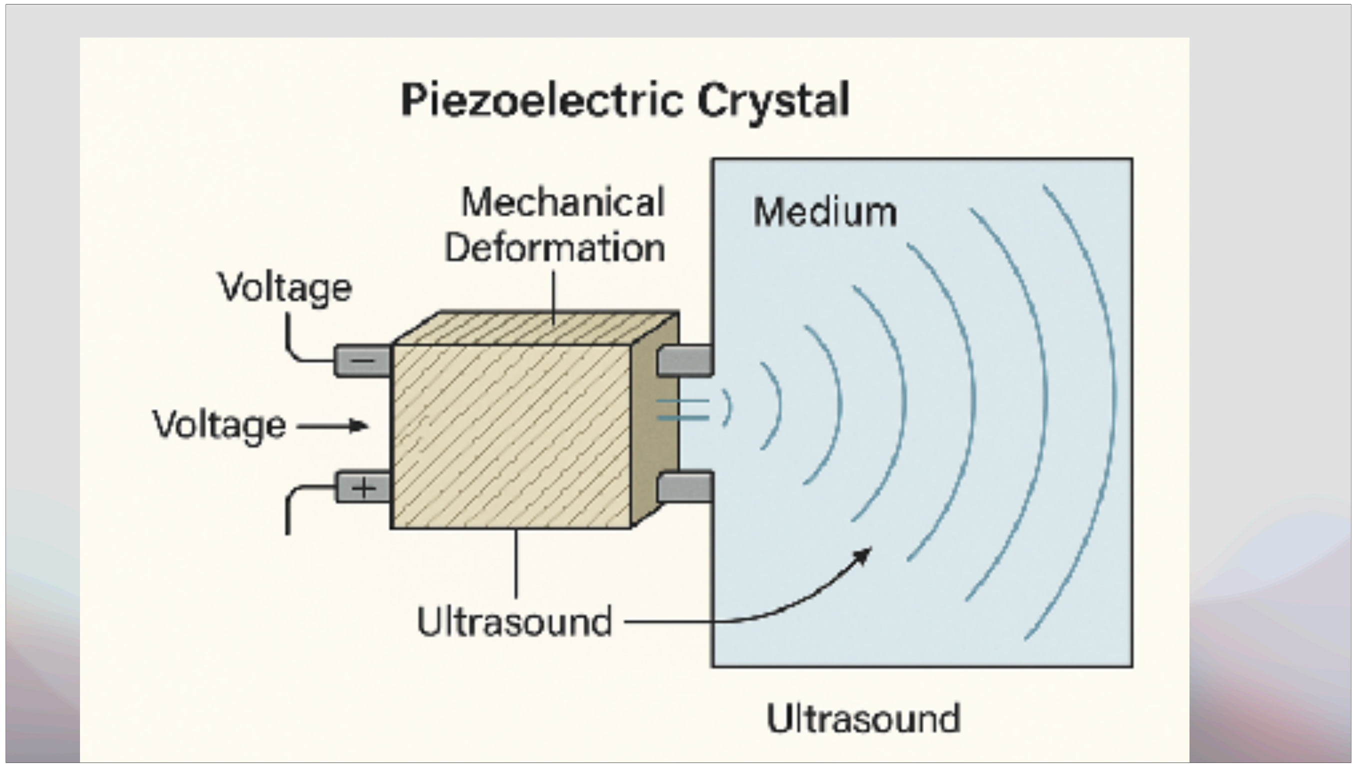
What is ultrasound?

- Ultrasound is any frequency of sound that is beyond our ability to hear, typically around 20 kHz.
- A Hertz = 1 cycle per second
- A kilohertz = 1000 cycles per second
- A mega heart = 1 million cycles per second

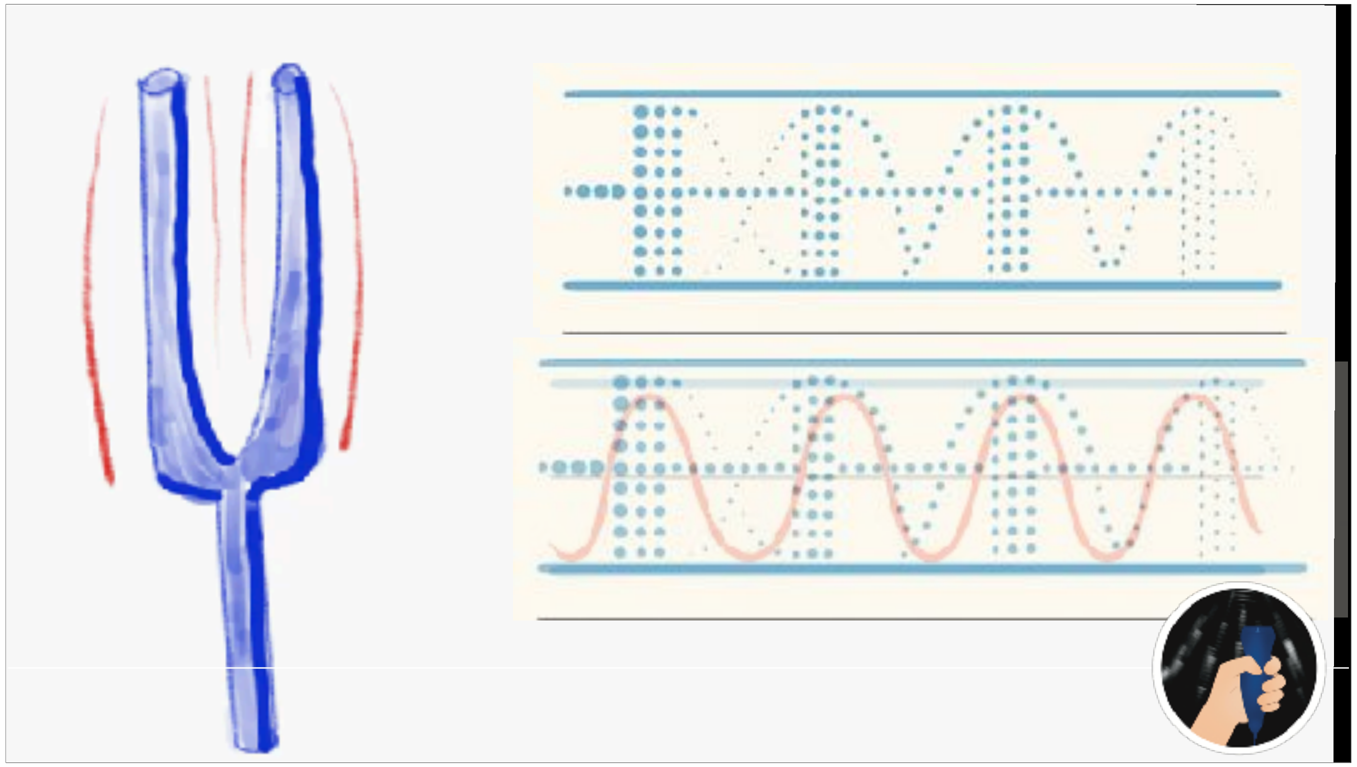




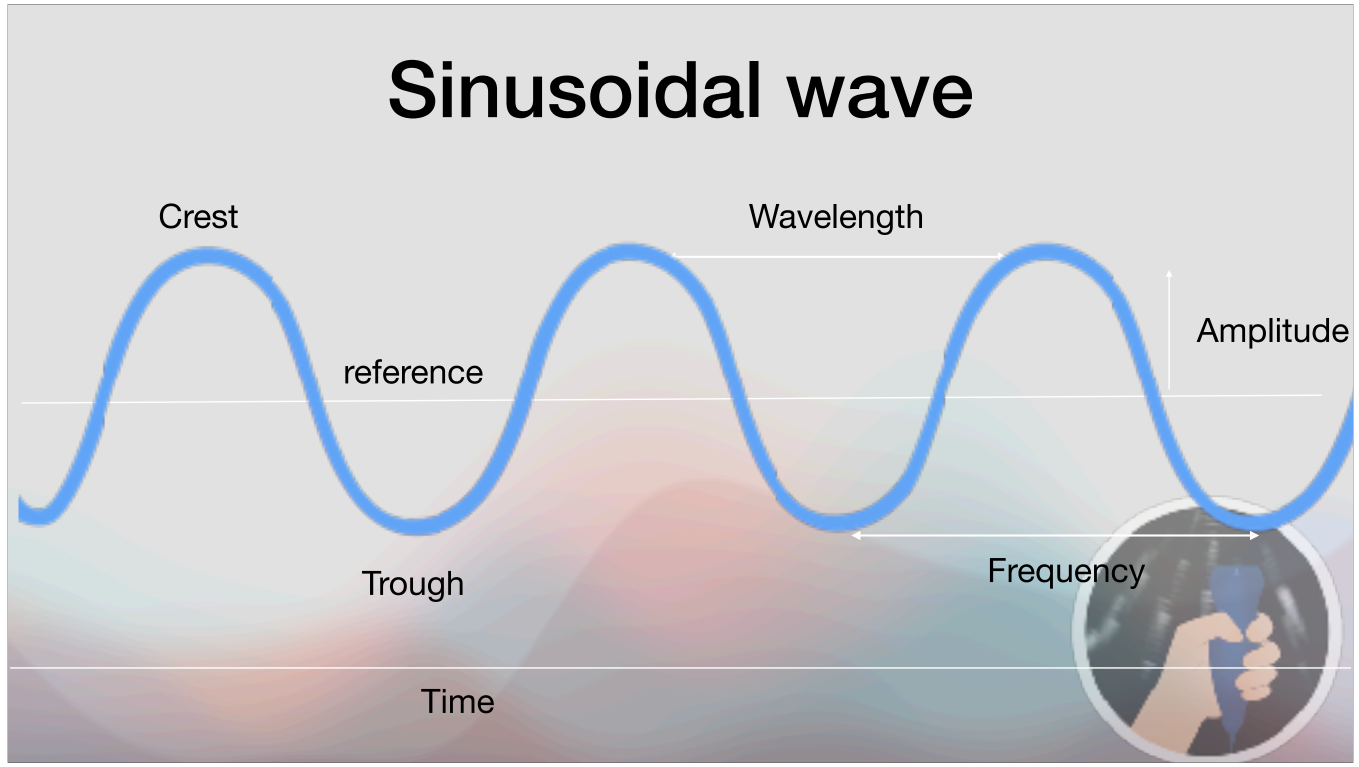
Again, a hertz is one cycle per second, a kilohertz is 1000 cycles per second, and a megahertz equals 1 million cycles per second



Medical ultrasound is produced thanks to piezoelectric materials. Piezoelectric materials are typically crystals or ceramics that vibrate in response to an applied voltage. These vibration is transmitted through the human body and the echoes are received by the piezoelectric material and transformed into voltage again, this way the voltage is sent to a computer that will interpret it and create an image for us to evaluate.



