Pulmonary ultrasound for the internist.

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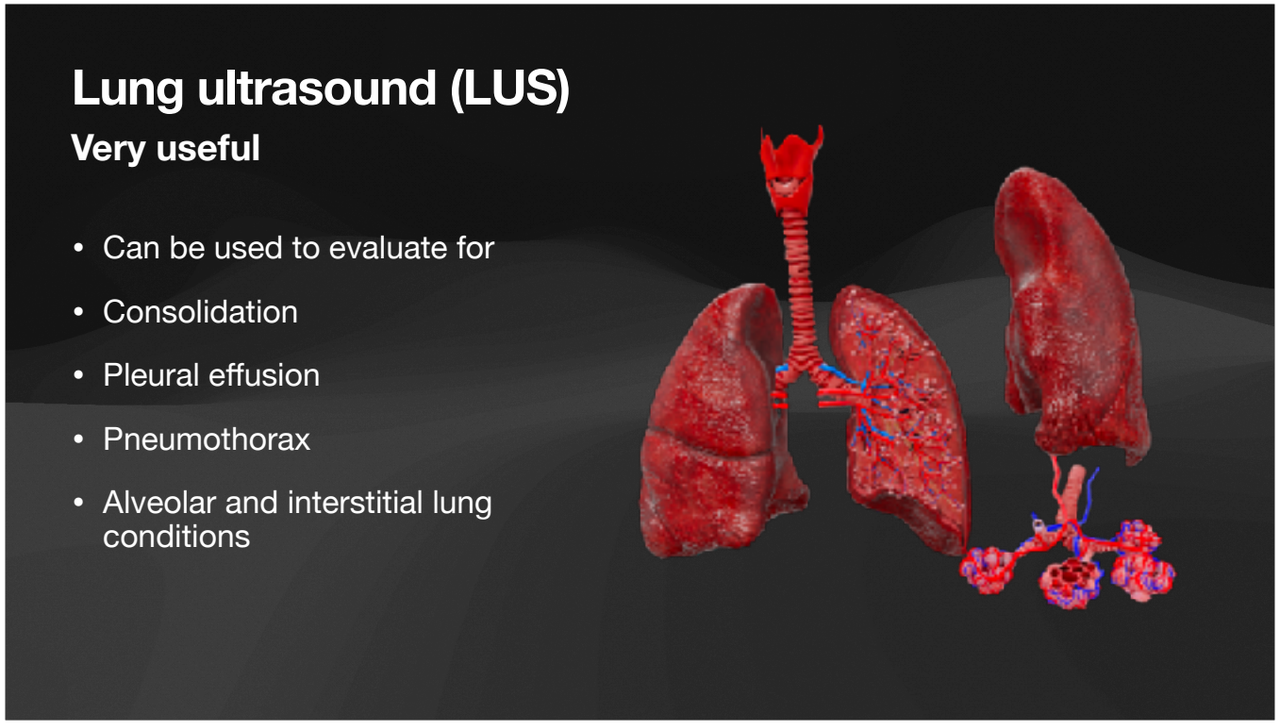
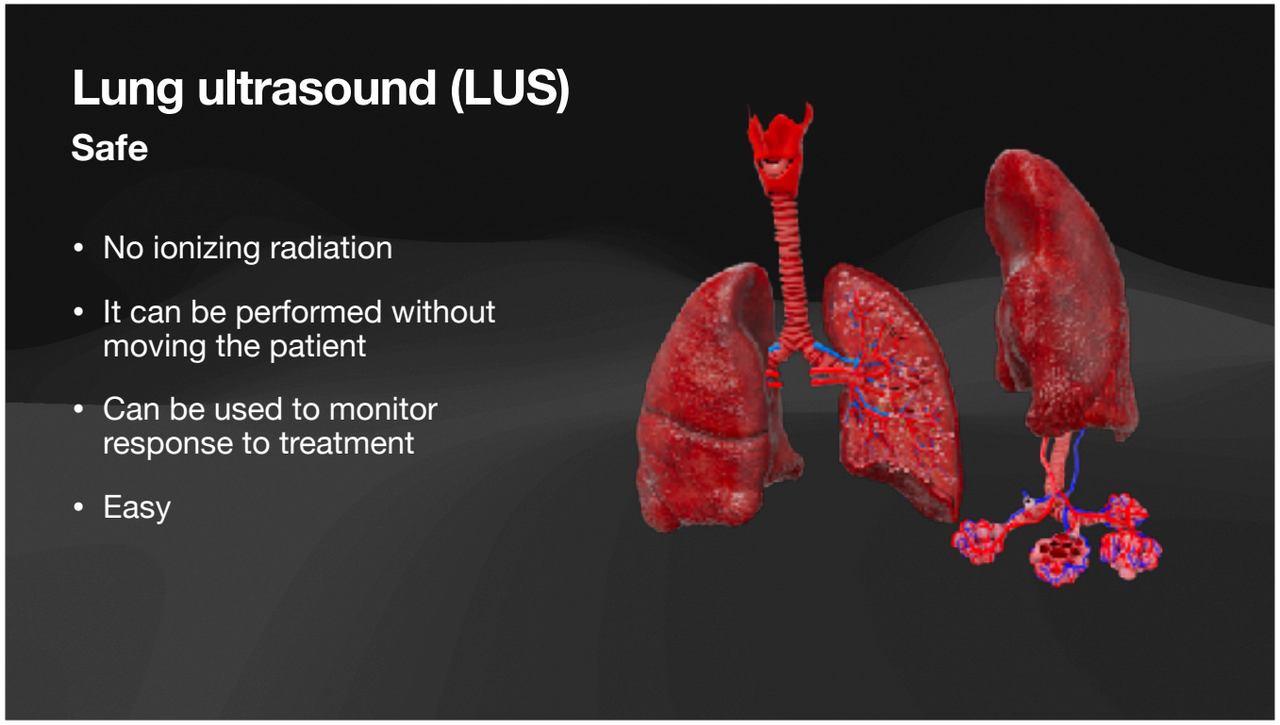
medpocus.com

No conflict of interest to disclose.

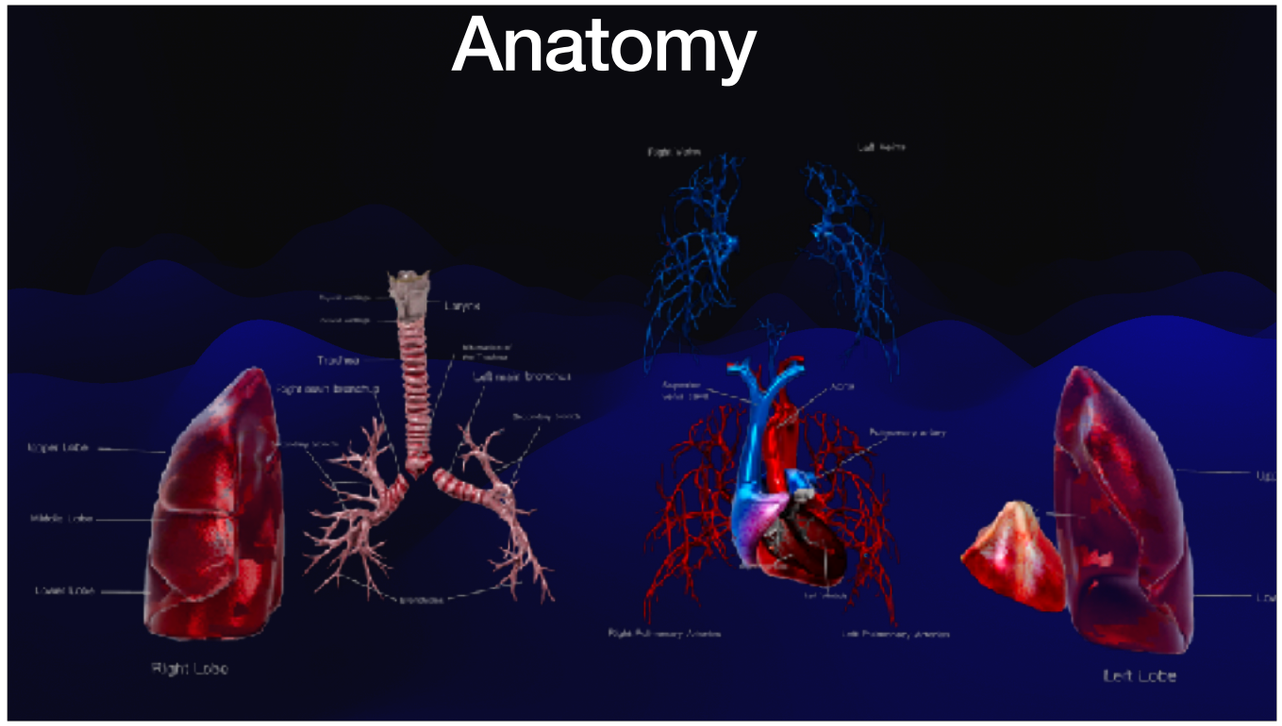


In this chapter, we will discuss the use of ultrasound in evaluating the lungs.
Although it was thought that the US couldn’t be used to evaluate the lungs because of the poor impedance of air and the presence of artifacts. The presence of these artifacts is precisely what makes ultrasound possible and very useful. Ultrasound of the lung may be more reliable than clinical examination and X-rays in many instances.
It can be used to evaluate for consolidation, pleural disorder, pneumothorax, and alveolar and interstitial lung conditions.



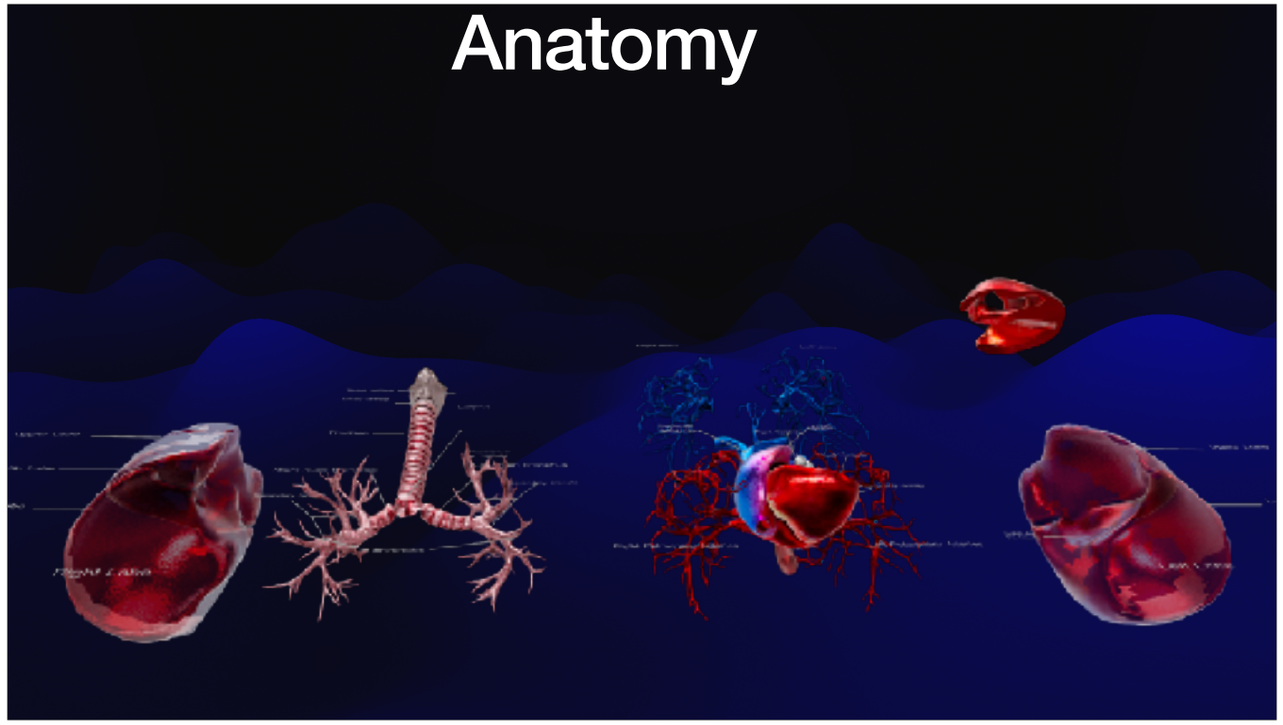
POCUS has many advantages: It uses no ionizing radiation. It can be performed right where the patient is, without the need to move them, thereby increasing your time at the bedside. It can be repeated as needed to monitor response to treatment.

Anatomy



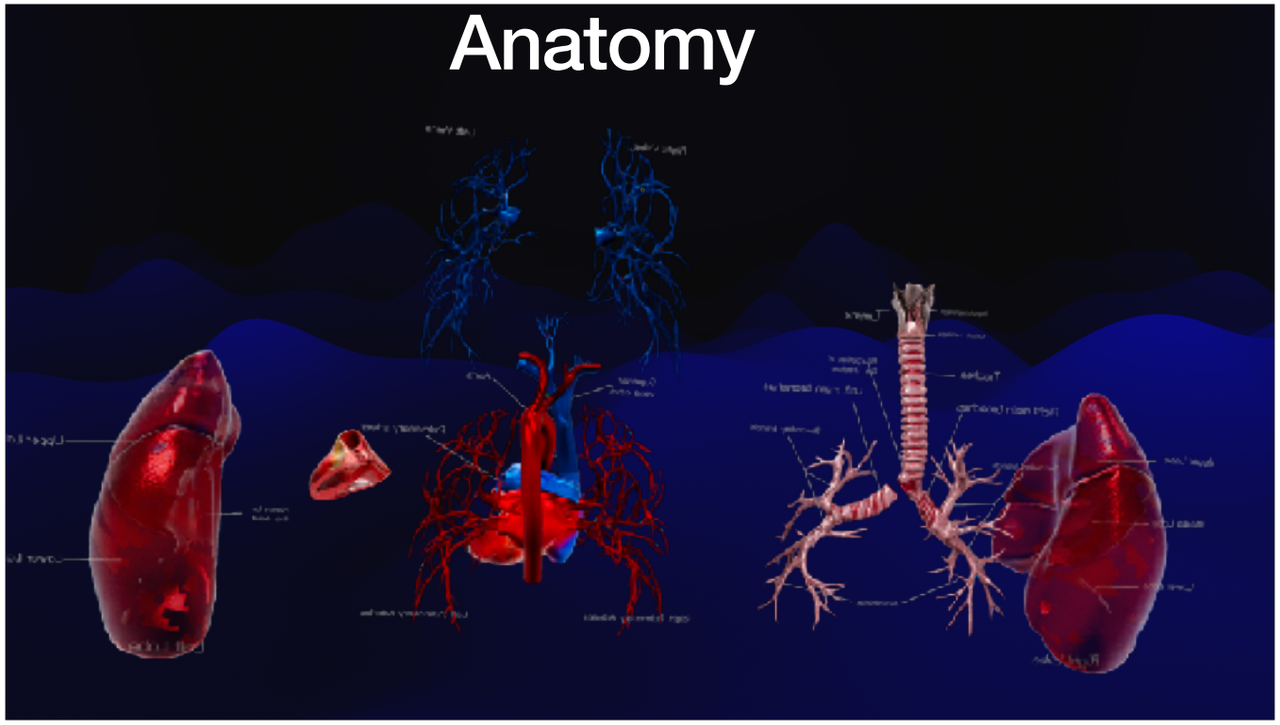
We need to remember that the chest contains many structures. Including the heart, blood vessels. The lungs have their own vessels and airways. The bronchi divide up to 28 times before turning into the alveoli. It is of the utmost importance that the internist is aware of the different structures in the chest. It is also important to remember that each lung has different lobes and segments. The knowledge of these lobes and segments can help the clinician in localize effectively different conditions encountered in the ultrasound.

Anatomy

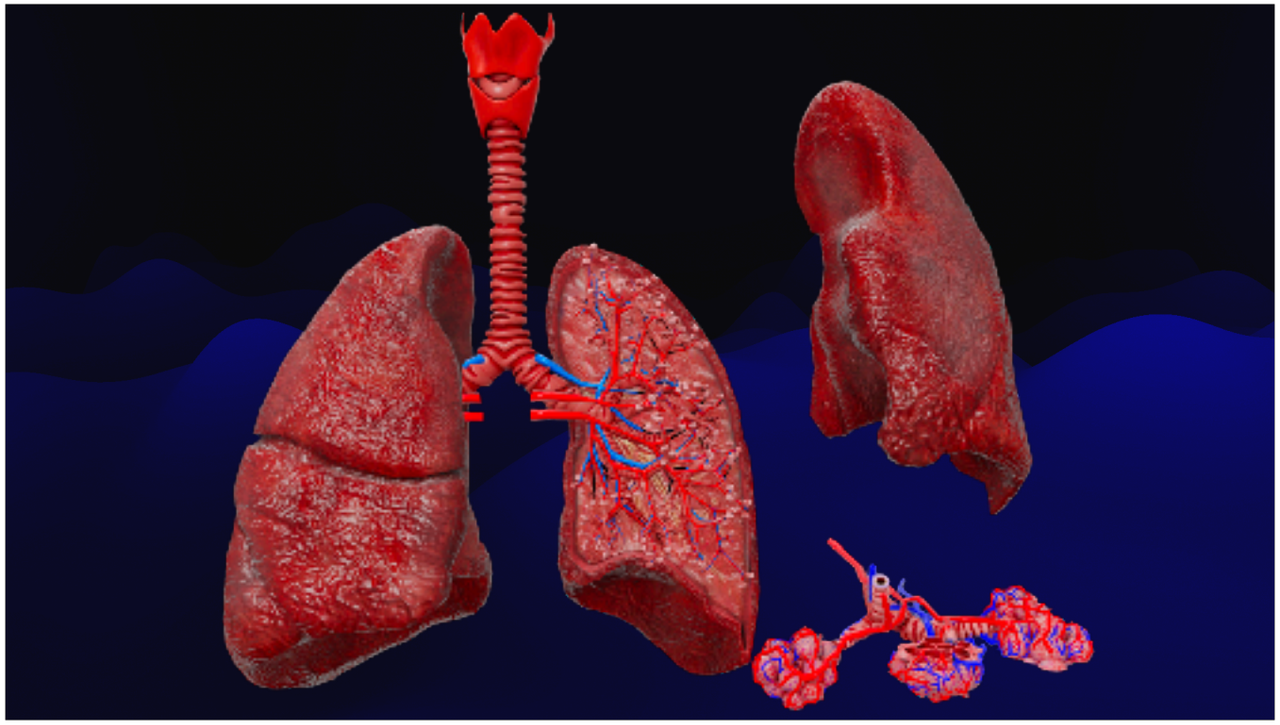


The chest is a 3d object evaluated by a 2D 1mm sector of the ultrasound beam. All structures will have different axes and cuts that can be used in tis evaluation