Sound is produced by a mechanical force that vibrates through a medium. In this illustration, we see a tuning fork vibrating, and you can observe the cycles of compression and expansion in the media over the first illustration on the right upper side of the slide. You can also see that some of the energy is lost, and there is less compression the farther away the medium is from the original vibration. At the bottom, we can see how these compressions can be represented in a sinusoidal wave.



Sound can be represented in many different ways. This is a sinusoidal wave. The sinusoidal wave has a wavelength that determines its frequency; a smaller wavelength corresponds to a higher frequency, while a larger wavelength corresponds to a lower frequency. There is a reference line and a crest in a trough. The difference between the reference and the crest is called the amplitude, which is directly related to the amount of energy the wave possesses. The time is usually measured to determine the wavelength and frequency. There are also square sound waves, triangular sound waves, and others.

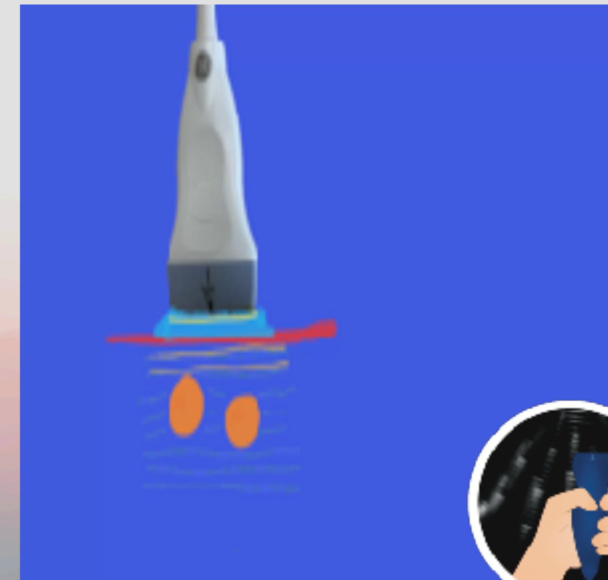
Physics

Medium	Velocity
Air	330m/s
Water	1500m/s
Fat	1450m/s
Muscle	1580m/s
Bone	4080m/s

The velocity of sound is approximately 330 m/s in air. As you can see, water, fat, and muscle have very similar velocities of sound transmission, making them ideal for evaluation by ultrasound.

Physics

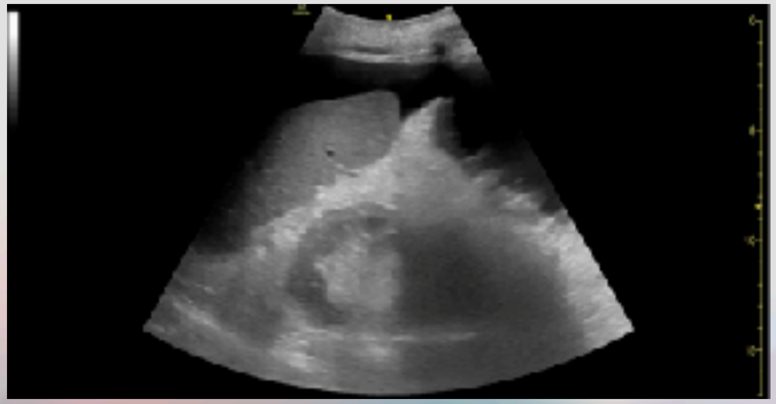
- Transmission
- Reflection
- Attenuation
- Refraction
- Scattering



Ultrasound is produced by the ultrasound probe and transmitted through a medium to the human body. We can see how ultrasound interacts with different media in the illustration. The ultrasound is first transmitted; some part of the ultrasound will be reflected, which is what gives us the contrast for the imaging. Some ultrasound will be received and attenuated, and some structures can refract and scatter the ultrasound.

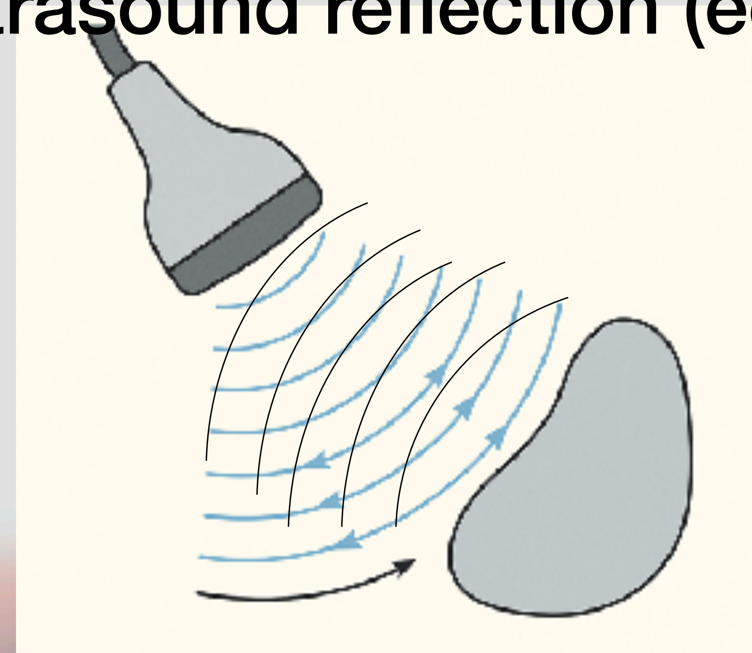
How the image is obtained

- The image is made out of the amount of of echoes that reach back to the probe and are converter in electric signals with different amounts energy that came back to the probe

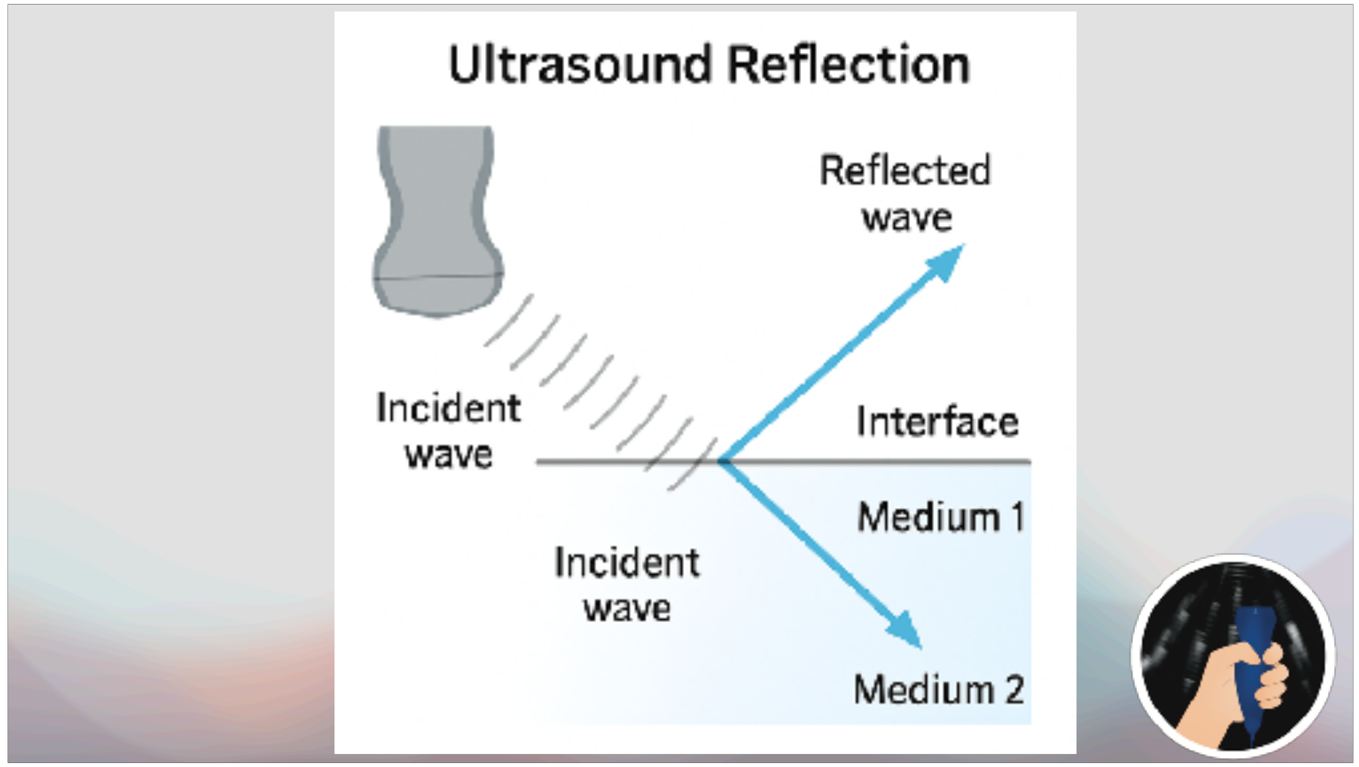


The ultrasound image and other modes of ultrasound are produced by the amount of echo that reaches the probe. In this case, we are seeing a gray-scale image from a patient who has cirrhosis and ascites. We can see the patient's abdominal wall in the near field. In the mid-field, we can see the spleen, fluid, and the omentum. In the far field, we can see the kidney.

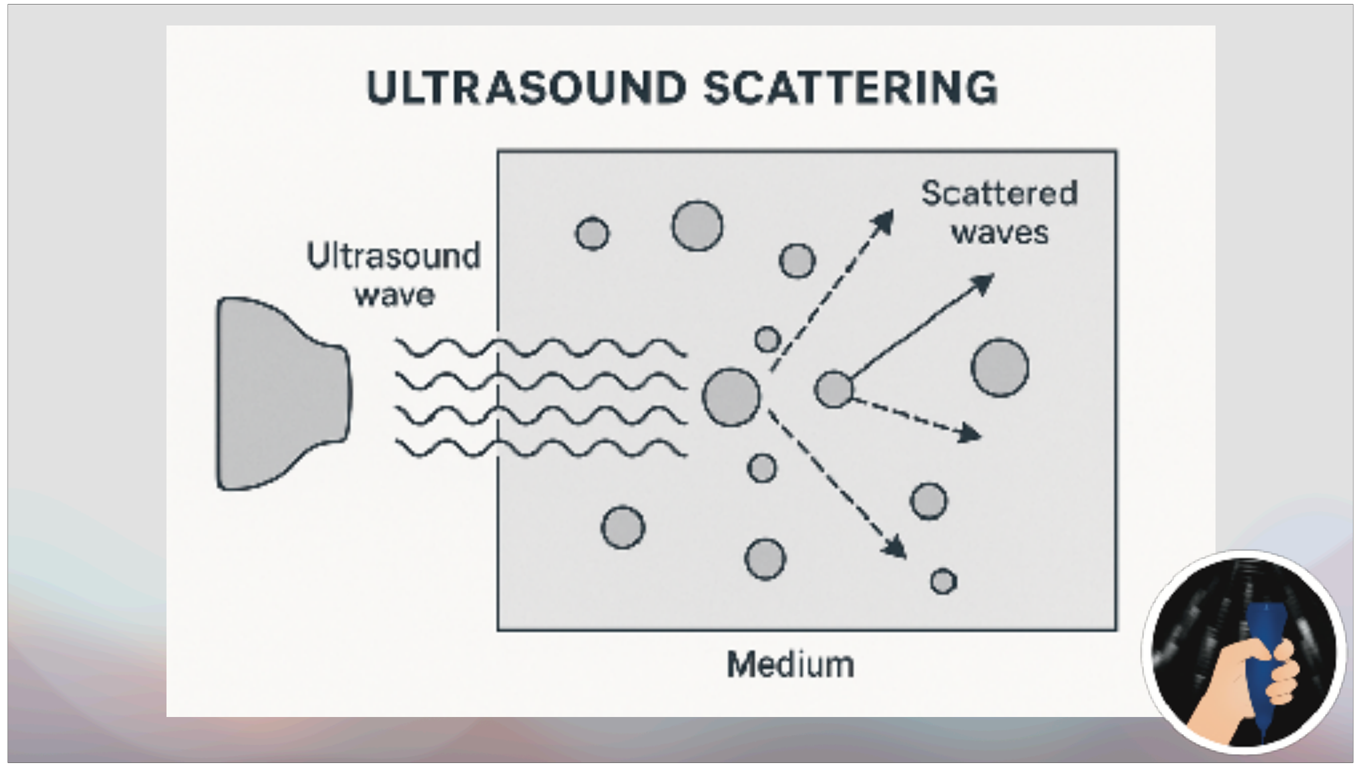
Ultrasound reflection (echo)



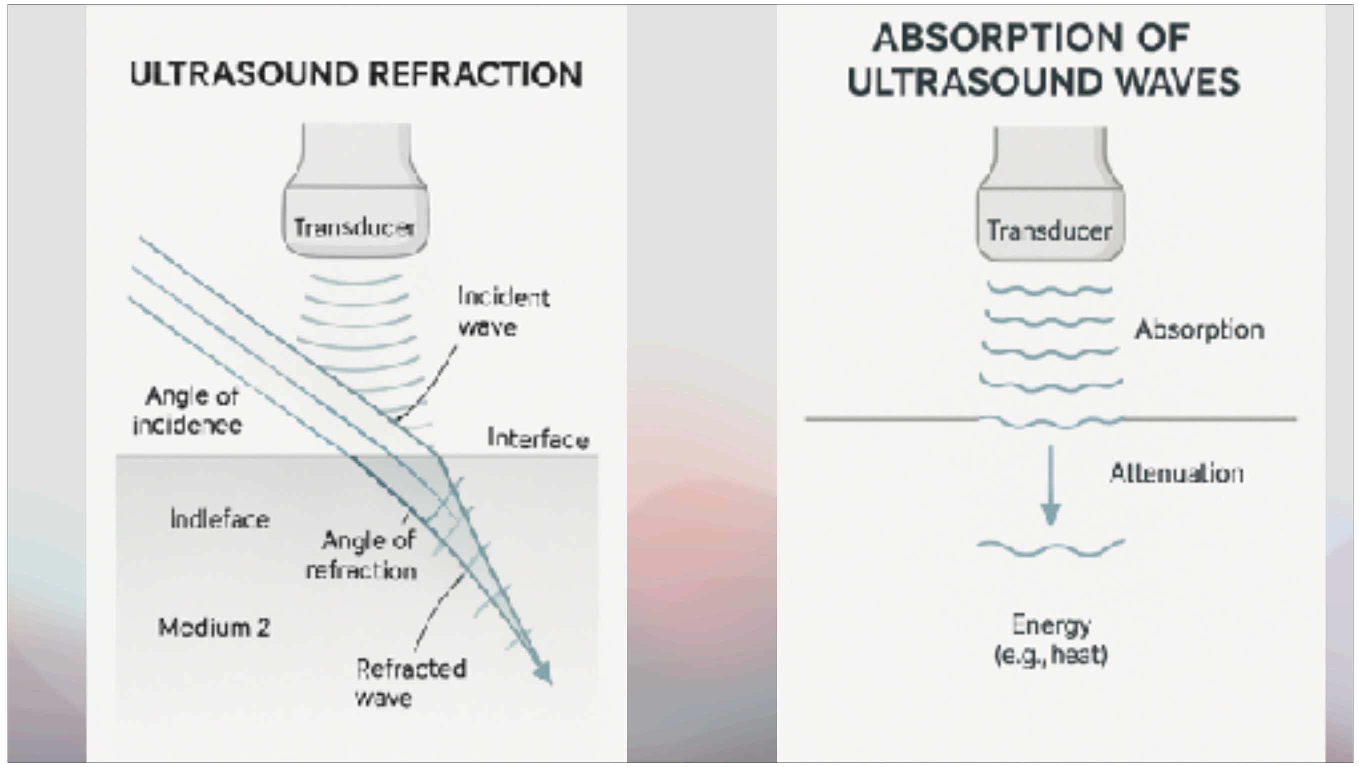
The different processes or phenomena that create our image in the ultrasound machine are the reflection of the ultrasound or echo. Here we can see a probe transmitting and receiving ultrasound from an organ. These echoes will provide the information needed to create the image.



The angle used to create the echo is very important. As we saw in the prior illustration, the angle of the probe was adequate to produce an echo. This angle is called the angle of isonation. In this example, the angle of isonation is not adequate, and the reflected waves will not reach the probe back.