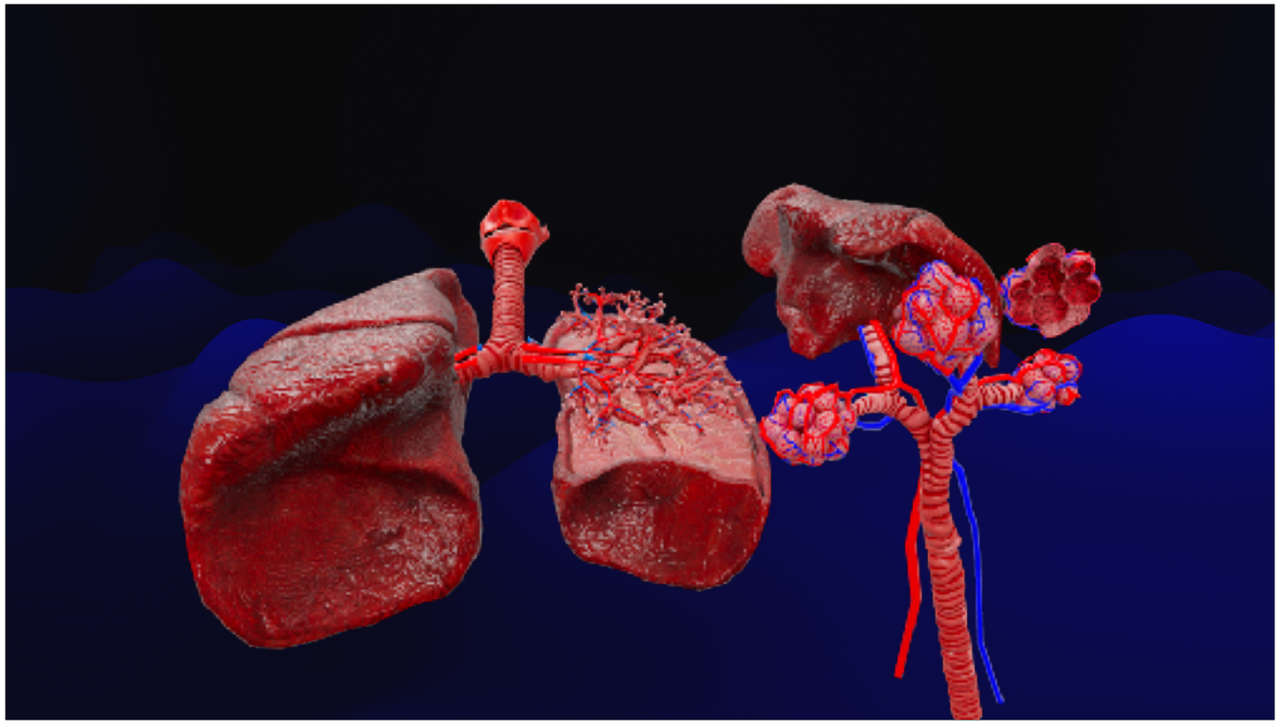
Anatomy



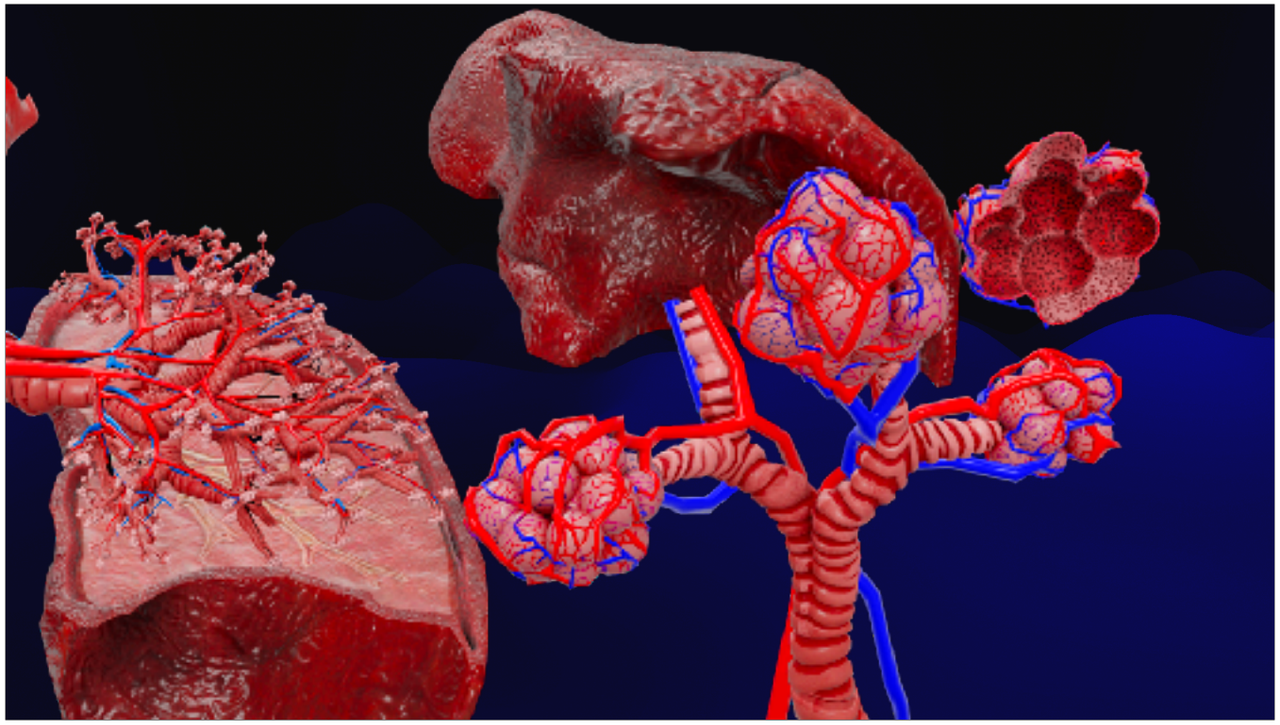
Again. The structures have different axes. In this image, the posterior chest is shown with all the structures. Take your time seeing the structures and remember them from your anatomy class.



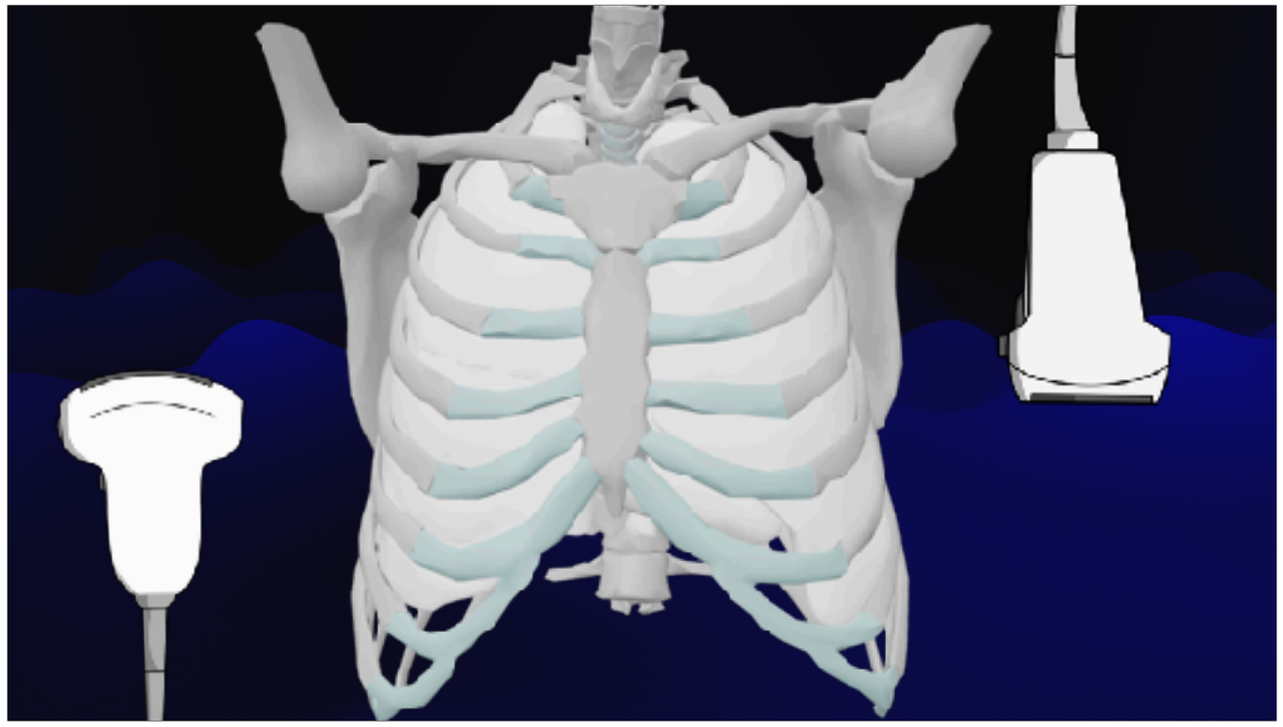
This illustration depicts the lungs and their interconnected airways, blood vessels, and alveoli. The alveoli are very peripheral. Normal alveoli will contain mostly air, which is what gives the lung its normal appearance in ultrasound.
One can note the fissures between lobes, which can be seen in ultrasound as comet-tail artifacts. The pleura is another structure that needs to be evaluated. Pleural disorders can be evaluated safely with ultrasound.



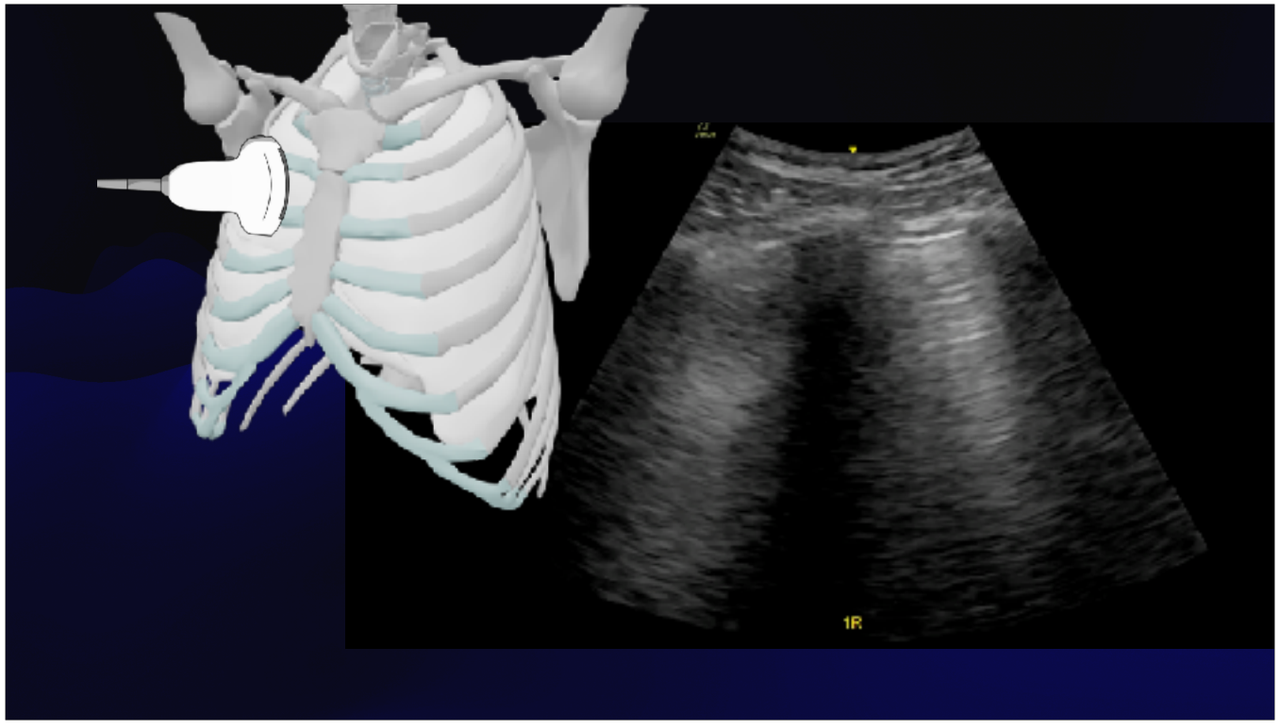
Again. The lungs are 3 D objects.
In the caudal part of the lung we will see how they interact with the diaphragm.



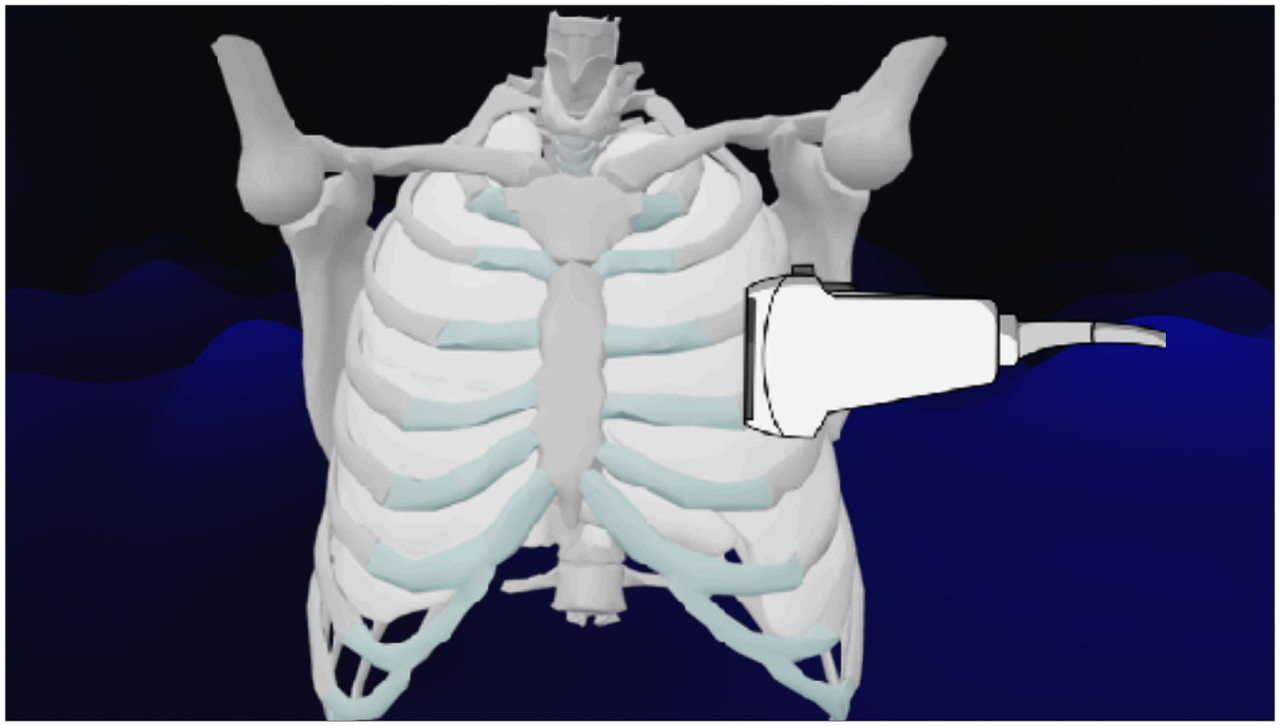
In this illustration, we see a close-up of the alveolar space.
Note how peripheral the alveoli are.
Again, most of the alveoli and airway will be filled with air. The presence of fluid from hemodynamic or inflammatory causes will create different artifacts and structures that are recognizable in ultrasound evaluations.



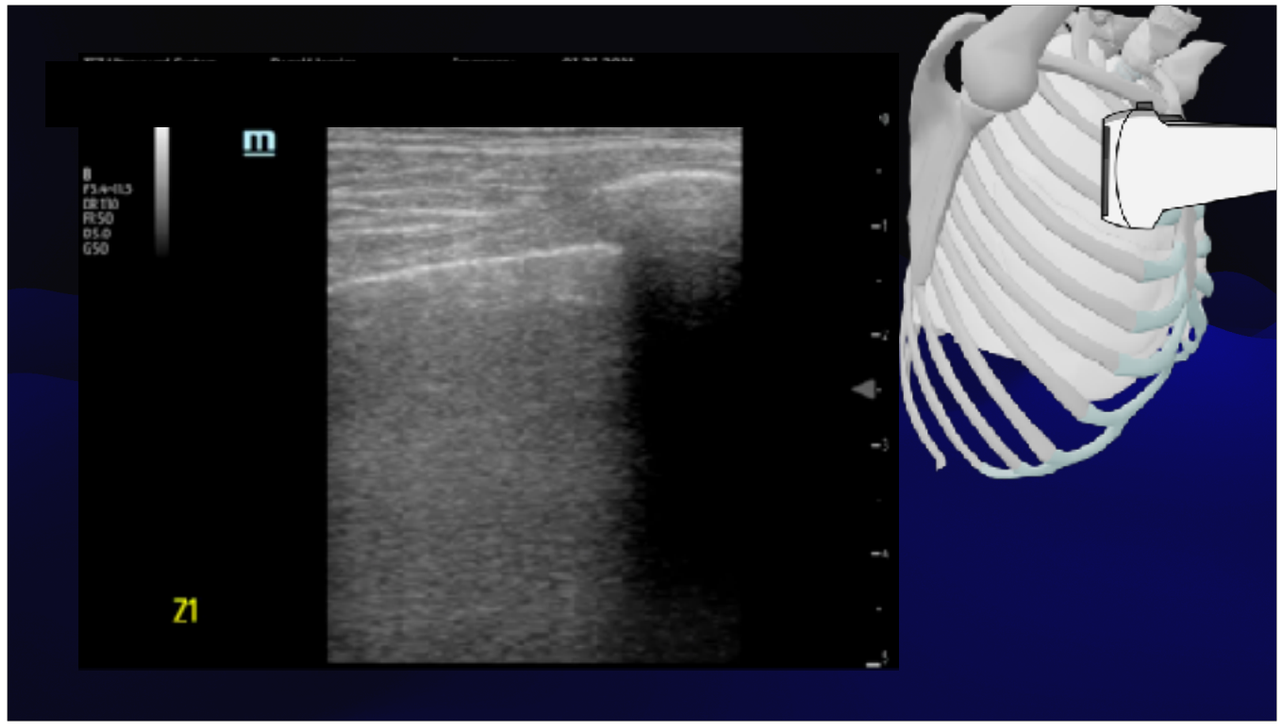
To evaluate the lung, we can use different probes depending on what we want to evaluate.



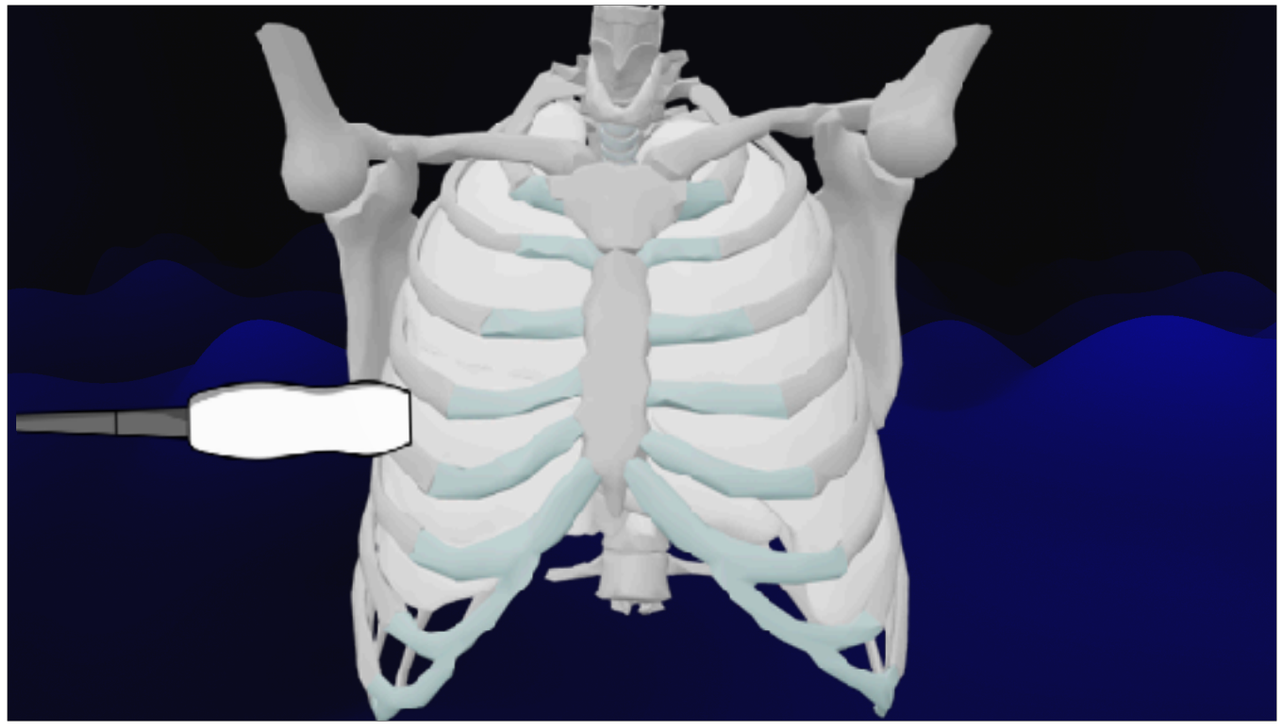
For example, in this image obtained with curvilinear ultrasound in lung settings, we clearly see “A” lines and can also evaluate different intercostal spaces.
Note how the area evaluated is marked at the bottom of the ultrasound sector as 1 R of area one of the right lung. Internists and clinicians assess the lungs for conditions other than generalized alveolar disease must familiarize themselves with the various areas of lung ultrasound. Documentation of the ultrasound with its areas is also important for follow-up studies to evaluate



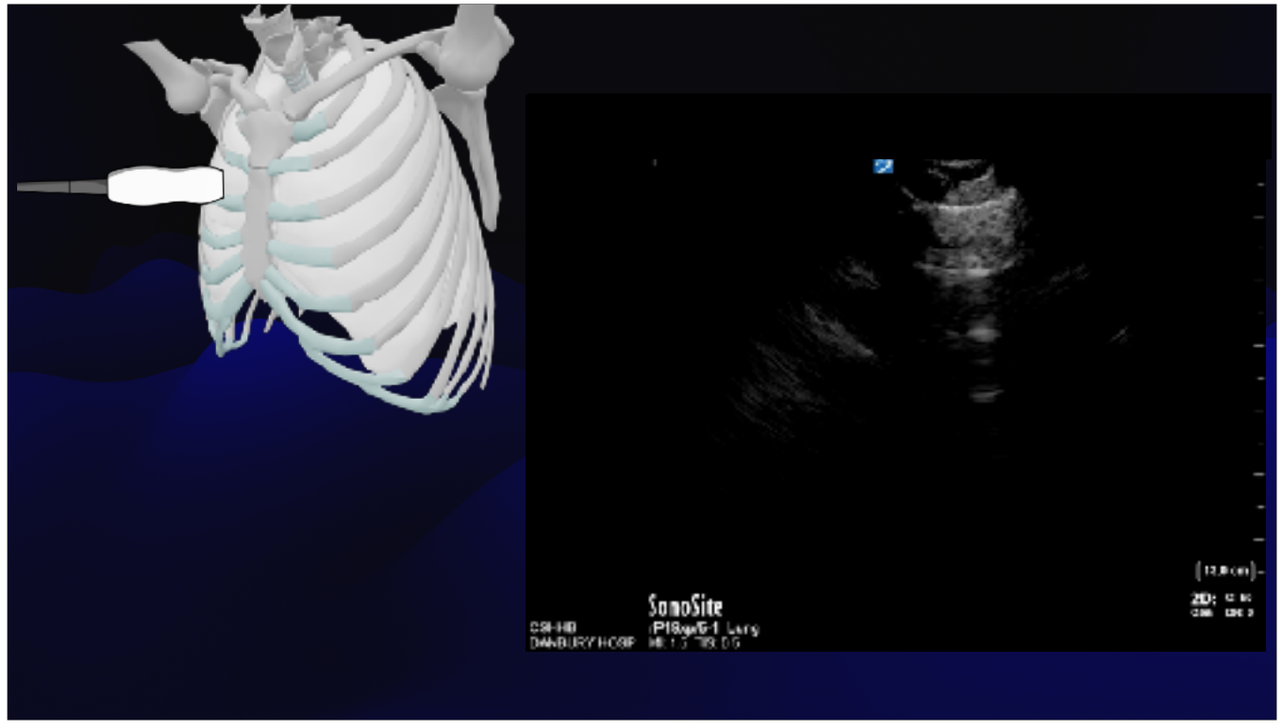
In this illustration, note that the probe's position should be vertical, with the indicator directed cephalad, or towards the patient's head. This is the case with all the probes that we use in ultrasound.