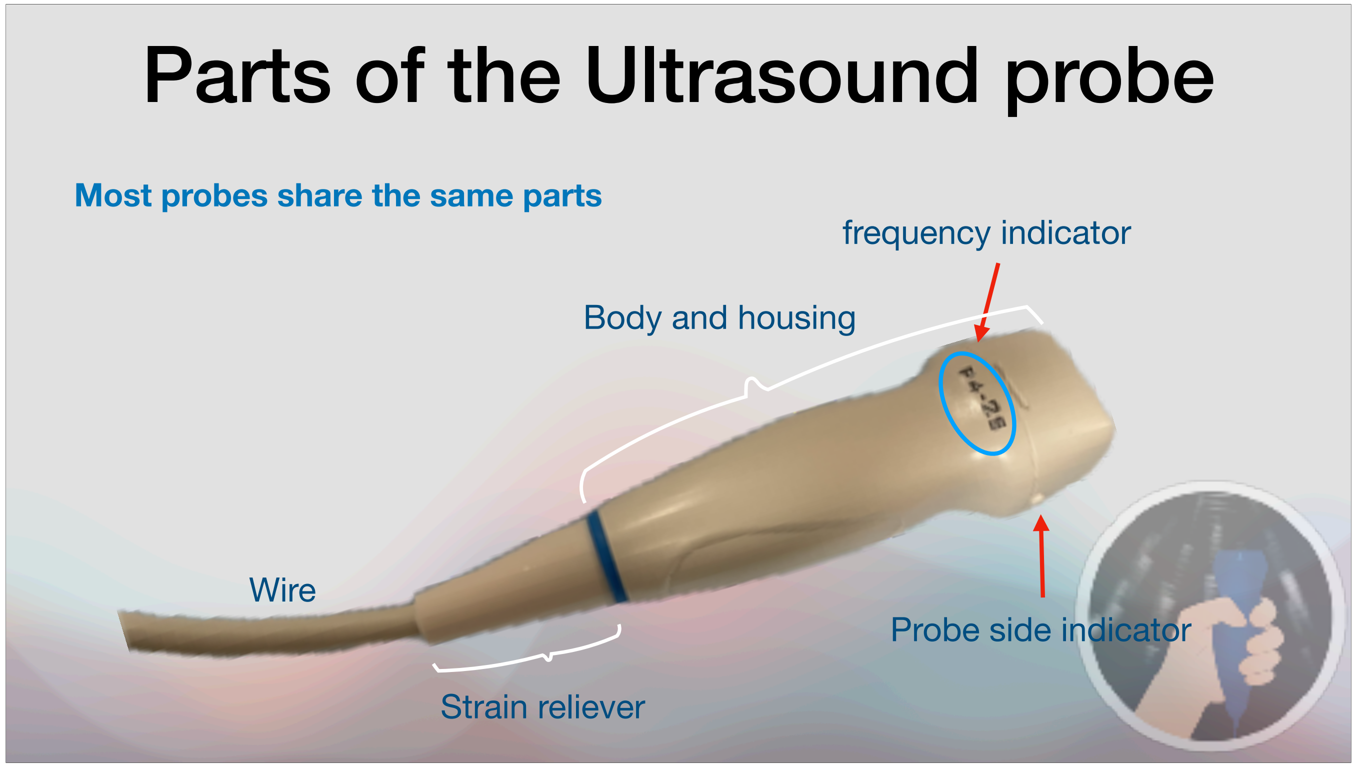


Some tissues will scatter waves, and gas is notorious for wave scattering, which creates noise in the imaging. Scattering can be a very useful tool to find gas in areas where it is abnormal, such as in subcutaneous emphysema and other conditions. One needs to be aware of this process.

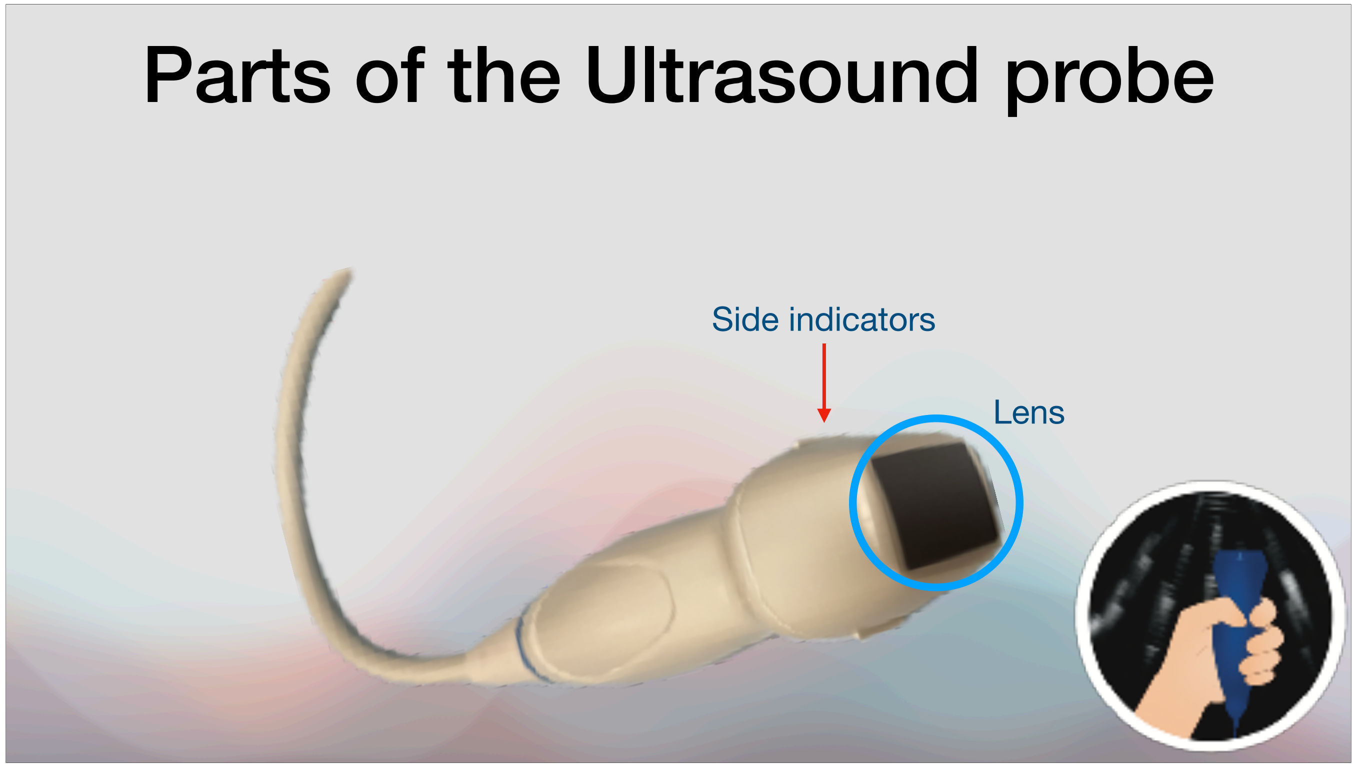


In this slide, we see two different phenomena. Ultrasound refraction occurs when the ultrasound beam reaches an interface between two media with different velocities of ultrasound propagation. This is not different than when you see a pencil bending when it enters the water. One needs to be aware of this phenomenon since structures may mask their true shape or position.

The second illustration demonstrates absorption of the waves and attenuation. The absorption of sound waves creates a contrast in the image. Every wave that is absorbed will create some heat. In ultrasound, there is no evidence that this heat is harmful. Attenuation is very important since it will give us the different echogenicities of tissue.

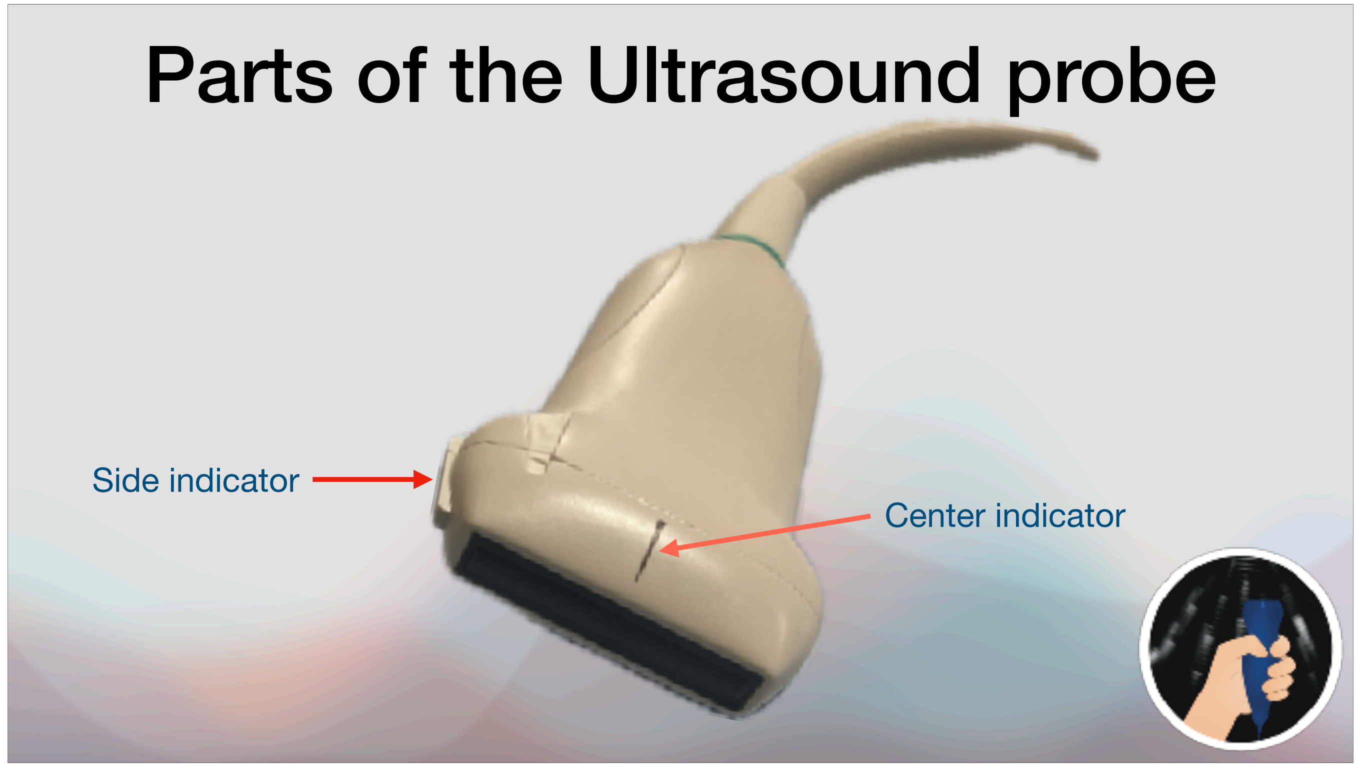


It is essential to be familiar with the components of the ultrasound probe. The ultrasound probe consists of a body and housing, where electronics and a capacitor are located. This is where you will hold your ultrasound probe. It is essential to recall that a capacitor is located inside the probe body; these capacitors can be hazardous if the probe is damaged. You will also find an indicator of the probe's frequency; in this case, the probe operates between 2 MHz and 4 MHz. The probe side indicator will display the position of the probe on the ultrasound screen. There is a strain reliever, which is designed to minimize damage to the wire that transmits information between the probe and the computer of the ultrasound machine.