In this example, we are using the linear probe to evaluate the pleura. Note the movement of the pleural line. This is an example of normal pleural sliding. You can also note that the area being scanned is annotated as Z1 or zone 1.



We can also use phased array transducers. This is especially useful when performing quick evaluations of the lung and heart without the need for different probes.



Here we are evaluating zone 1 of the lung. You can also see A lines and pleural sliding. The sector image is typical of a phased array probe.

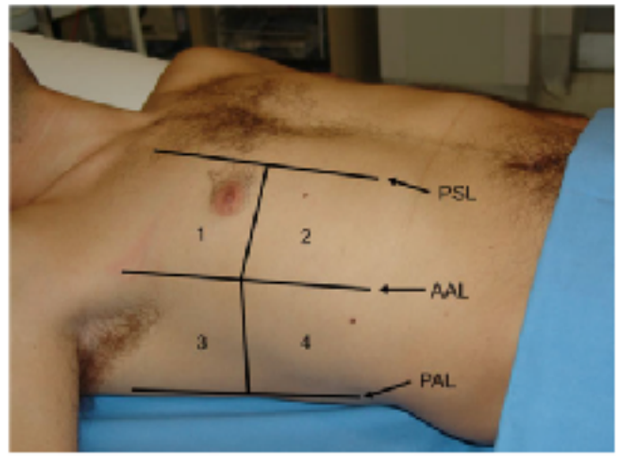
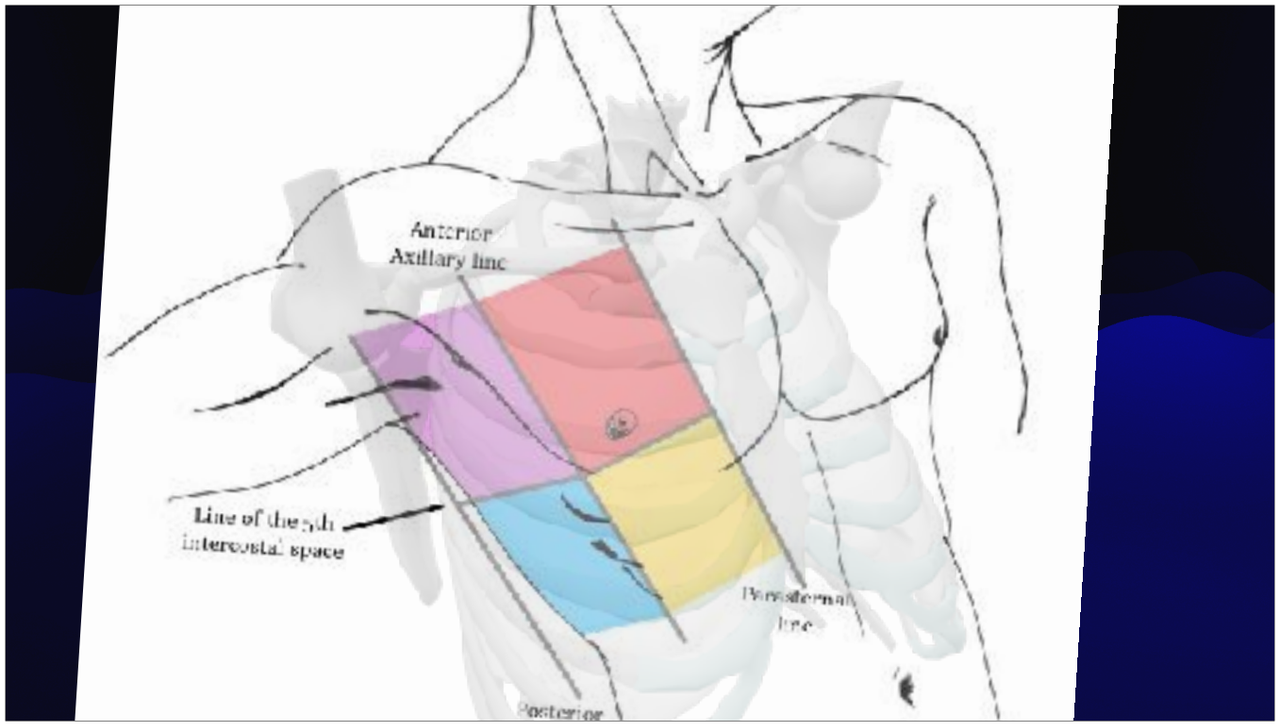
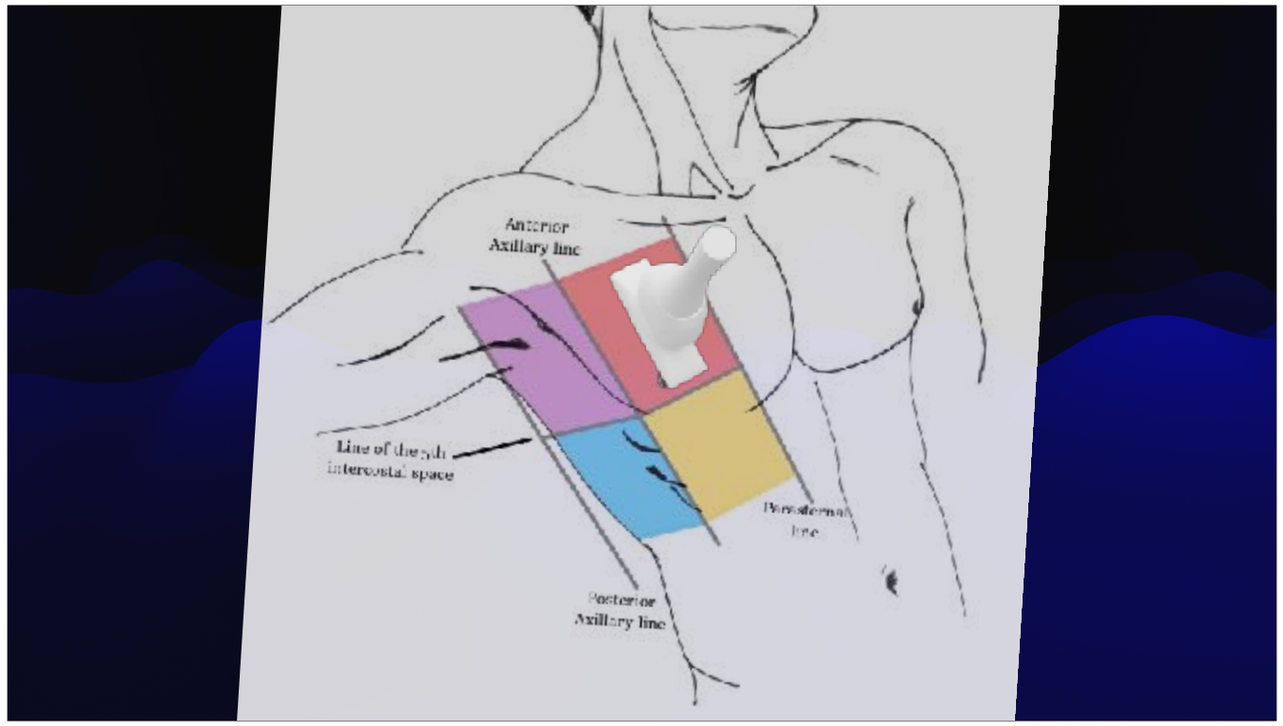


Fig. 2 The four chest areas per side considered for complete eight-zone lung ultrasound examination. These areas are used to evaluate for the presence of interstitial syndrome. Areas *1* and *2* denote the upper anterior and lower anterior chest areas, respectively. Areas *3* and *4* denote the upper lateral and basal lateral chest areas, respectively. *PSL* parasternal line, *AAL* anterior axillary line, *PAL* posterior axillary line (modified from Volpicelli et al. [19])

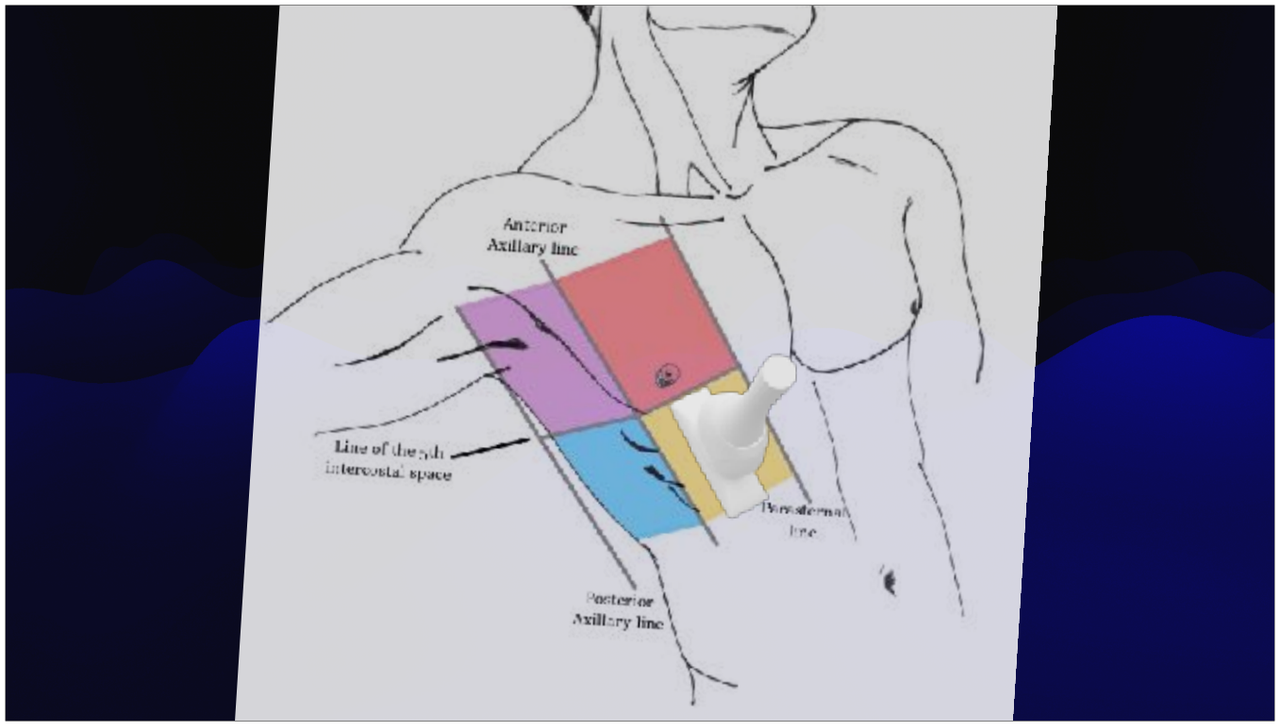
Guidelines exist on how to perform a point-of-care ultrasound of the lungs.
I prefer using the eight frontal areas as described in the 2012 guidelines.
Volpicelli, G., et al. (2012). "International evidence-based recommendations for point-of-care lung ultrasound." Intensive Care Med 38(4): 577-591.

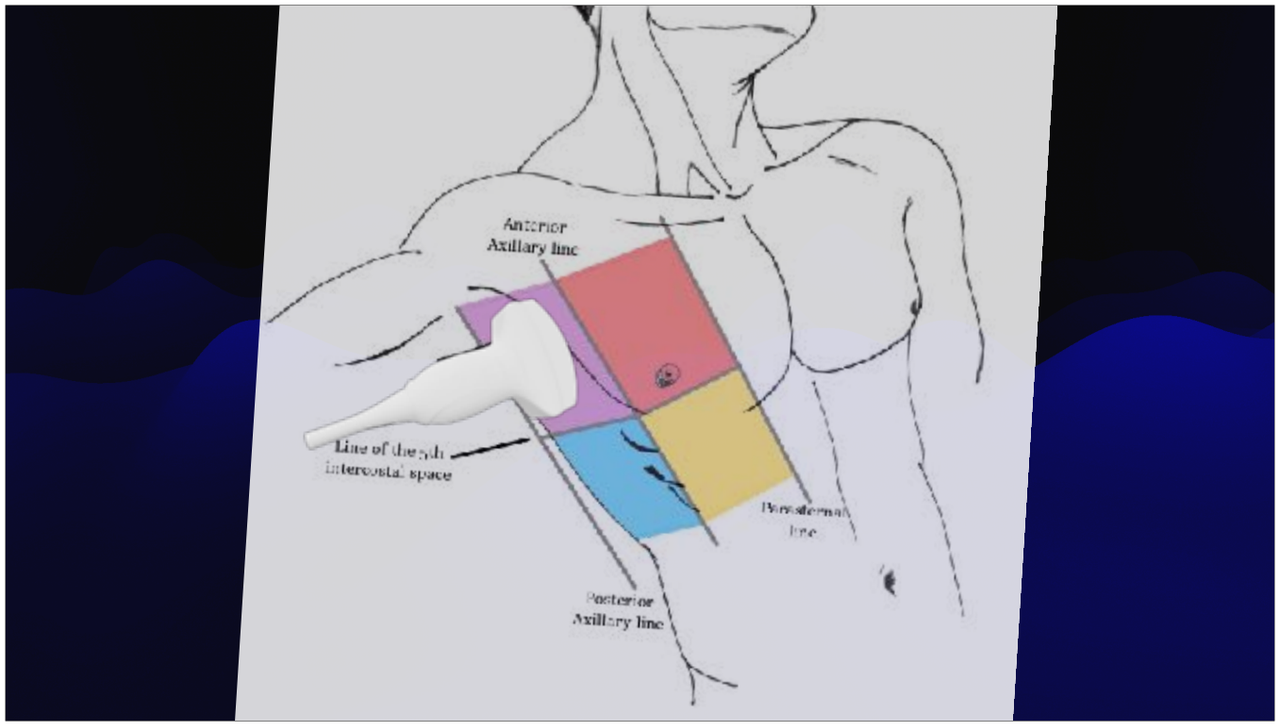


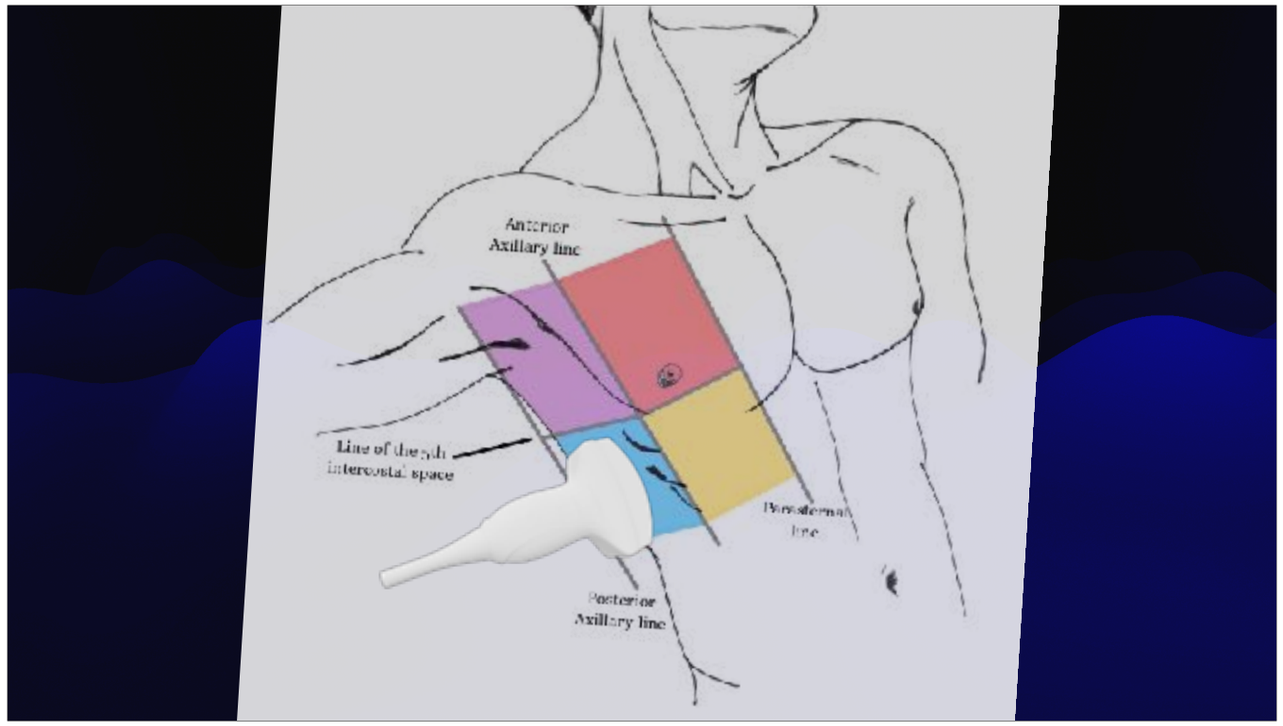
In this illustration, we can see the chest area being scanned with an ultrasound on the right. You can use the same areas on the left. I strongly advise that every time you obtain a recording of each area, you save it, marking the area that was evaluated.



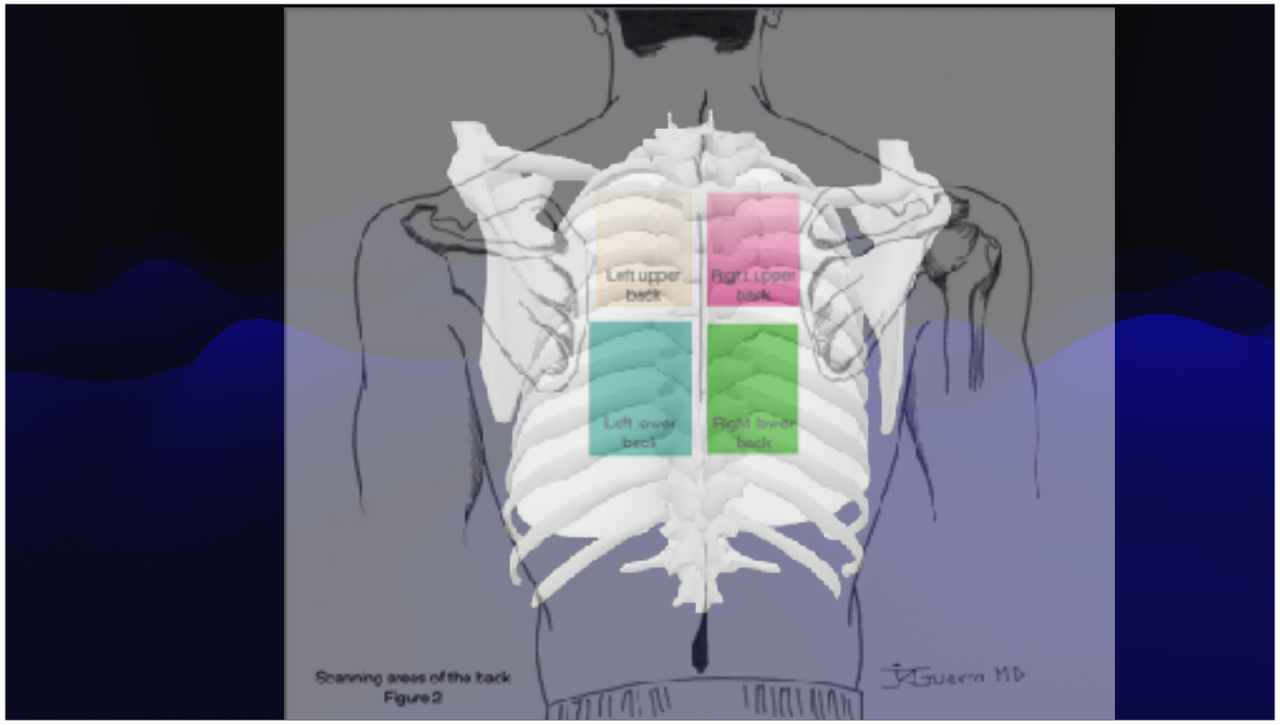
While scanning the lungs, slide your probe from area one to area two, then to areas three and four.


Anterior
Axillary line
Line of the 5th
Intercostal space
Posterior
Axillary line

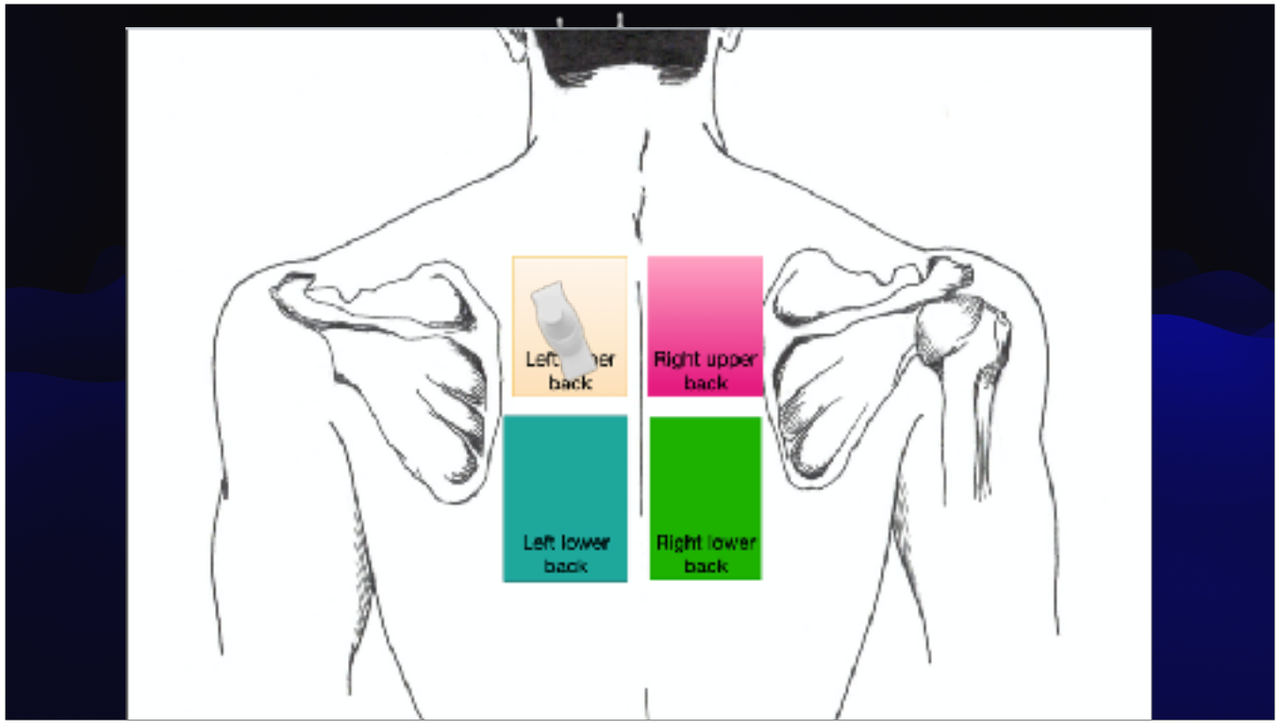

Anterior
Axillary line
Line of the 5th
Intercostal space
Parasternal
line
Posterior
Axillary line



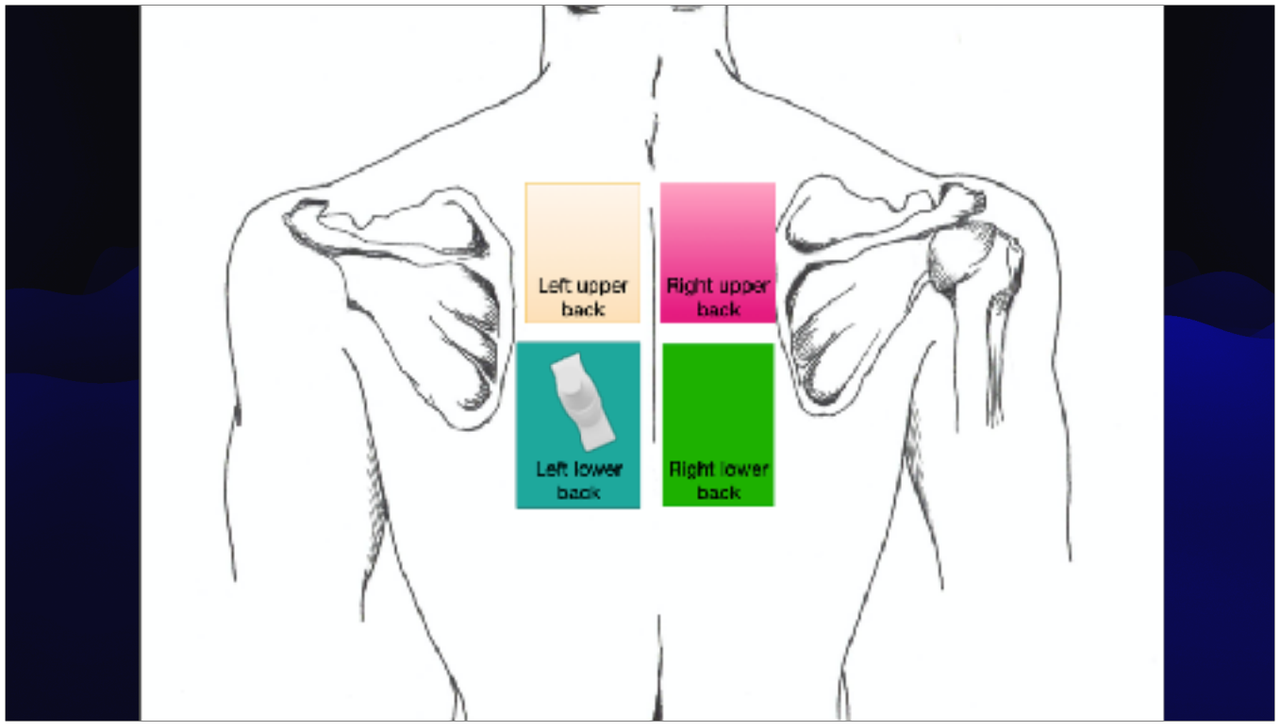
This will enhance your anatomical understanding of the lesions or abnormalities encountered during ultrasound procedures.
I advise that a complete scanning of the eight frontal areas be performed in any patient who is lying down.
I also advise documenting every finding in each area to improve anatomical understanding.

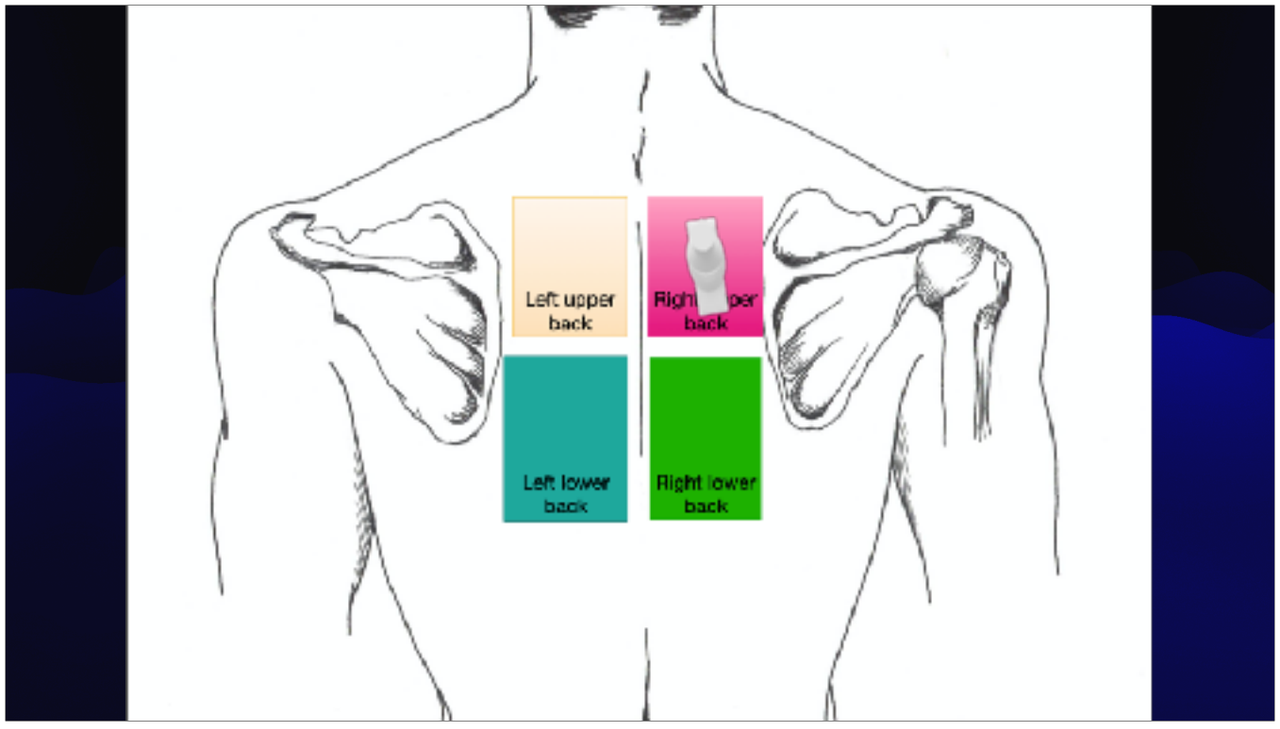


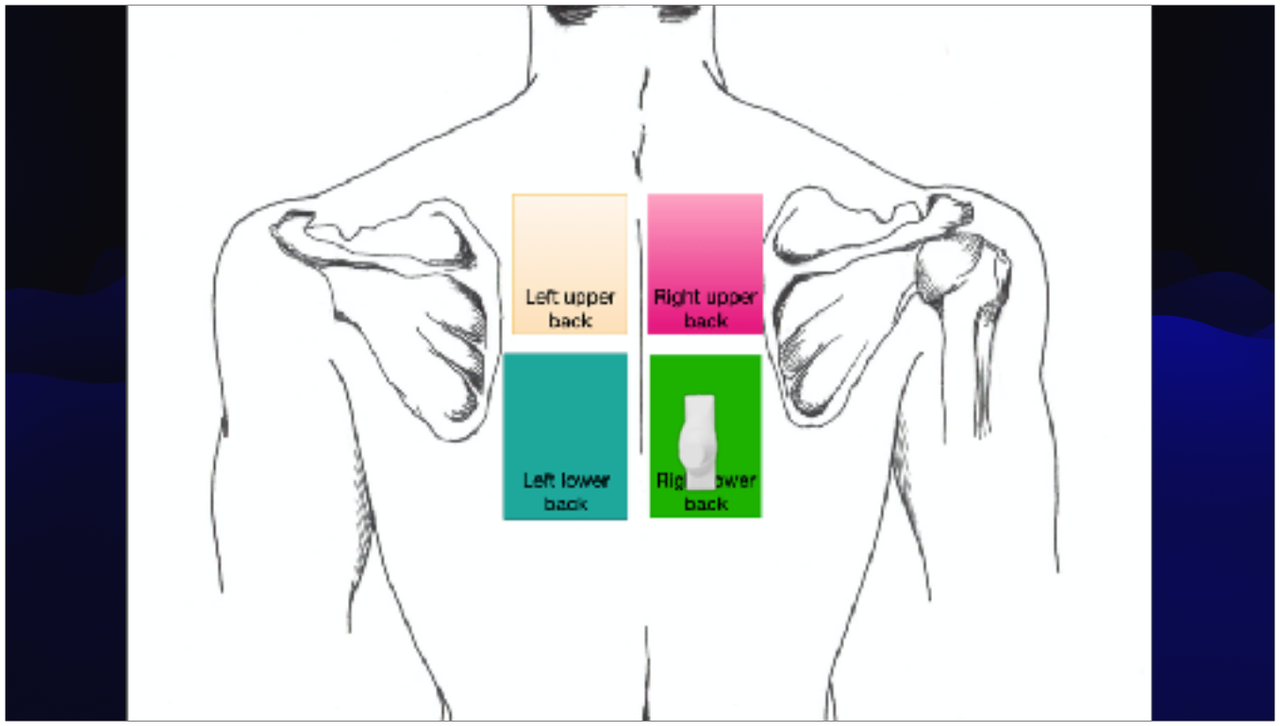
When patients can sit up, perform POCUS of the back of the chest. This is especially useful when you find crackles or any other finding, and you want to perform a lung ultrasound to confirm the presence of various lung conditions.



Again, slide the probe methodically through the different quadrants of the patient's back.


Left upper back
Right upper back
Left lower back
Right lower back


Left upper back
Right upper back
Left lower back
Right lower back

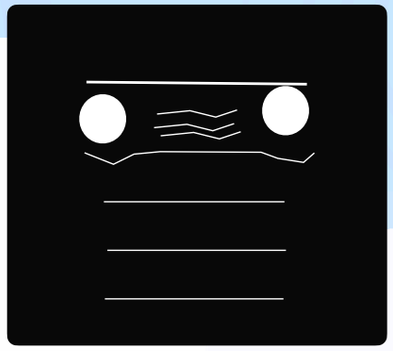


I always advise obtaining videos of each area and marking the areas being scanned to understand the anatomy better and emulate them for improvement in the patient's condition.

Reverberation artifact -A lines-

Soft tissue: 1.62 × 10^6 Rayls

Air: 4.1 × 10^2 Rayls



As we stated before, there is a large difference in impedance between tissue and air. The lungs are mainly composed by air. This creates an area where ultrasound cannot be transmitted at the pleura. The pleura then acts as a mirror, creating reverberation. This reverberation creates the illusion of multiple pleural images that are equidistant. This phenomenon is called A lines and is correlated to normal lungs.

3900-fold difference in impedance

🔷 Air

ρ ≈ 1.21 kg/m³
c ≈ 343 m/s
≈415 Rayls
Z≈415Rayls

🔷 Water (20 °C)

ρ ≈ 1000 kg/m³
c ≈ 1480 m/s
1000
1480
1.48×10 6
Rayls
Z=1000×1480=1.48×10 6
 Rayls

🔷 Soft tissue (average, “muscle”)

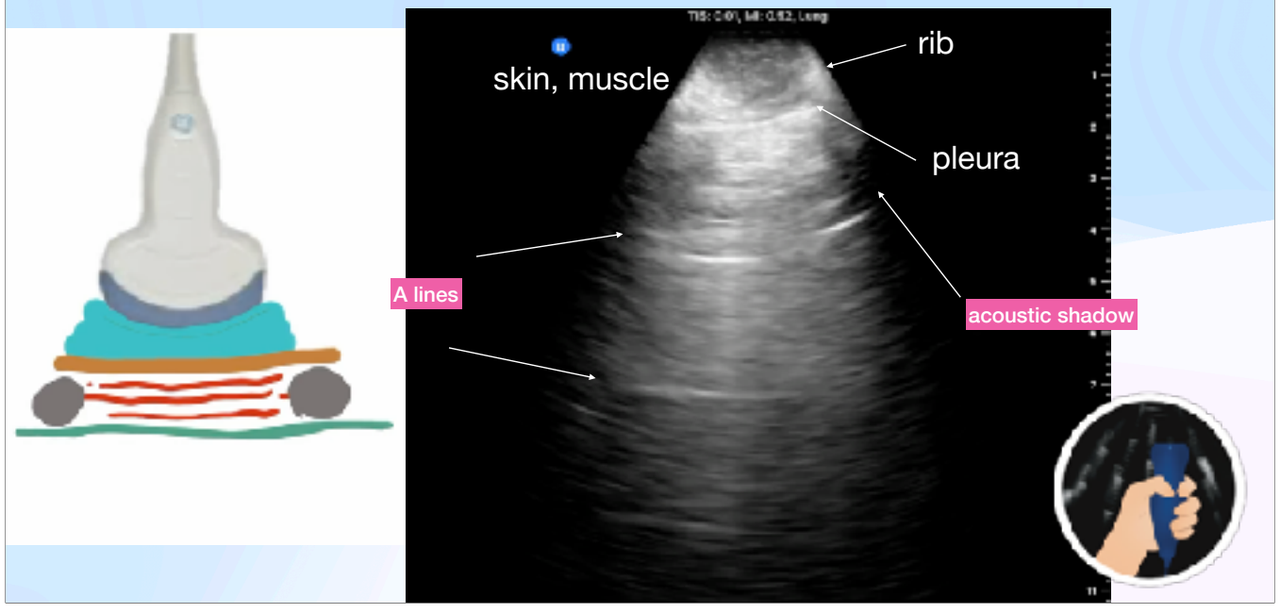
ρ ≈ 1050 kg/m³
c ≈ 1540 m/s
Z 1050
1540≈1.62×106

Rayls
Z=1050×1540≈1.62×10
6
Rails

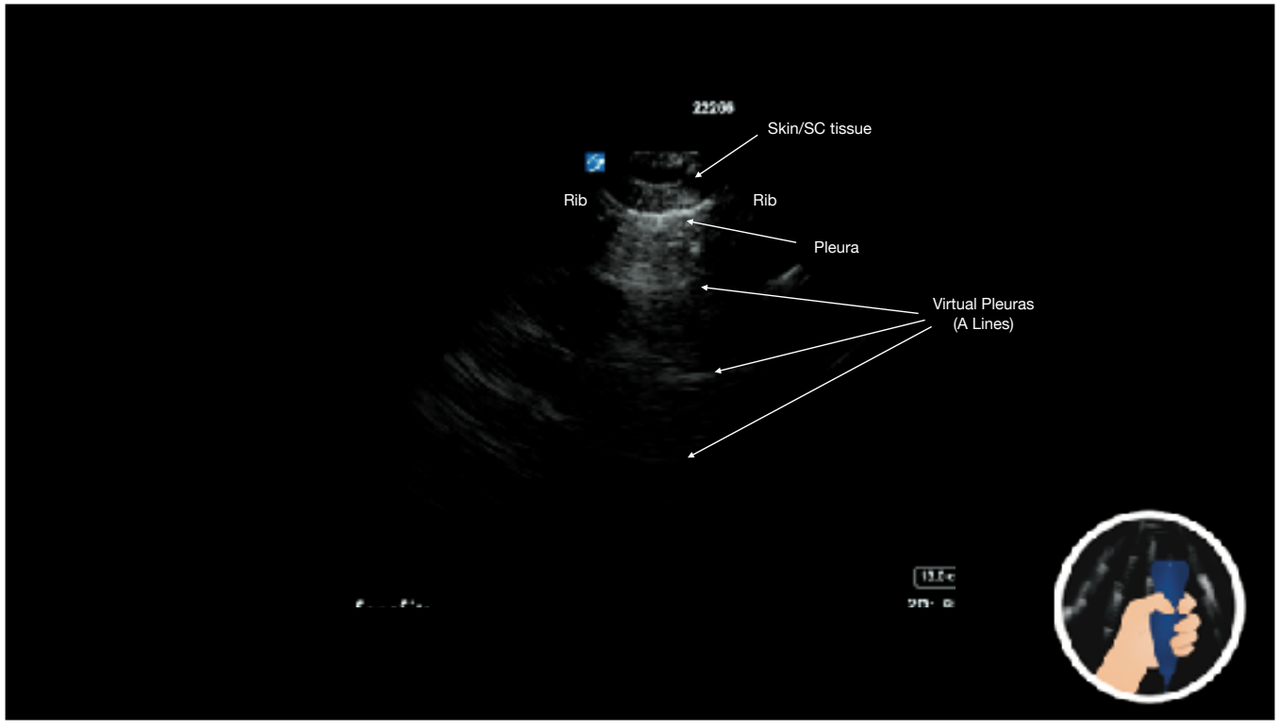
🔷 Comparison

Air: 4.1×10^2 Rayls
Water: 1.48×10^6 Rayls
Soft tissue: 1.62×10^6 Rayls
That’s about a 3,900-fold jump in impedance from air to tissue!