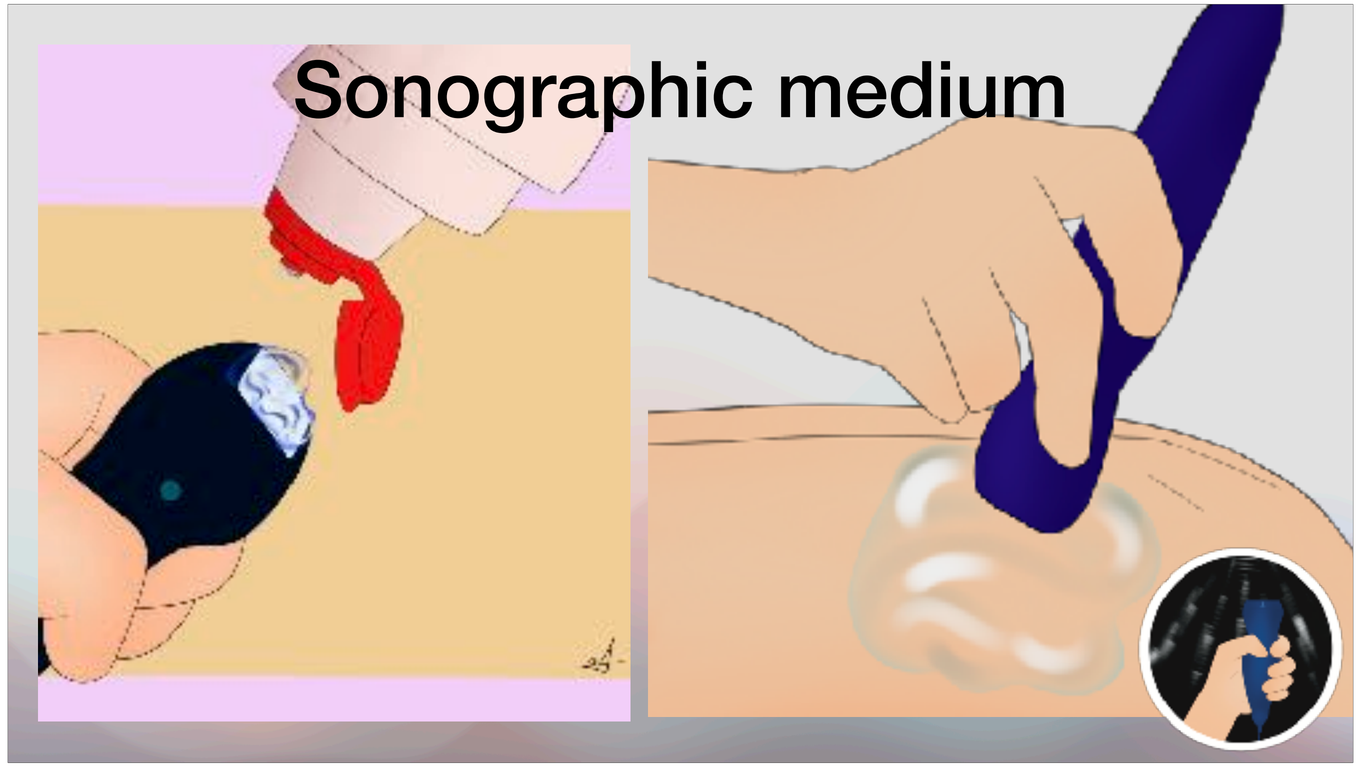


Ultrasound probes have a lens. The lens is where the piezoelectric material interacts with the body. There might be side indicators to help you position the probe. They are especially helpful when performing procedures or positioning the probe, as you are unable to look at it directly.

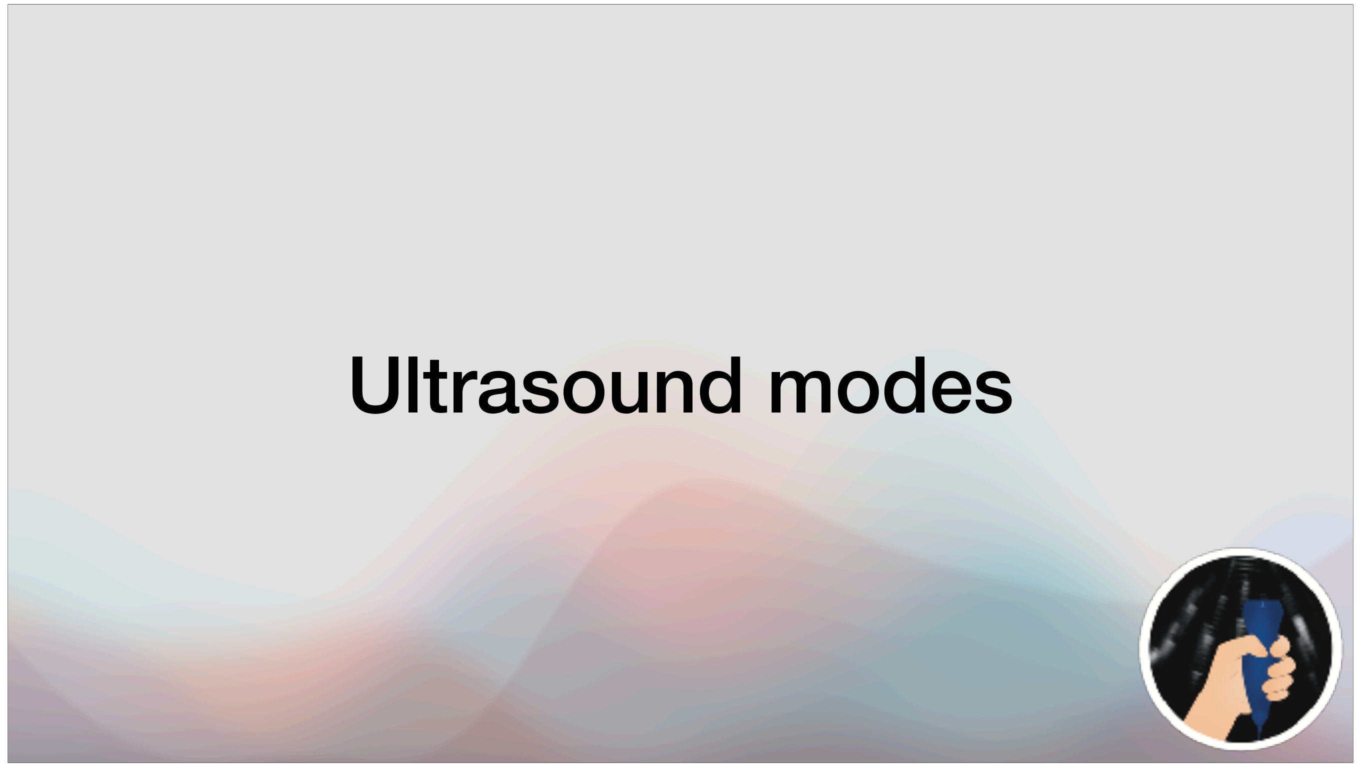
One needs to think of the lens as if it were the lens of a camera that captures the image that you see on the screen.