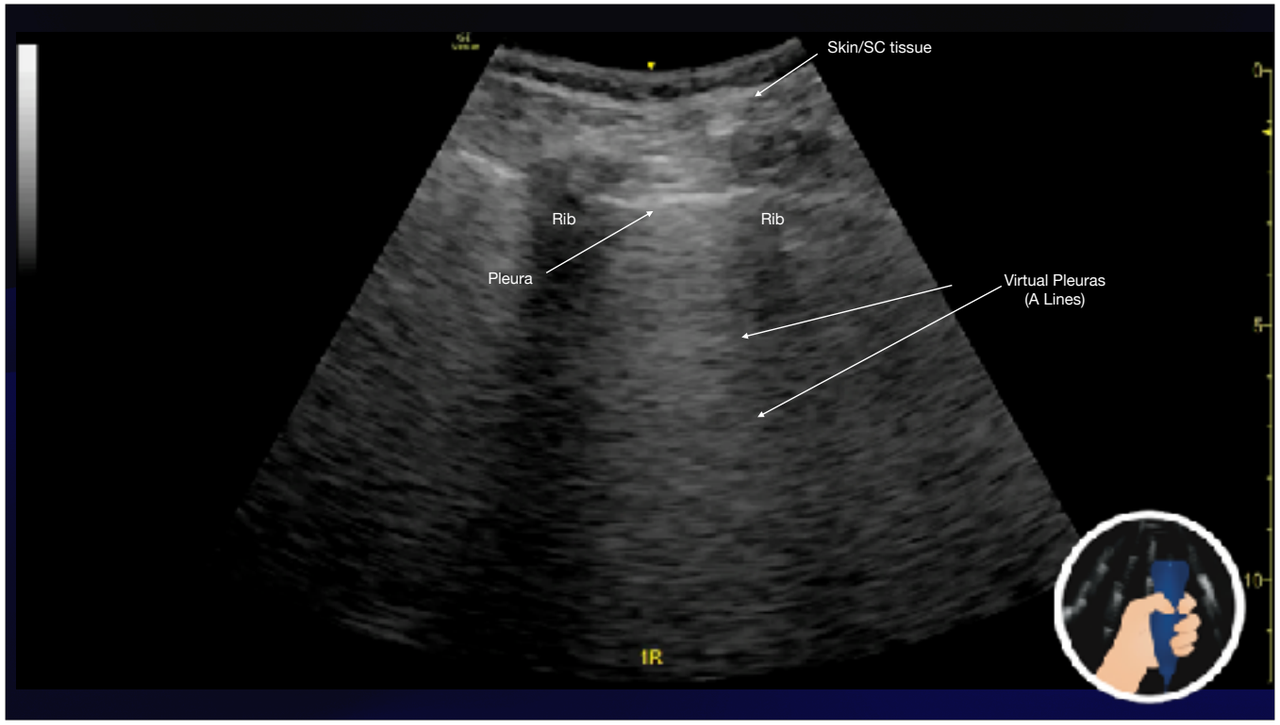
Reverberation artifact -A lines-



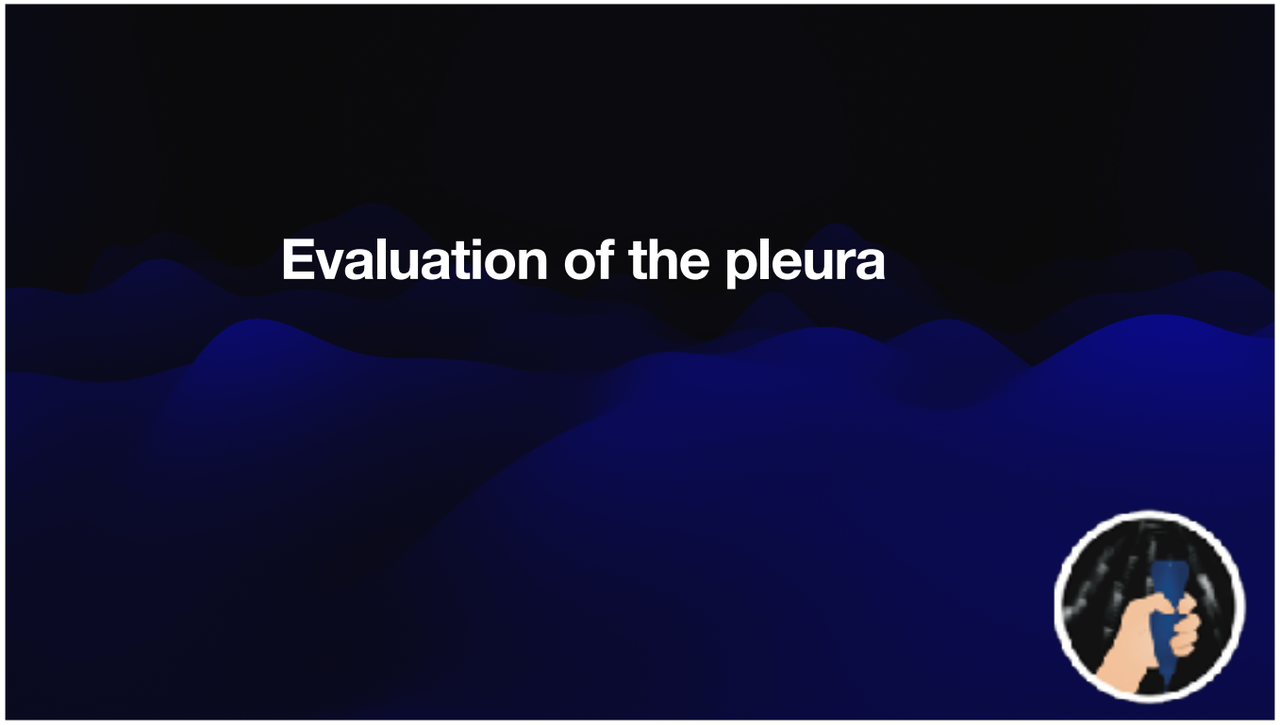
In this slide, we can see the different A lines produced by the reverberation of sound waves at the pleura.
It is very important to have a good angle of isonation to obtain A lines.
If your angle of isolation is off, you'll end up with a specular reflection and won't see A lines, even in normal lungs.



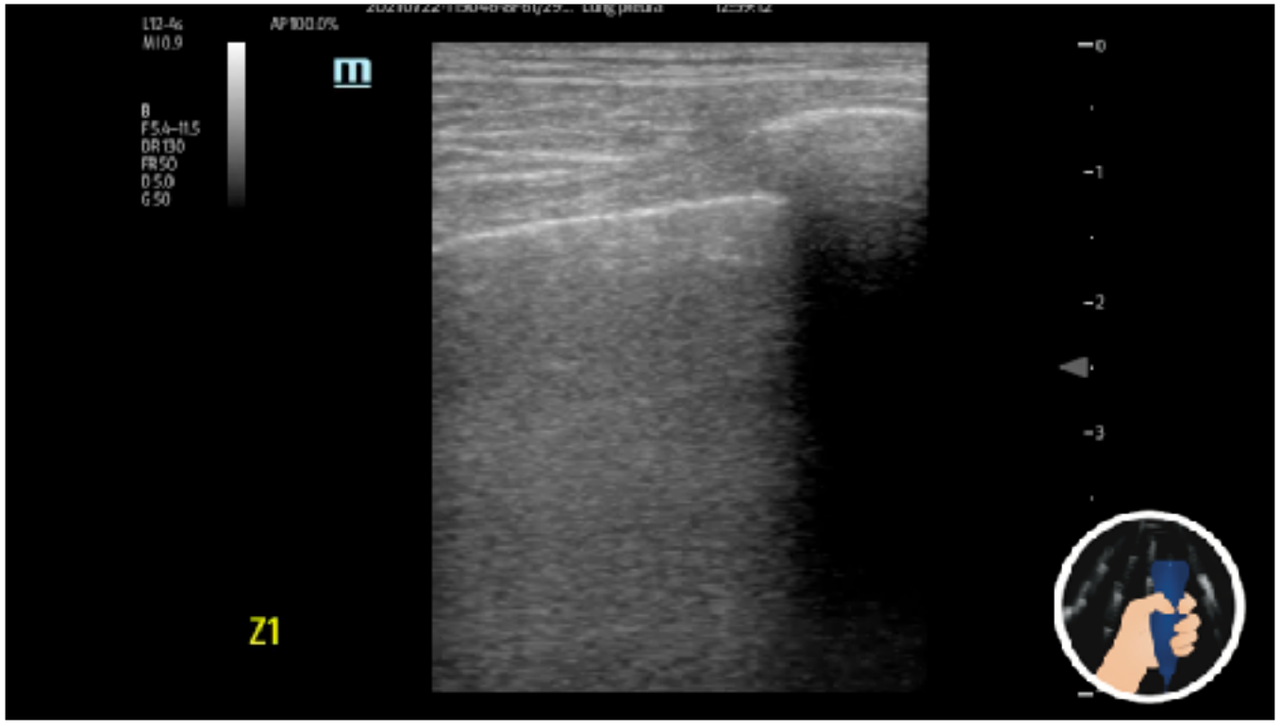
Normal A lines.
Here with me: normal A lines using a phased-array transducer in lung settings.
Note all the important structures.



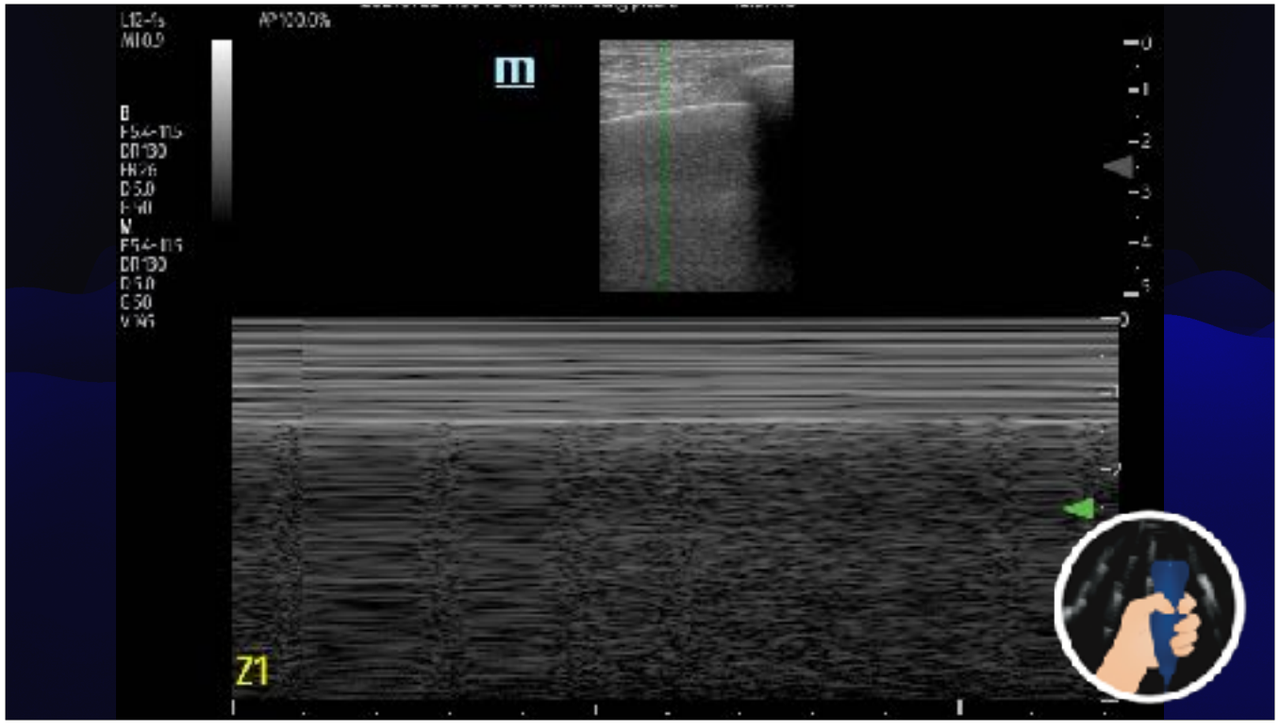
And this slide has normal A lines. Using a curvilinear transducer. You can also note the normal plural sliding. Please take a moment to see all the structures. This is a clip obtained from area one of the right lung.



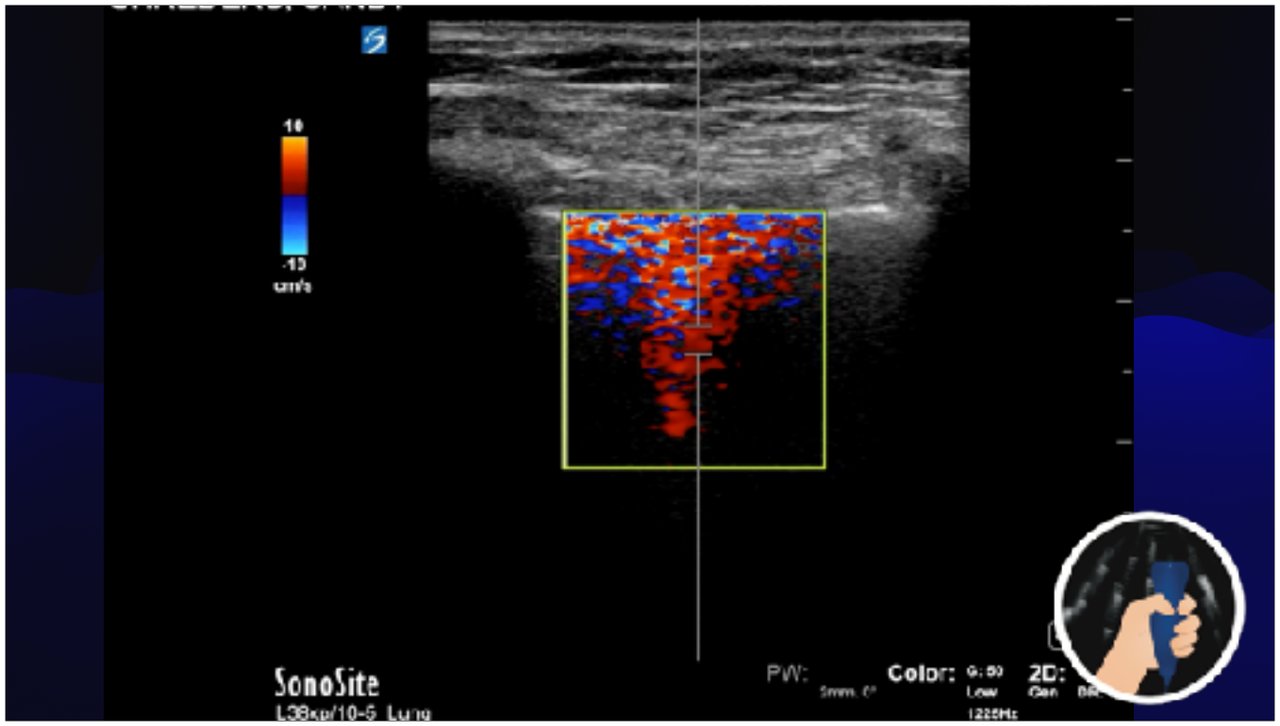
When the objective of the point-of-care ultrasound is to evaluate the pleura closely, a linear array transducer is usually preferred.



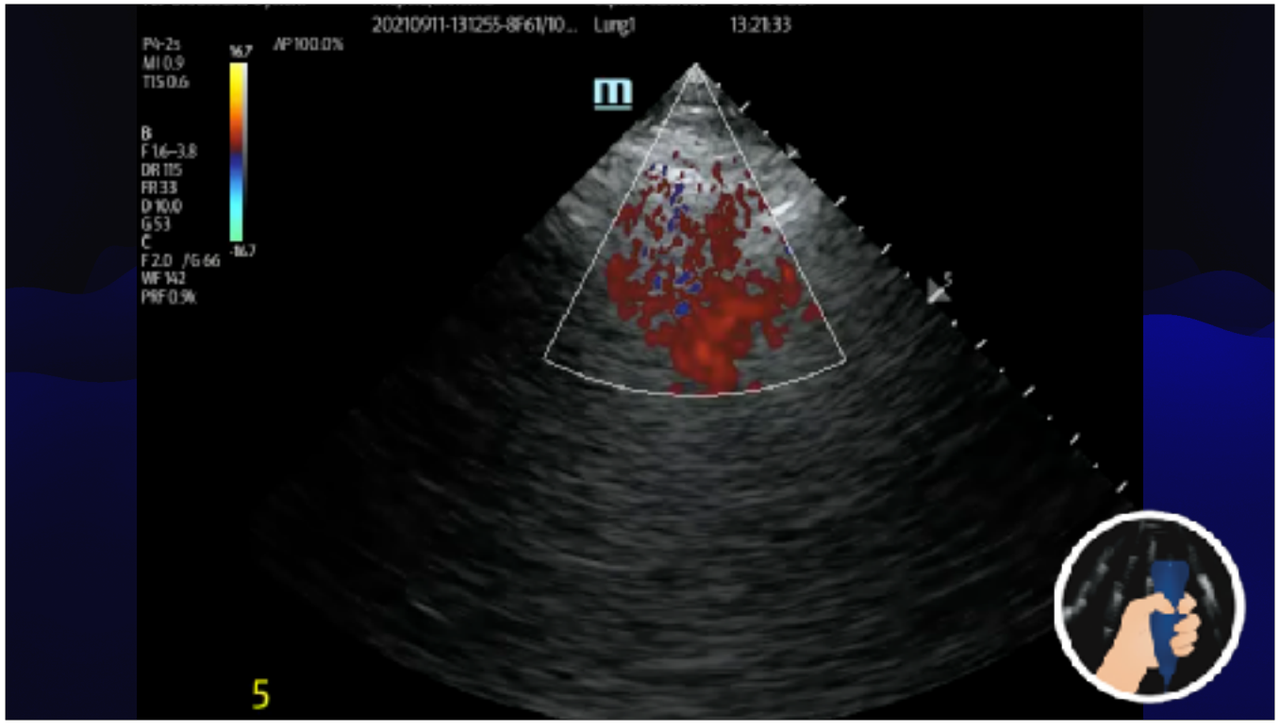
We saw this video at the beginning of the lecture. You can see normal pleural sliding. The pleura is apparent immediately after the subcutaneous tissue and muscles. To your right, you can see a rib operating acoustic shadowing. This is a great example of normal pleural sliding.



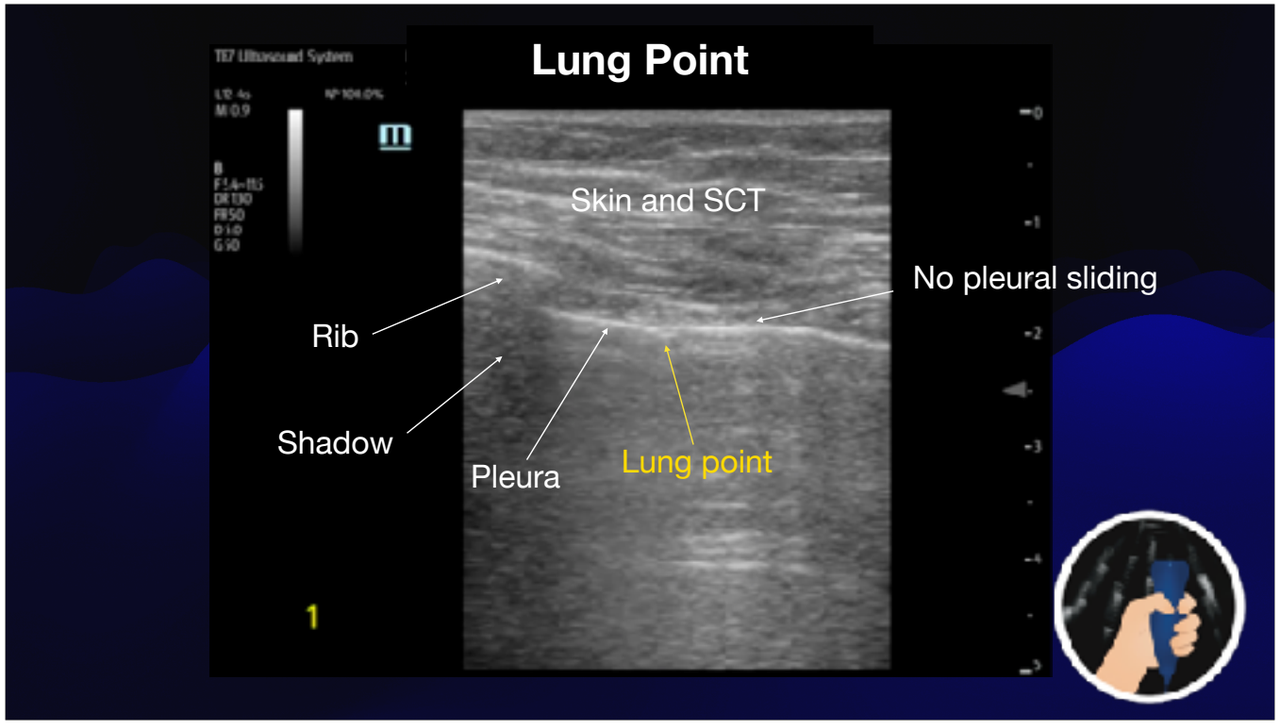
Pleural sliding can be illustrated with M-mode.
As you can see in this M-mode image, the areas scanned within the muscle and subcutaneous appear with no movement between zero and 1.5 centimeters deep. After that, we can see the pleura. The plural moves and creates a “noise” beginning at 1.5 cm and below. This is called the “seashore sign”. Demonstrating this sign essentially rules out pneumothorax. This is an easy and fast way to document normal pleural sliding.



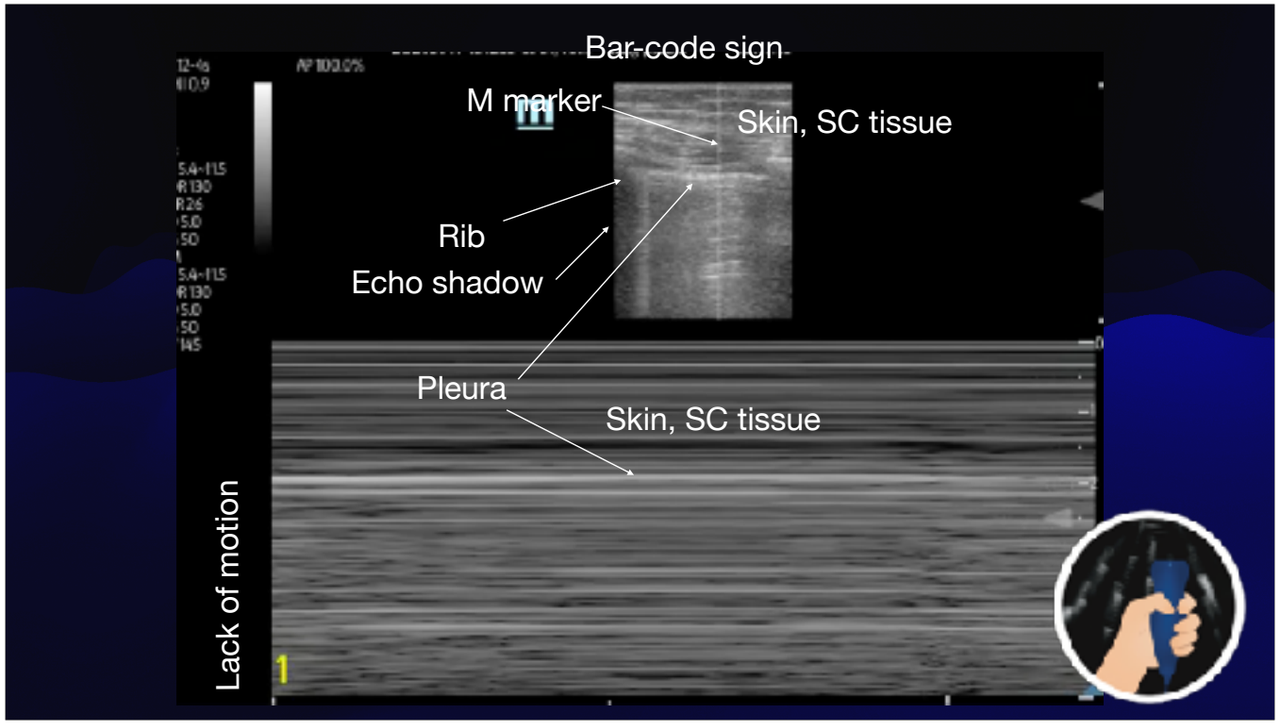
Normal pleural sliding can also be demonstrated with Doppler. One can use Doppler or power Doppler to demonstrate normal pleural sliding. The presence of a Doppler signal with Doppler reverberation in the area being examined is a good sign that there is no pneumothorax in the pleural cavity and that the pleural cavity is sliding normally. The advantage of this technique is the same as that of M-mode. One can document a normal finding with a picture.



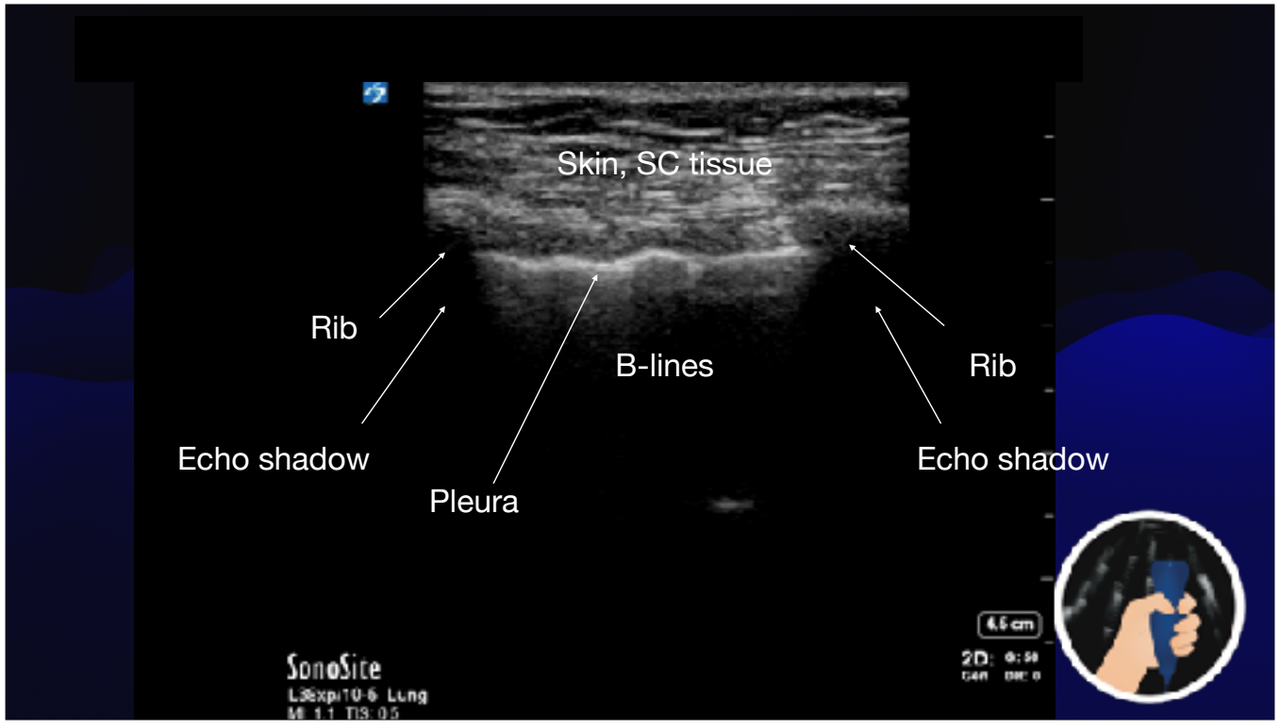
This is another example of normal plural Doppler. Notice how Doppler starts at the level of the plural and reverberates through the Doppler field being evaluated. It is very important to use either power Doppler or color developer with a very low velocity. Some machines will not be able to perform this with standard color Doppler.



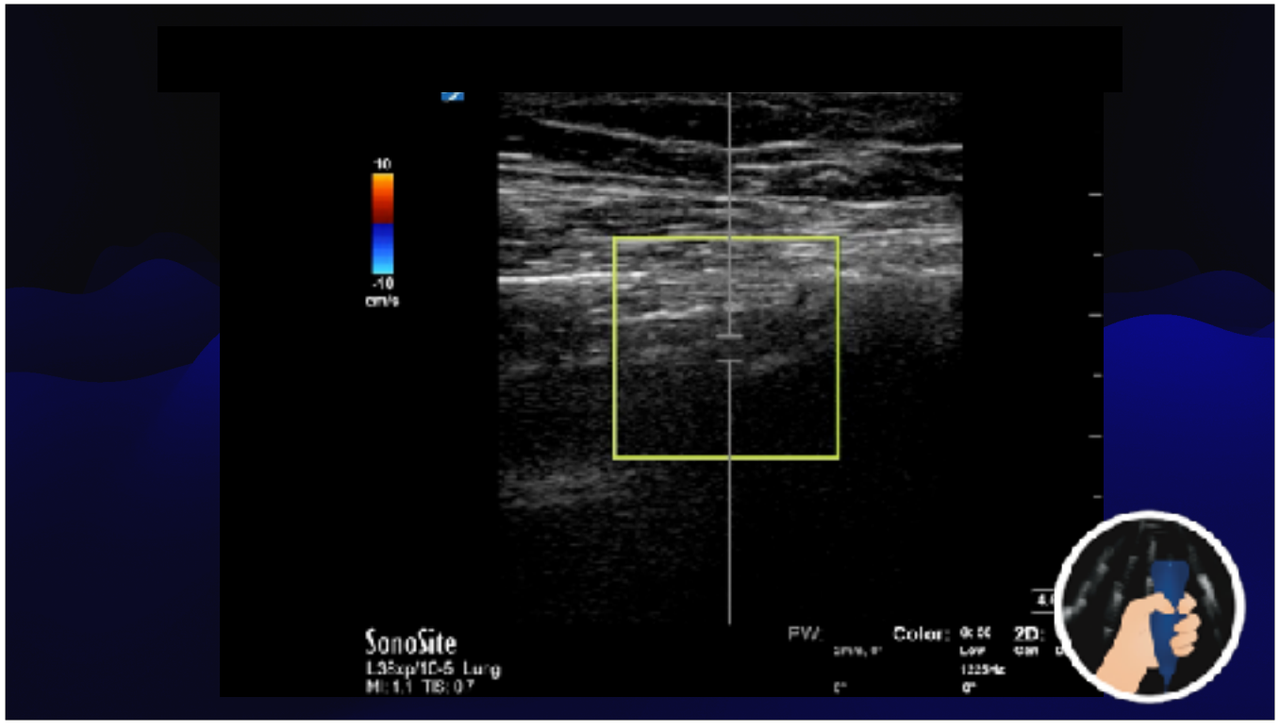
Since we are explaining the evaluation of the pleura, I believe we can start with one of the most important signs of pneumothorax.
A pneumothorax is the presence of air in the pleural space. The air disrupts the intimate contact between the visceral and parietal pleura to varying degrees. Within the area where the visceral pleura touches the parietal pleura, one can observe what is called the lung point. The lung point is an area where normal sliding can be observed in an otherwise non-sliding region. This is well illustrated in this video. The area of disruption of pleural sliding is referred to as the lung point, and its presence in the right scenario is characteristic of pneumothorax.



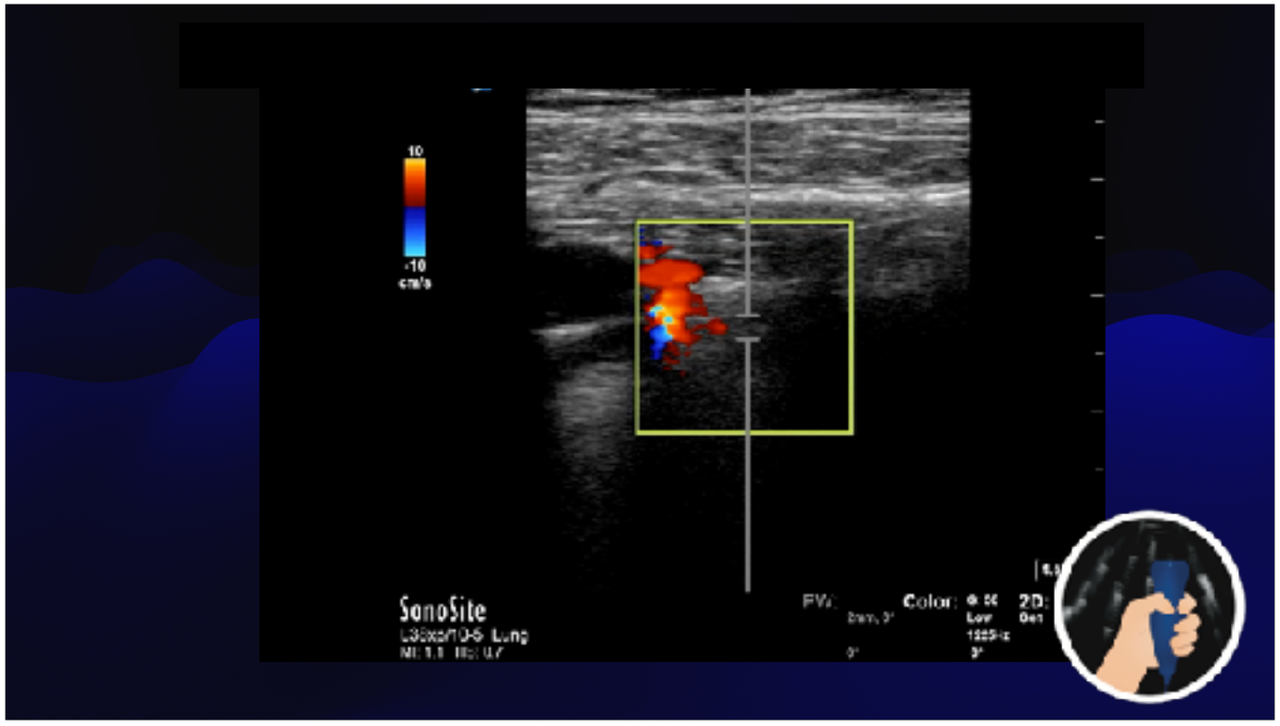
This is an M-mode scan of the pryor area of the lung. This time, it is scanning an area where there is no pleural sliding. As you can observe, and then compare to the normal seashore sign, this time we have no noise or degradation after the pleural line, creating the illusion of no movement after the pleura. This sign is called the “barcode sign” because it resembles a barcode. This sign is primarily observed in pneumothorax; however, other pleural diseases, such as pleurosymphysis, and conditions that may impair the pleural sliding can also cause it. Additionally, a patient intubated without auto-PEEP can also exhibit this sign, particularly in cases of severe COPD.



Another way to rule out pneumothorax is to identify B lines. B lines occur in the alveoli or very near the surface of the pleura. Here we can observe dynamic B lines.

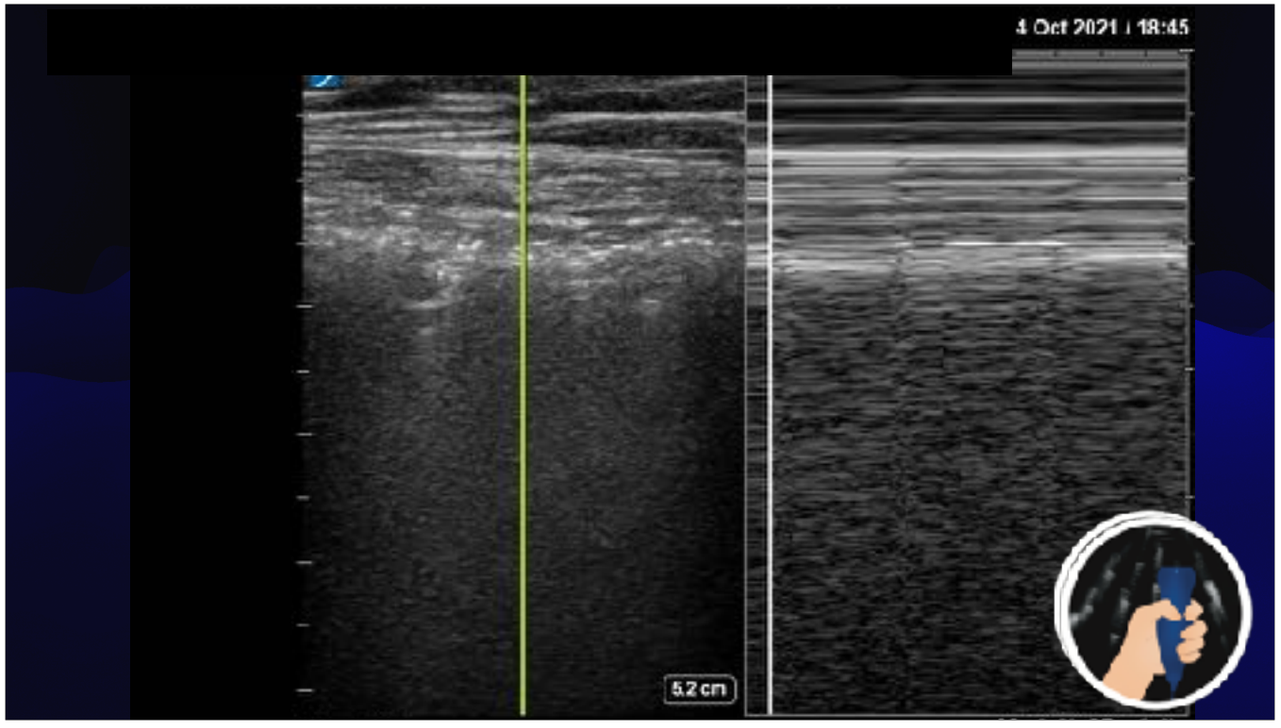


This is a case of pneumothorax. Although we do not see a lung point here. We have evaluated the plural space with Doppler. If you compare this to the prior slide showing the Doppler signal with reverberation, you can see that there is none. This is a very good indicator that pleural sliding is absent.