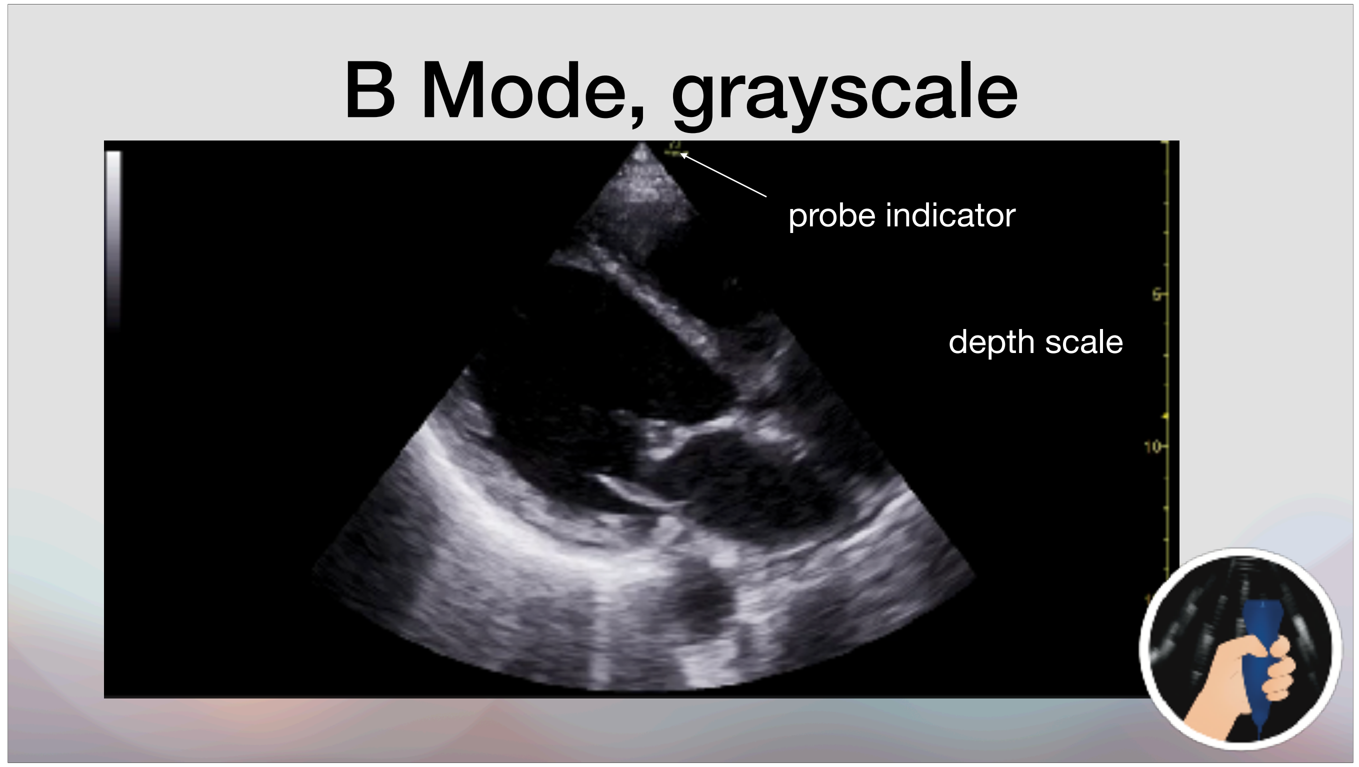
Some probes have center indicators that are very useful when performing procedures. Some probes may have knobs that are useful to change settings on the screen, especially during procedures or when you cannot do it independently in the ultrasound machine.



It is very important to remember that air is not a good medium for ultrasound transmission; therefore, we need to use a sonographic medium, usually ultrasound gel.

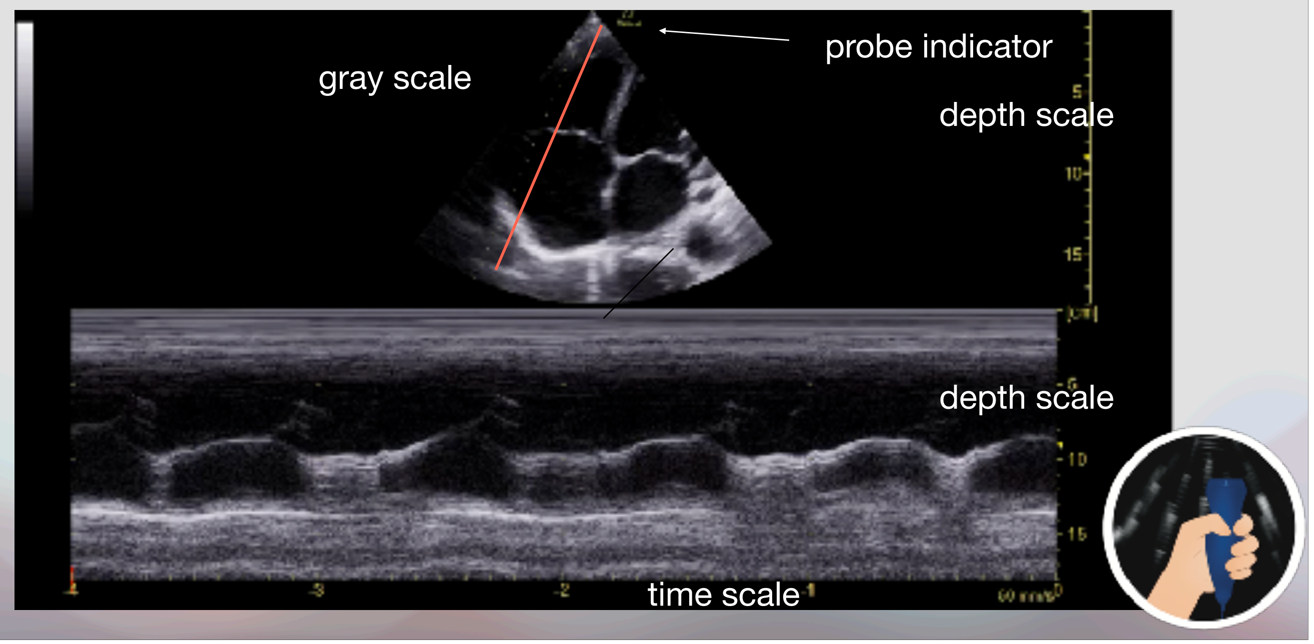


There are different types of ultrasound modes. Each ultrasound mode serves a purpose, and you should be familiar with the different types of imaging that you can obtain from the ultrasound machine.

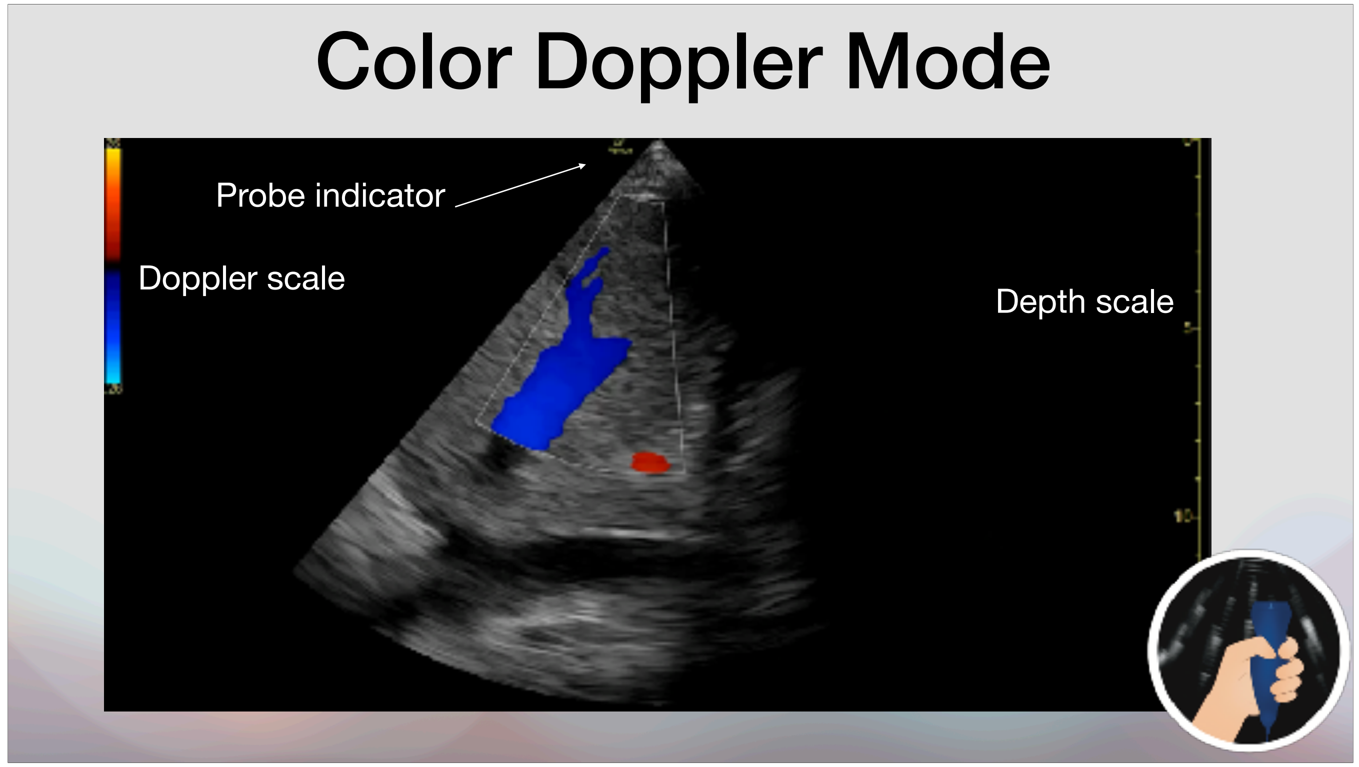


The first ultrasound mode is grayscale. In this ultrasound mode, the piezoelectric materials create a two-dimensional image, typically associated with the movement of the structure being evaluated. This two-dimensional image is about 1 mm thick. This means that you will need to scan a 3D organ in multiple planes to get an idea of the entire structure. In this ultrasound, we can see a heart in what we call the parasternal long axis, you can see a probe indicator towards the left of the screen, and this one tells you where the indicator in the probe is oriented to, in this case, we are seeing an image of the heart in the cardiology convention with the probe indicator pointing to the left of the scale. You are viewing a heart with a low ejection fraction, and a depth scale is visible, which can help you quickly determine the dimensions and depth of the structures you are seeing.