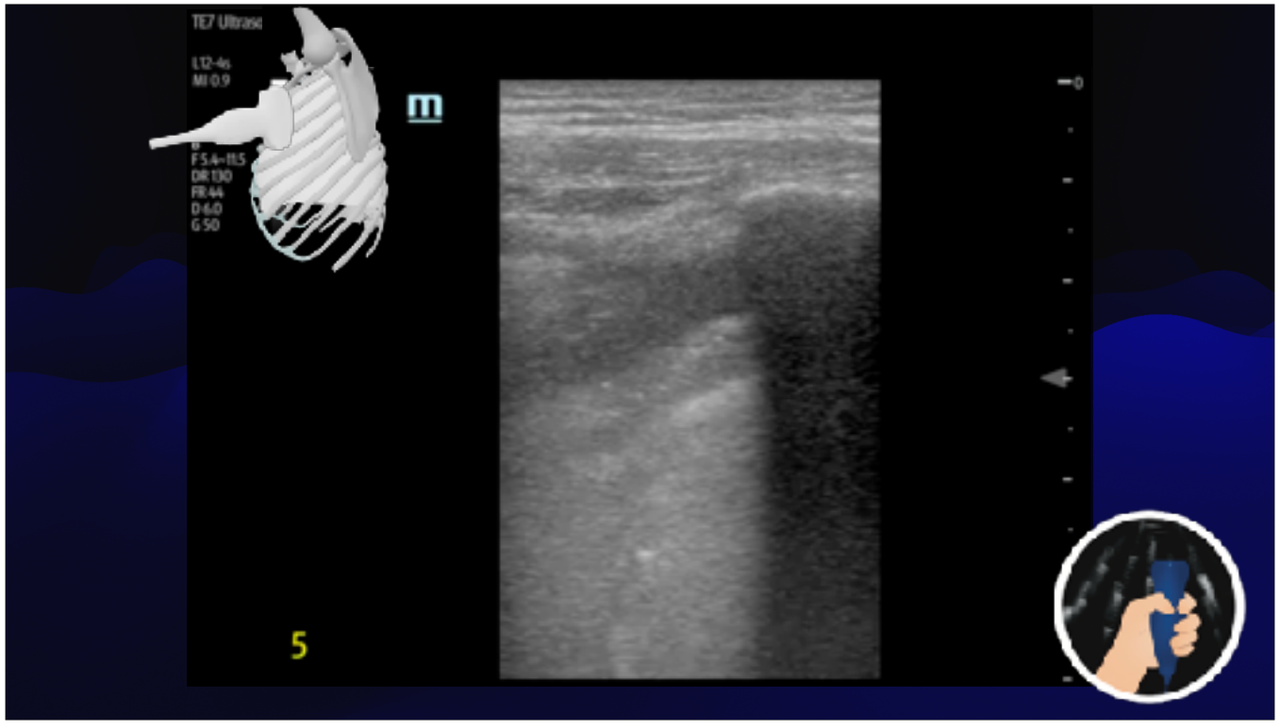


This is another example of a lack of pleural sliding evaluated by Doppler. No Doppler is coming from the pleura. This slide is interesting, right below the rib. A large vessel lies directly above the potential pleural space. You can observe that Doppler can create a mirror artifact just like gray-scale ultrasound.

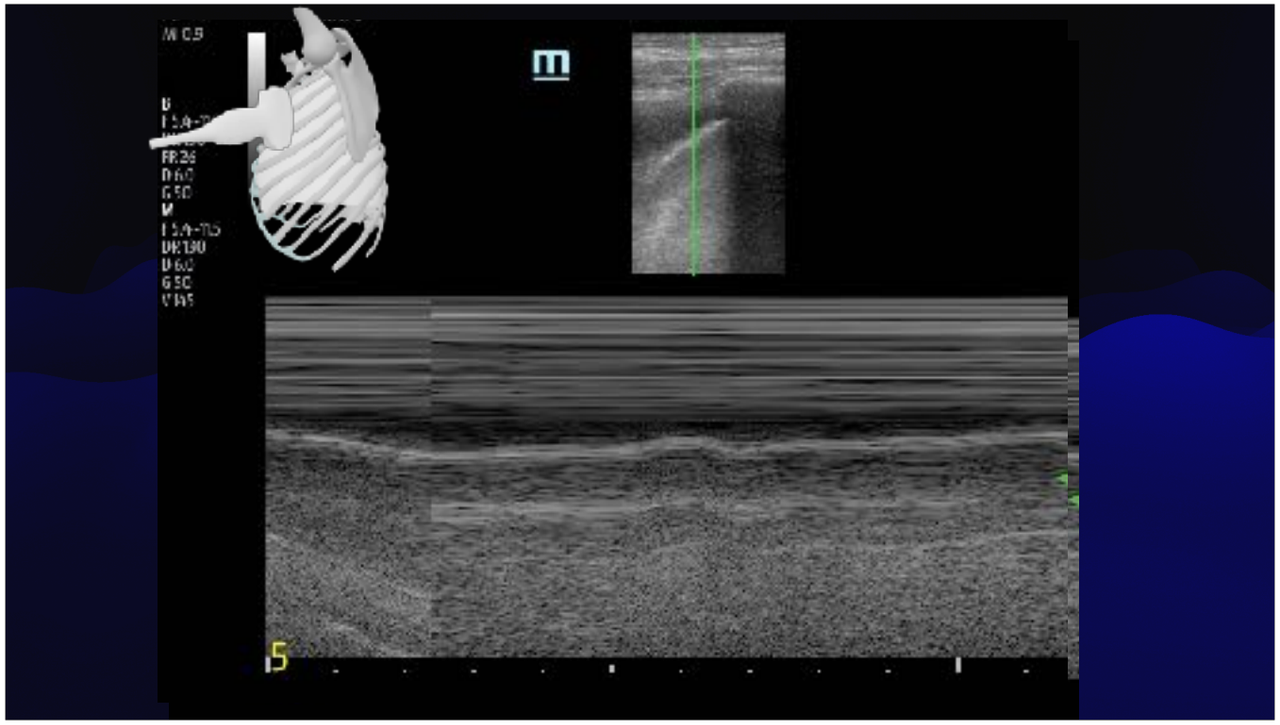
This is another evaluation of the pleura with a linear transducer. You can see a speckled artifact on the tissues being examined. We discussed this in a previous episode. The artifact makes the evaluation of the pleural space difficult; in both extremes of this illustration, the ribs are barely noticeable. This speckling is created because of the presence of air in a case of subcutaneous emphysema. And accompanied by a lack of pleural sliding. It is interesting that there appears to be an artifact similar to B lines. One needs to be aware of the possibility of subcutaneous emphysema and pneumothorax, which can create lines that resemble B lines. These specific lines are called E lines. These lines are only observed in pneumothorax with subcutaneous emphysema.



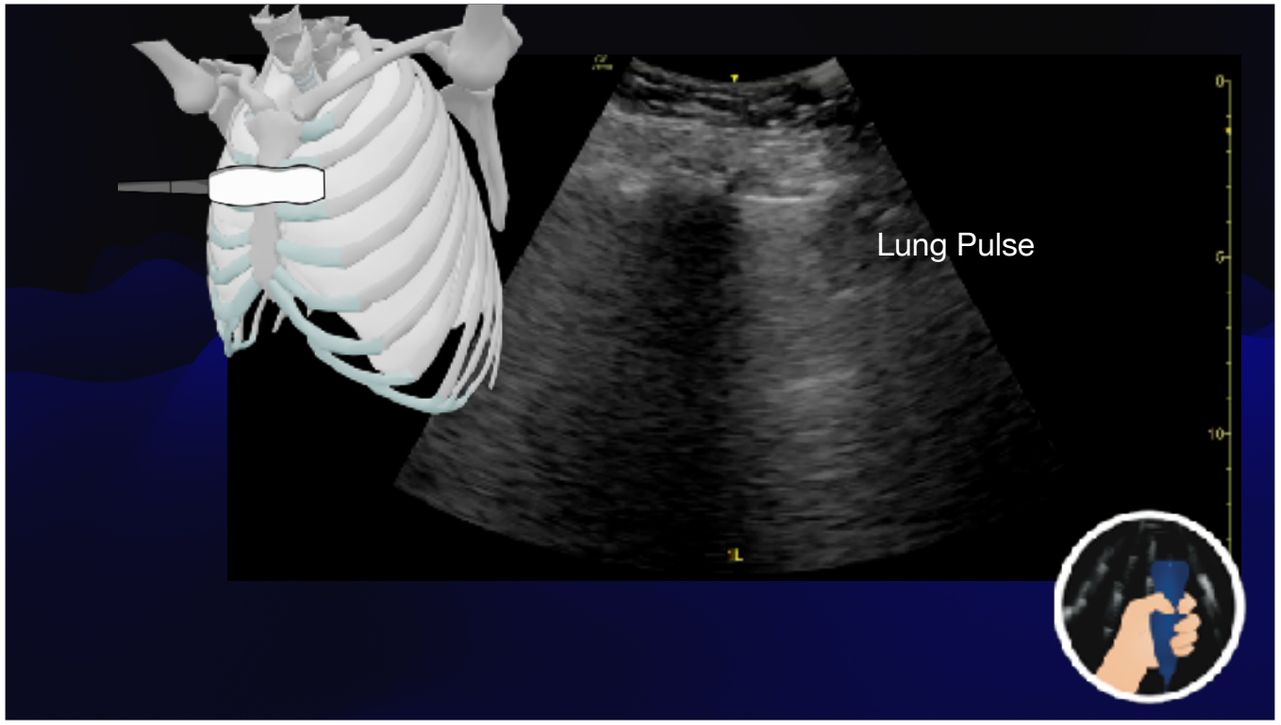
This is an M MOD illustration from the prior grayscale. Noticed that because of the presence of a speckled artifact, the M mode can look like a normal seashore sign, giving the illusion that there is pleural sliding. Again, it is of the utmost importance to know that a case like this can present at any time, especially during mechanical ventilation, or after trauma or procedures.



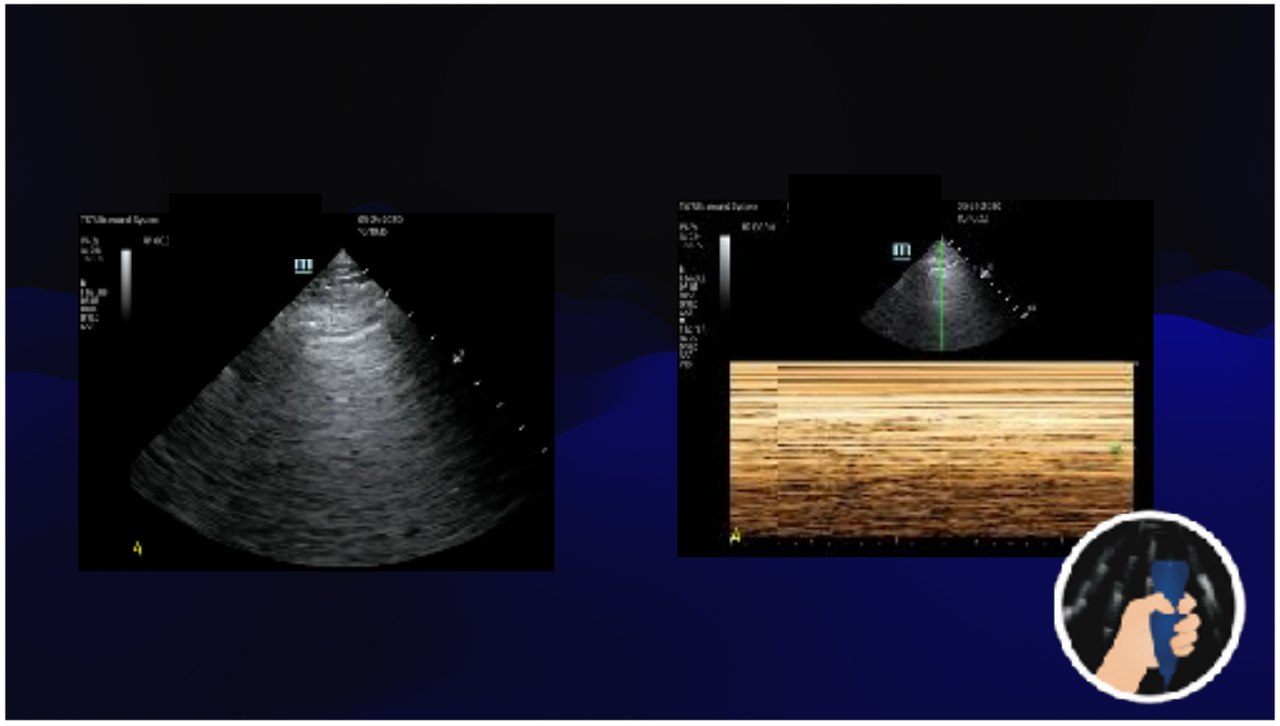
This is another evaluation of the pleural space in area five with a linear probe. In this case, we can see another lung point; however, we note fluid and the lung parenchyma immediately below the pleural line. Long point can appear in cases of plural effusion. It is also said that the lung is pulsating. This is a very common phenomenon when observing the left lung near the heart. It is possible to observe that the heart transmits its pulsations. This is called “Lung pulse” and is very common when evaluating consolidations near the heart.



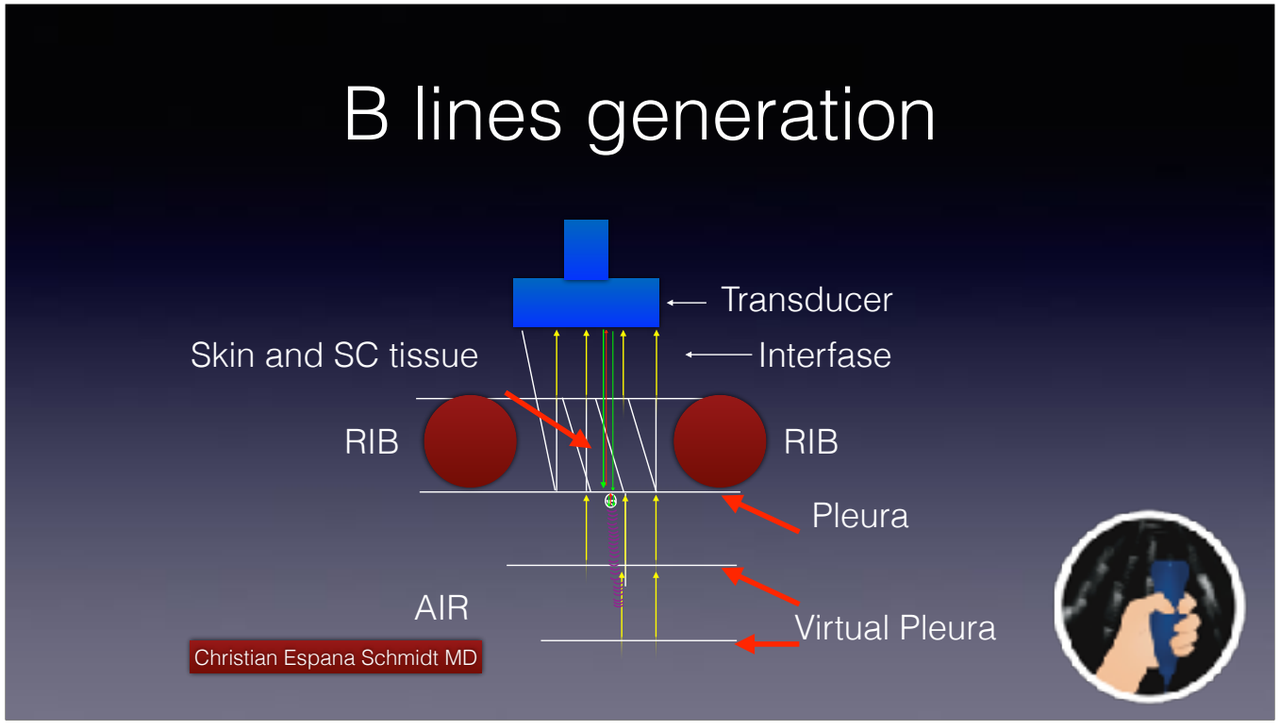
Here we have an M-mode of the same area, showing how the lung parenchyma pulsates.



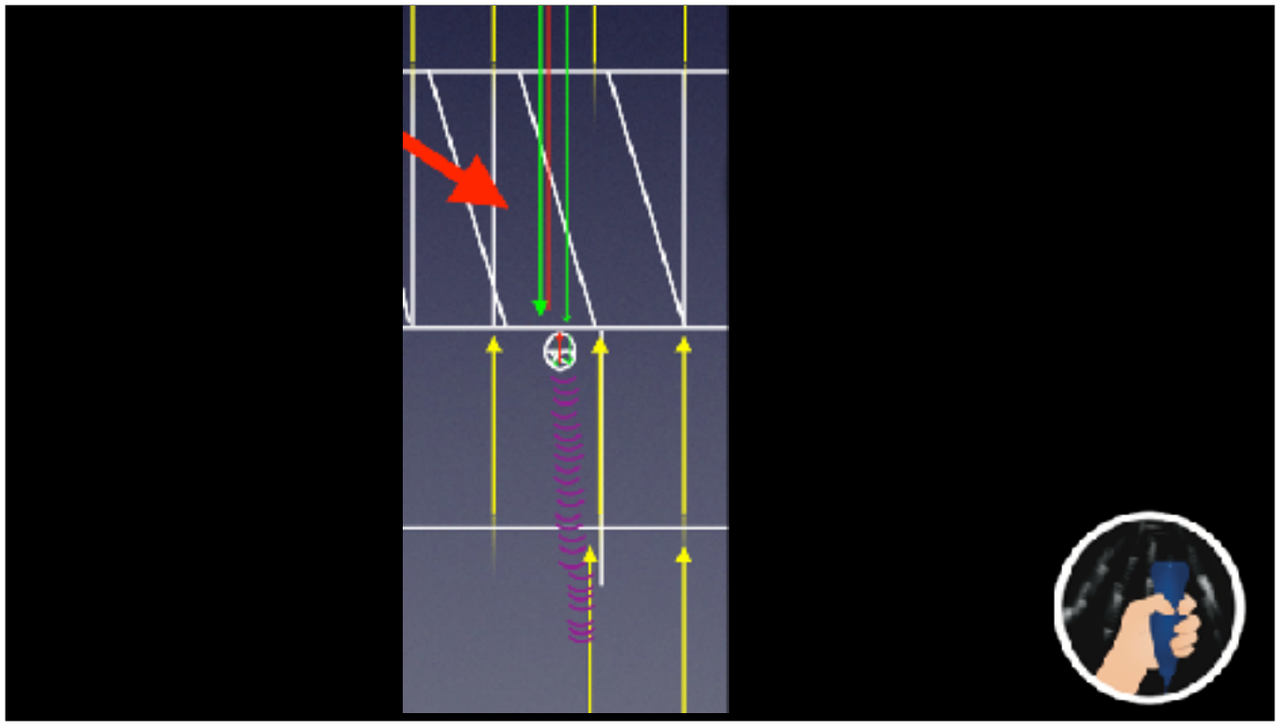
This slide shows a curvilinear probe evaluating area 1 of the left lung. If you look at the middle of the image, you can see the rhythmic movement of the lung. This is called the lung pulse. This is explained by the transmission of the heart's pulsations through the lung tissue. It is common to see this in areas of the lung near the heart. The presence of consolidation increases the chances of finding a lung pulse.



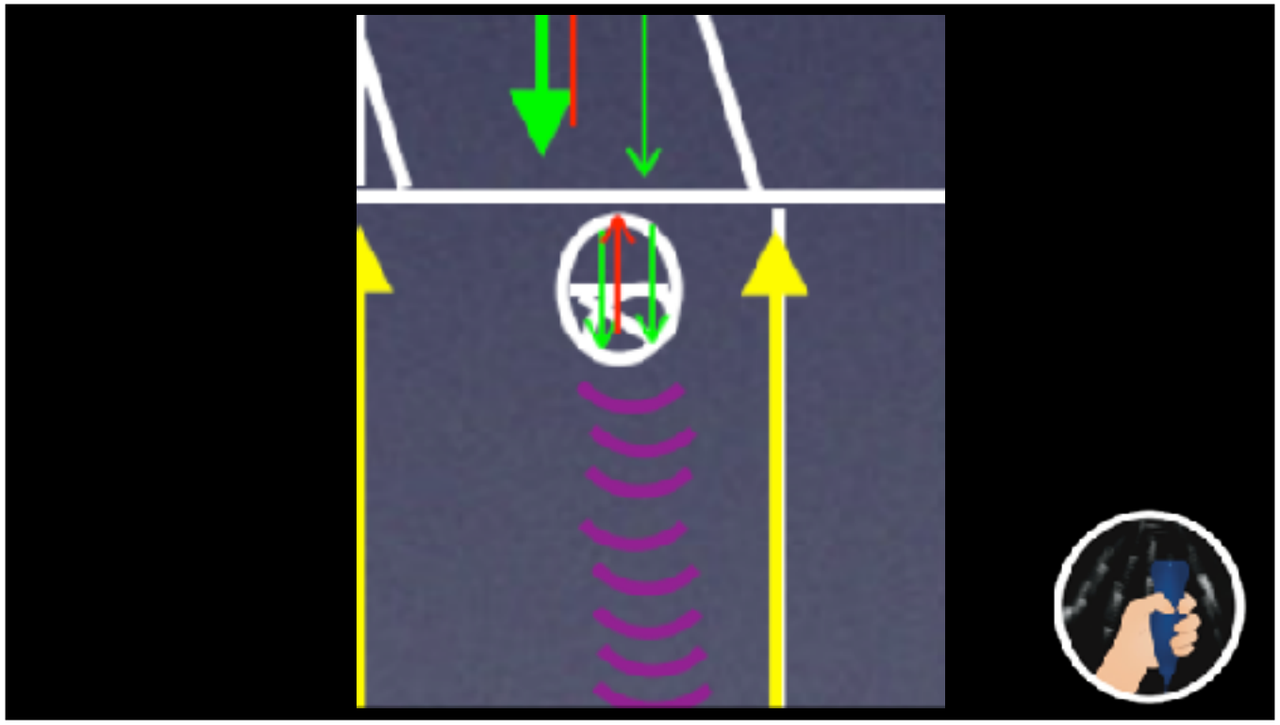
This is a case of a patient who presented with shortness of breath and severe COPD. One can see that the pleura is barely sliding in the M-mode recording, which appears to be very similar to a barcode sign. It is crucial to interpret your ultrasound evaluation within the broader clinical context of the patient.