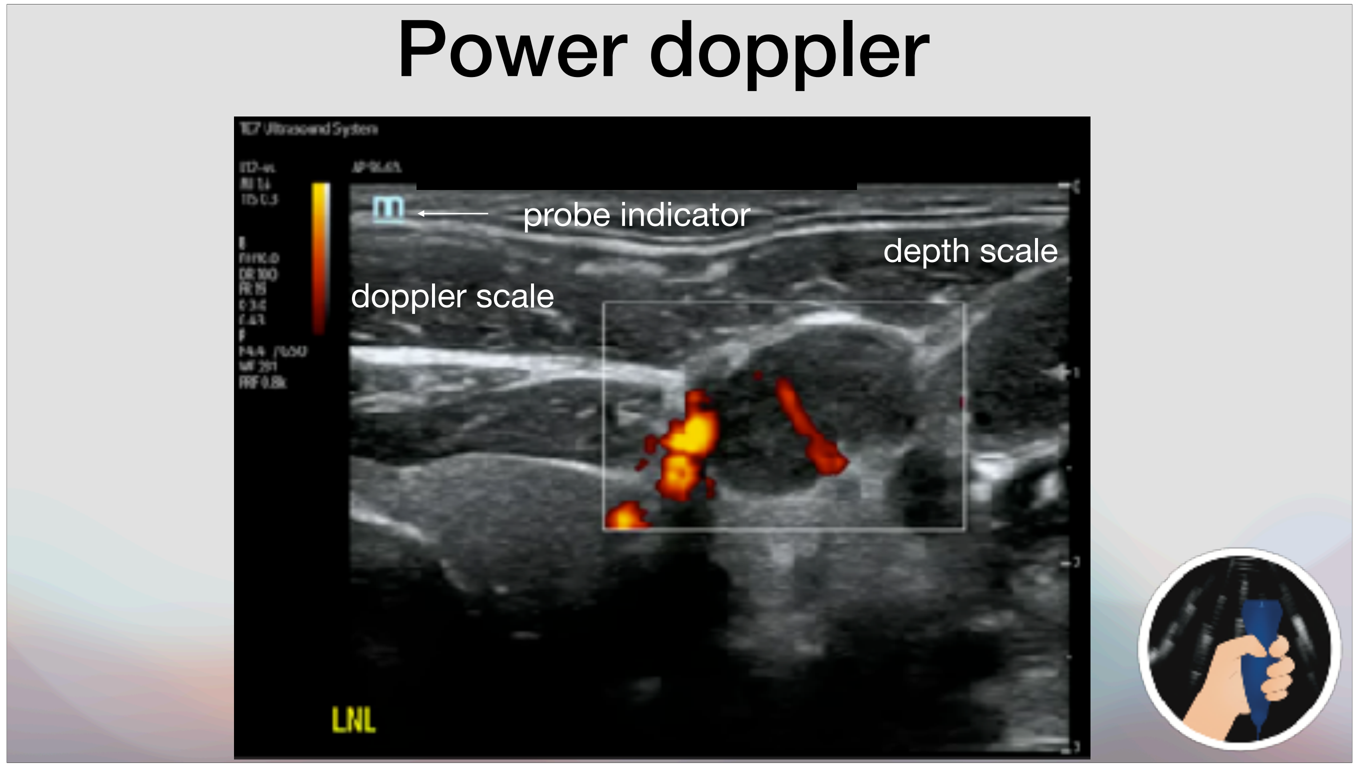
M-Mode



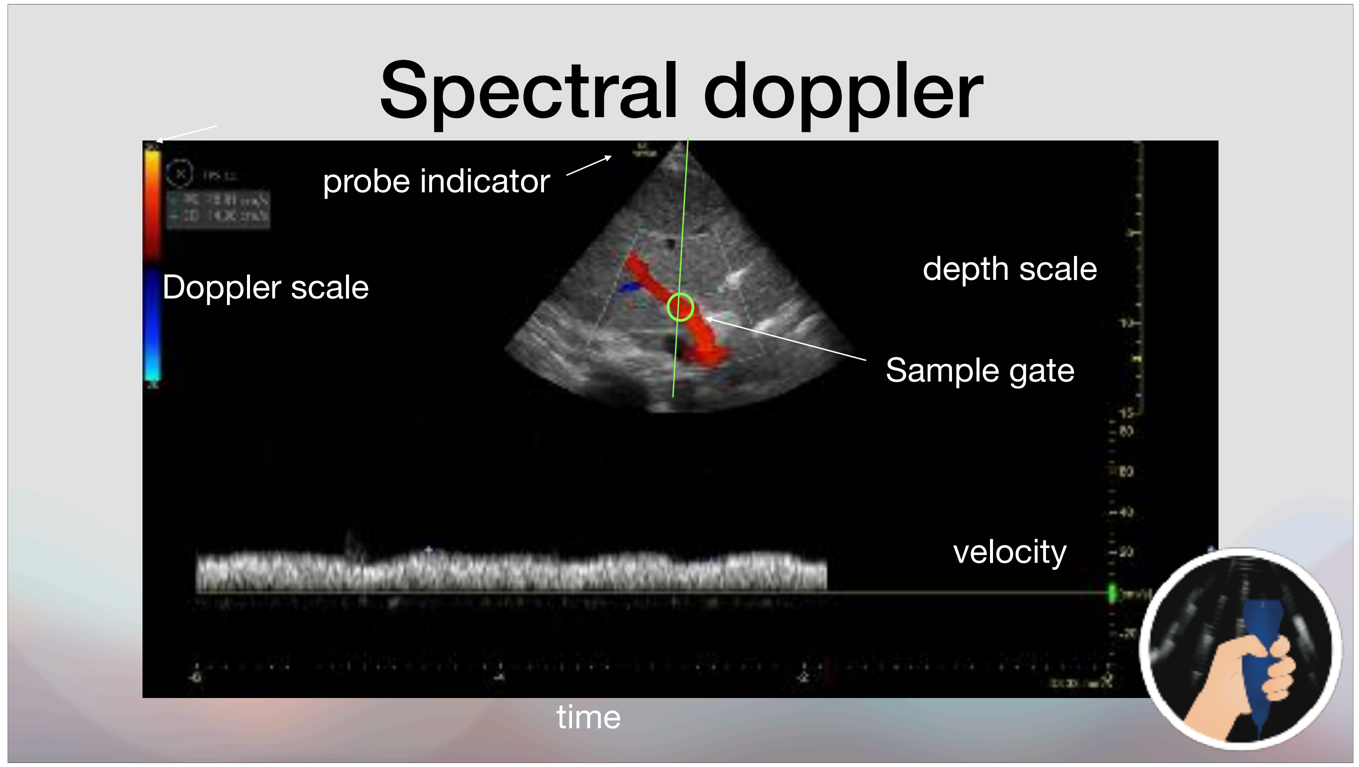
The next mode is called M mode. In this mode, only a fraction of the grayscale image is scanned to evaluate the movement of the specific area being scanned. This is very helpful when evaluating the heart and lungs. You can see a grayscale image at the top of the illustration. This includes the probe indicator in cardiology convention, a scale that corresponds to the depth scale in the M mode, and a time scale that ranges from -4 to 0 seconds. This way, you can evaluate the timing between events happening in the area being scanned, as well as the measurements of the movement in time of the scanned area. In this case, we are observing the movement of the posterior leaflet of the tricuspid valve, a measurement that is useful for evaluating right ventricular function.



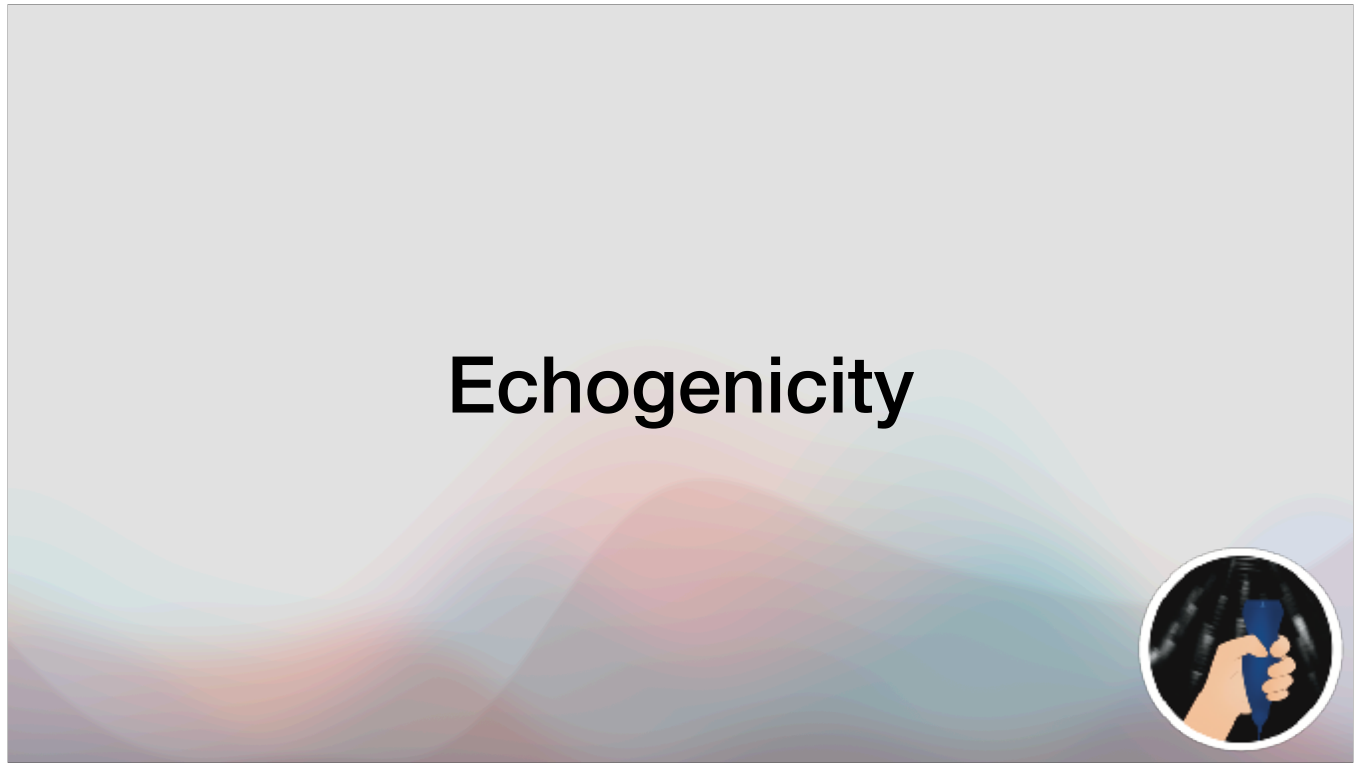
Another ultrasound mode is the color Doppler. In this case, the probe is able to detect movement in the areas being scanned. Any movement towards the probe will be represented as red, as you can see in the Doppler scale over the right upper corner of the screen, and any movement away from the probe will be represented with the color blue. There is a mnemonic called BART, “blue away, red towards”, from the probe. It is essential to note that these settings can be adjusted on certain machines, and you must be aware of the direction of the flow set in your ultrasound machine. You can also see a depth scale towards the left of the illustration. It is important to know that when using Doppler mode, the grayscale image is usually degraded when compared to a purely gray-scale image.



A different type of color Doppler is the power Doppler mode. In this case, as you can see, there is only one color on the Doppler scale, located in the upper right area of the screen. Power Doppler is useful for evaluating low-flow areas, as in this case, where we are examining an abnormal lymph node in the lower left neck. One can see the circulation or the Doppler signal secondary to the circulation of blood right in the hilum of the lymph node one can see also a couple of vessels in one of the poles of the lymph node in a vessel near the periphery of the lymph node, this vessel is abnormal, and this is a lymph node that was found in a patient with a metastatic cancer to that lymph node. Power Doppler is again useful to evaluate flow in areas where the velocity of the blood flow may not be picked up by color Doppler.



Another way to see or evaluate Doppler is the spectral Doppler. Spectral Doppler is divided into two types: continuous wave Doppler and pulsed wave Doppler. In this case, we are seeing a spectral Doppler with pulse wave Doppler of the portal vein. In the upper center of the illustration, a grayscale image with color Doppler is clearly marked, showing a large vessel with flow directed towards the probe, indicated by the color red. This is an image of the portal vein. We have placed a sample gate where the sample of the movement will be obtained. At the bottom, you can see the spectrum. The spectrum consists of the time in the velocity sampled at the gate. In this case, the velocity of the portal vein is normal with about 21 cm/s, as you can see in the velocity scale towards the lower left corner of the illustration. Again, you can see a color Doppler scale in the upper right corner. Continuous wave Doppler is different from pulsed wave Doppler, or PWD, in the sense that it will obtain the velocities of everything within the sample line in the ultrasound. In our experience, pulse wave doppler is more frequently used in internal medicine.



Echogenicity is the word used to describe the amount of echo that a structure produces. A higher echogenicity will look whiter, and a structure with lower echogenicity will look darker. Echogenicity is a result of the amount of impedance to the ultrasound of a specific structure.

Impedance

$Z=p*c$

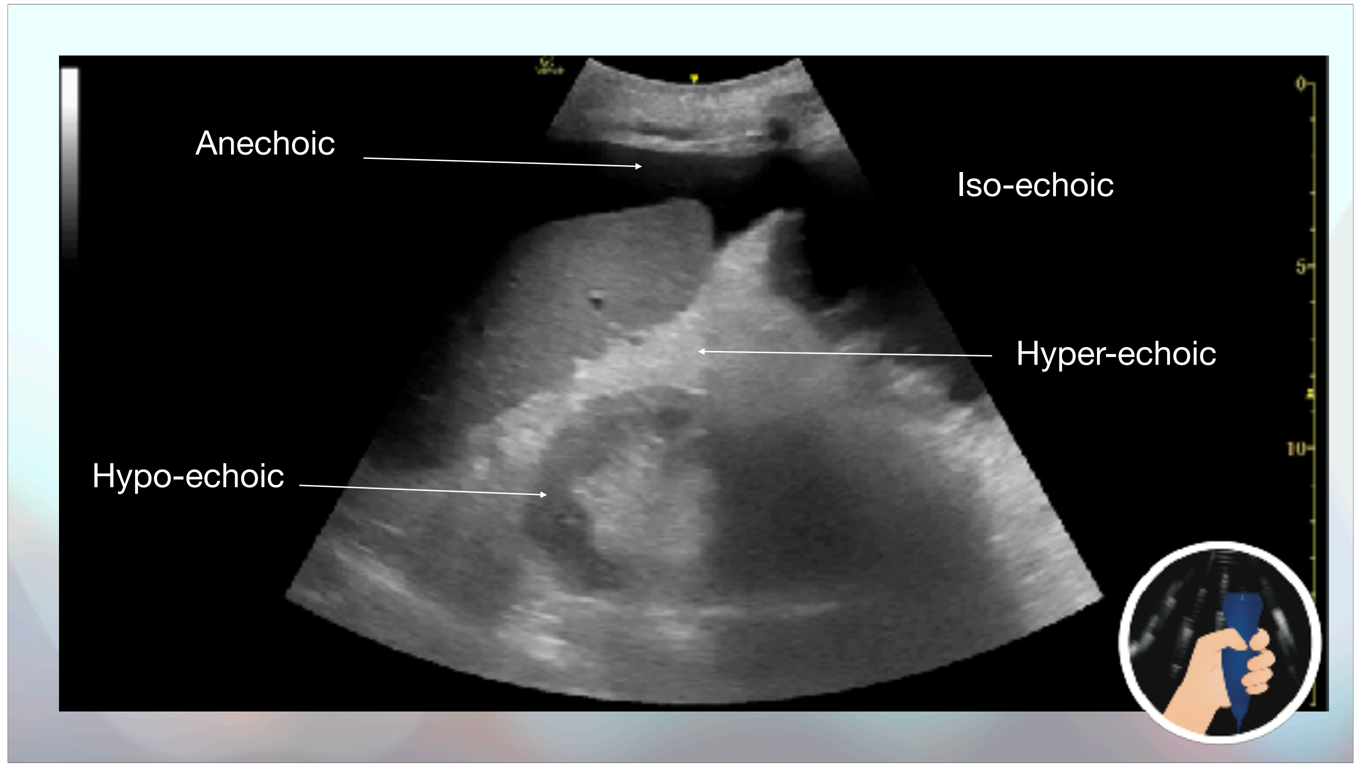
- High impedance tissues will appear brighter.
- Low impedance tissues will appear darker

p (rho) density in Kg/m3

c (speed of sound)

Kg/m2*s

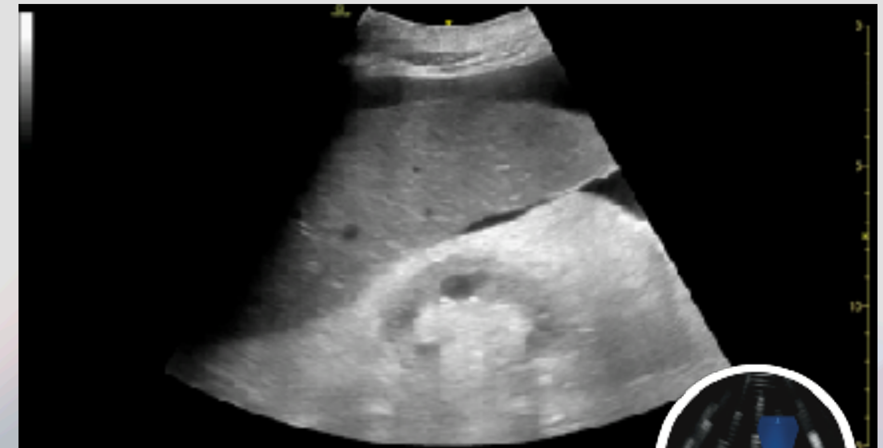
Tissues with high impedance will appear brighter because they reflect more echoes back to the probe, while structures with lower impedance will appear darker because they reflect fewer signals back to the probe. Impedance is determined by the density of the tissue in kilograms per cubic meter and the speed of sound. The more density, the more echoes; the less density, the less echo.



This ultrasound, obtained using a curvilinear probe, demonstrates varying echogenicities. The anechoic part appears darker and is ascitic fluid, which has a low impedance. The hypertonic part is the fibrous capsule of the spleno-renal recess, an area with a high content of fibrous tissue in the surrounding fat that will send more echoes to the probe. Right below, we see an area that is hypoechoic. This concept compares two tissues that appear darker than the other. The cortex of the kidney is hypoechoic compared to the fibrous capsule of the kidney and the splenorenal recess because it has a lower impedance. Iso-echoic tissue is a concept of comparison. If a tissue has the same echogenicity as other tissue, it will appear with a similar color.

Echo-texture

Homogenous
Heterogeneous



Echotexture: Different tissues produce distinct echo textures. In this case, we see an ultrasound of the right upper quadrant of a patient who has ascites and cirrhosis. The liver's architecture is heterogeneous, a very common finding of cirrhosis. The texture of the momentum below is homogeneous. It is essential to be familiar with the echotexture of various tissues and organs.

Echo-texture

Homogenous
Heterogeneous

Here, we see a model from our ultrasound lab, obtained using a Butterfly ultrasound in abdominal settings. Clearly shows an oval structure with varying echogenicities inside, demonstrating a heterogeneous echo texture.