Now, we are going to discuss B lines. This is an artifact due to reverberation. B lines are not different from comet tails.



They are produced due to the reverberation within the peripheral alveoli field, which contains a mixture of air and fluid.

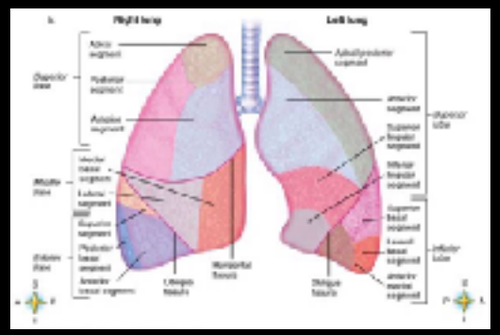


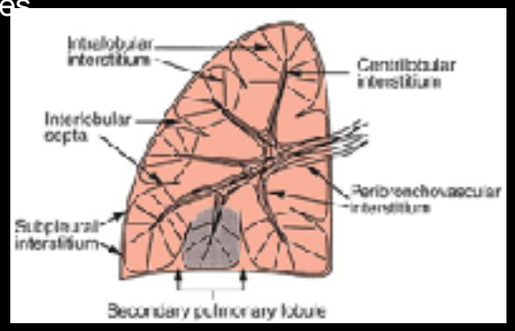
Here we can see the process closely.

Normal B lines

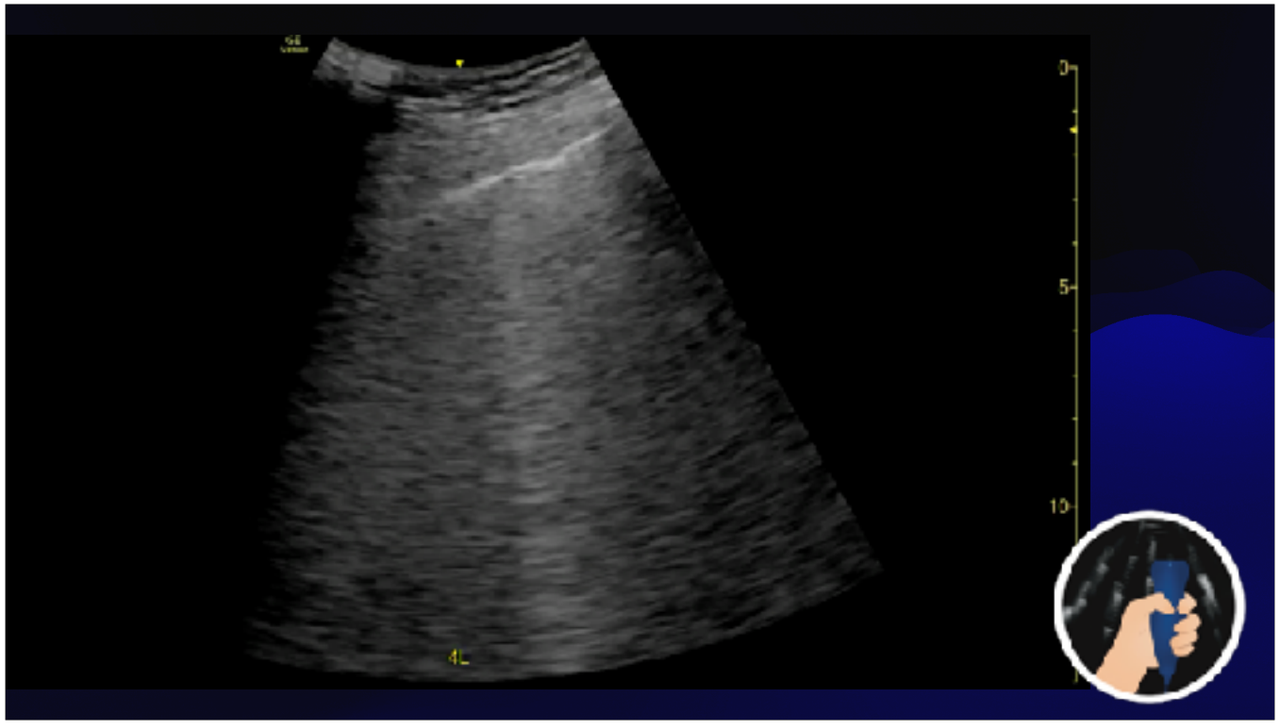
We can see up to 2 B lines per quadrant

- Fissures
- Segments
- Lobules

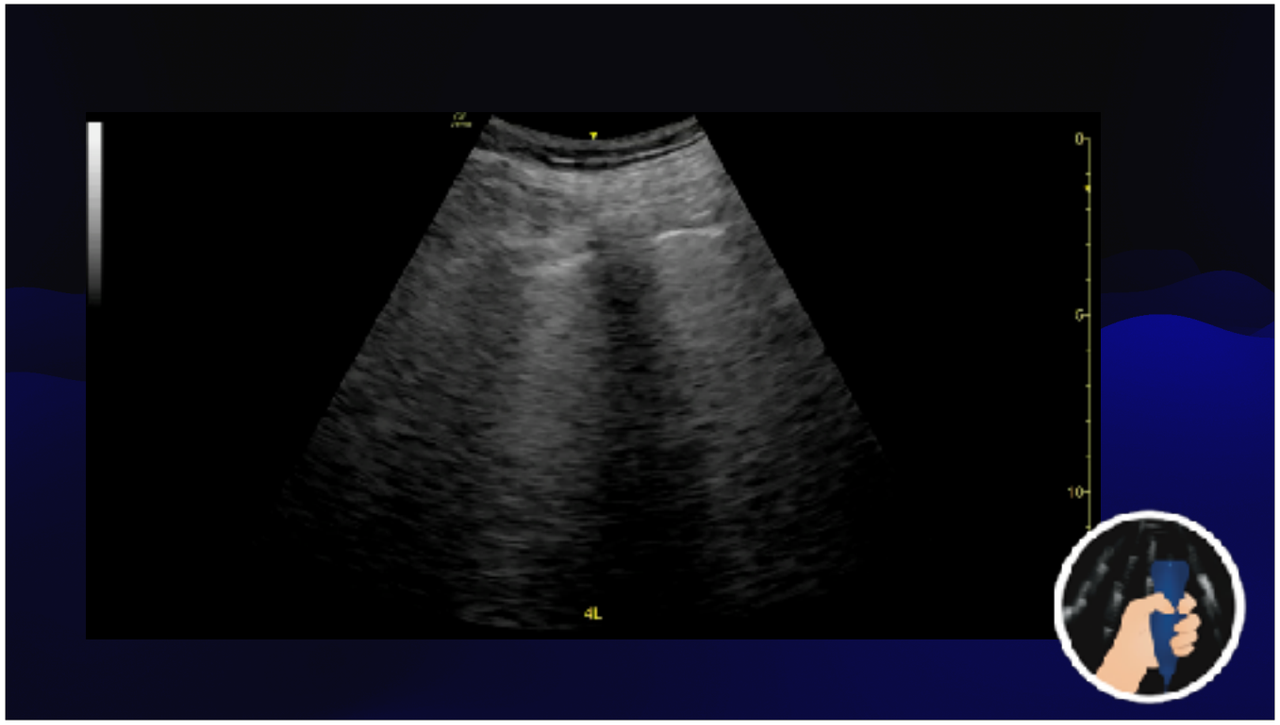




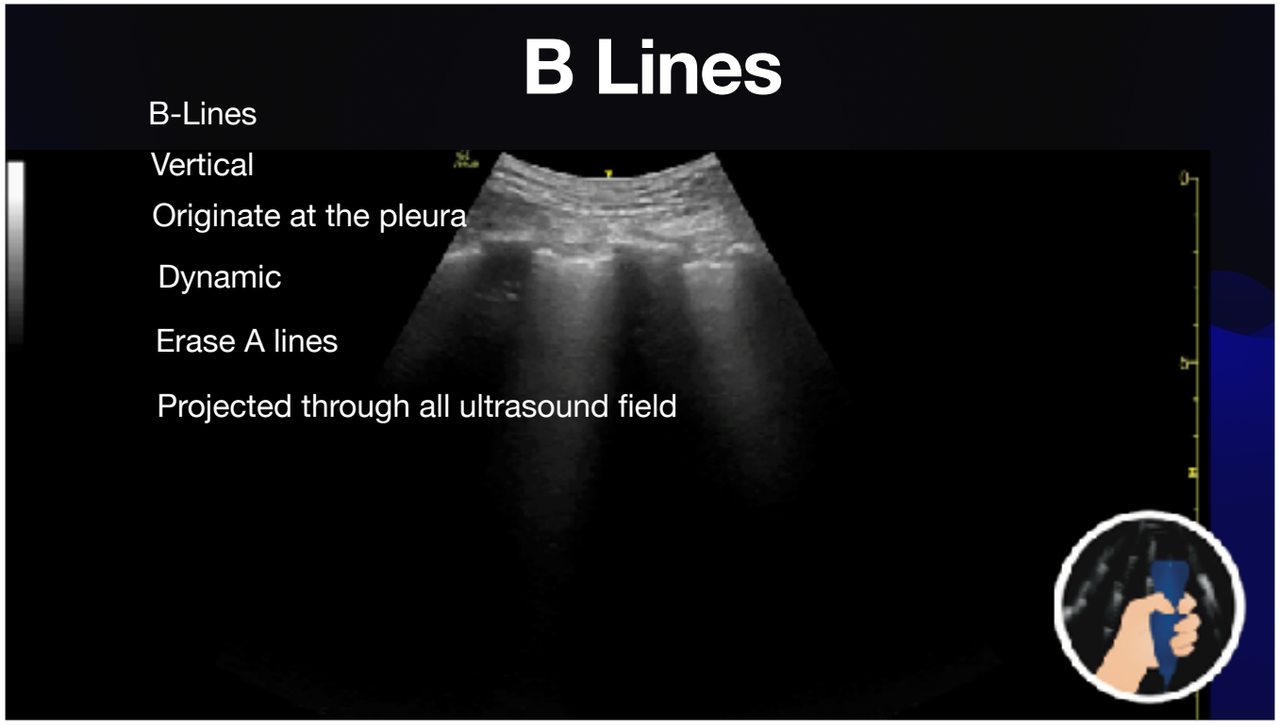
Sub-pleural structures, such as septa and fissures, can create B lines. It is normal to observe two B lines in one scanned area of the lung.
B lines can also be produced because of lung fibrosis.



This is a classic example of B lines secondary to pulmonary edema. In this case, the patient had heart failure. You can see multiple B lines emanating from the pleura, erasing the A lines. There are more than three B lines in this field.

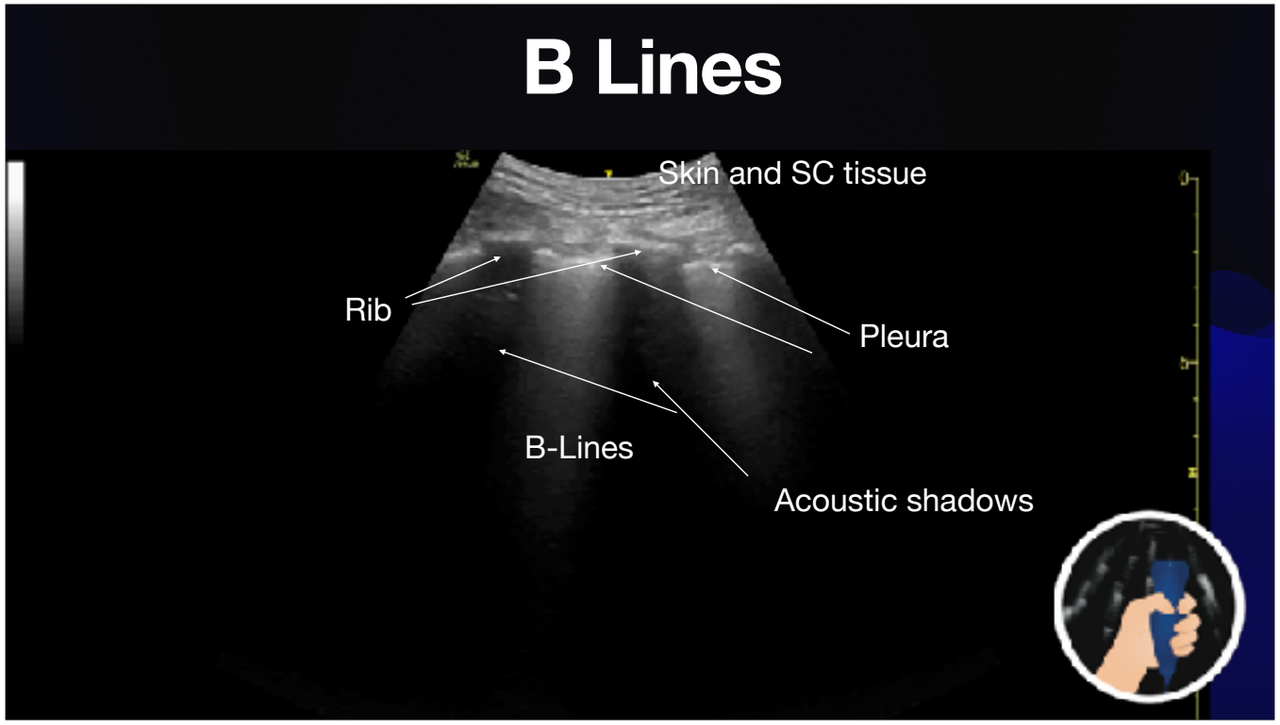


This is the same patient as before; however, we can see more pleural lines with B lines.

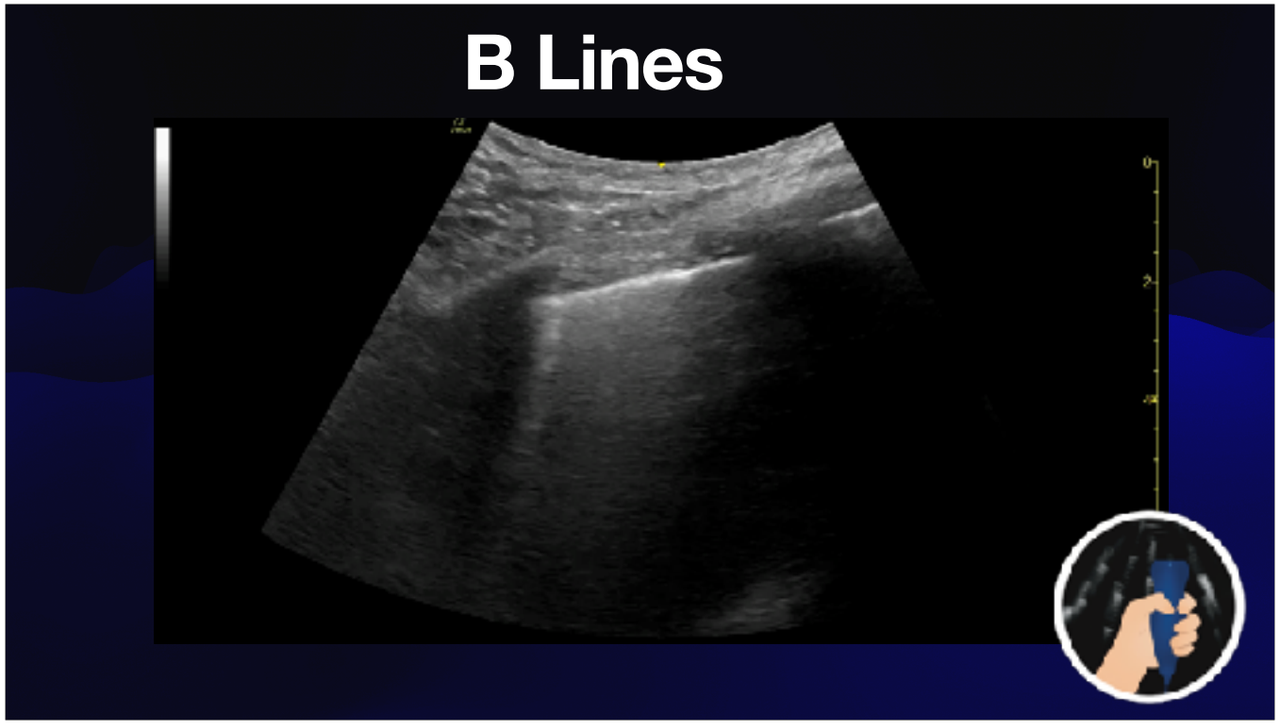


B lines have certain characteristics:

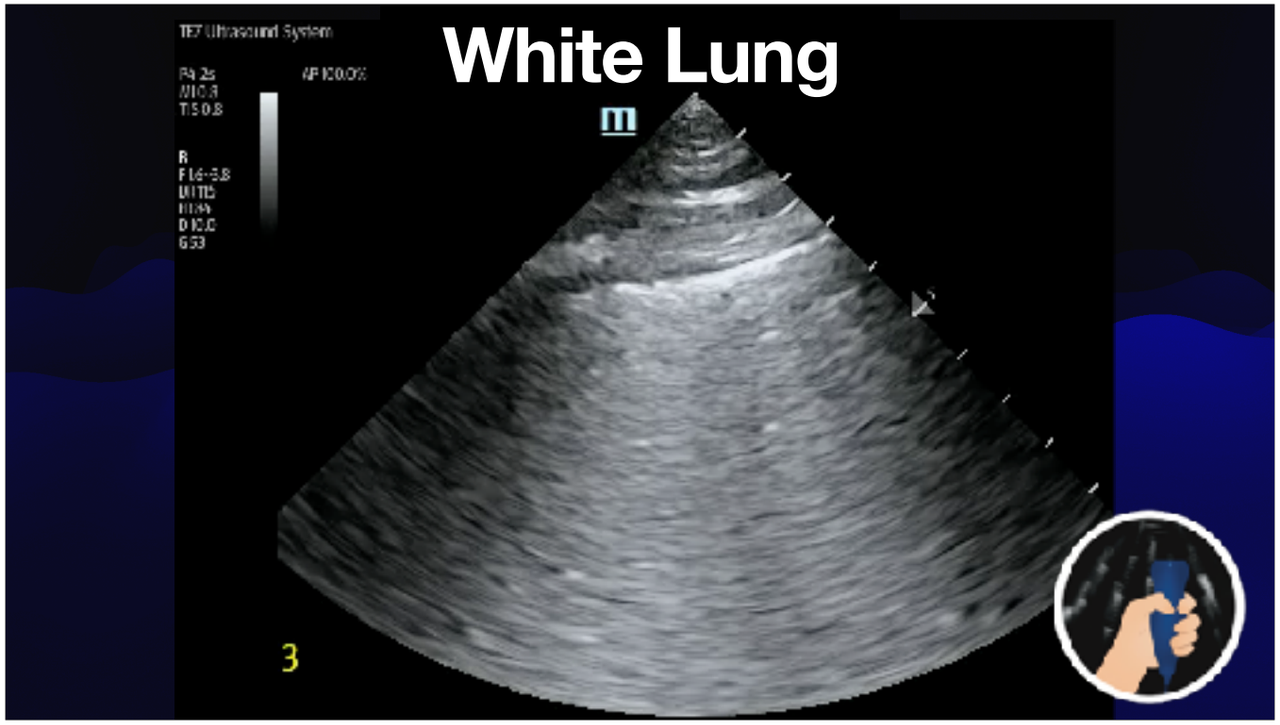
1. They are vertical.
2. They originate at the pleura.
3. They are dynamic.
4. Erase A lines.
5. Are projected through the whole ultrasound field.



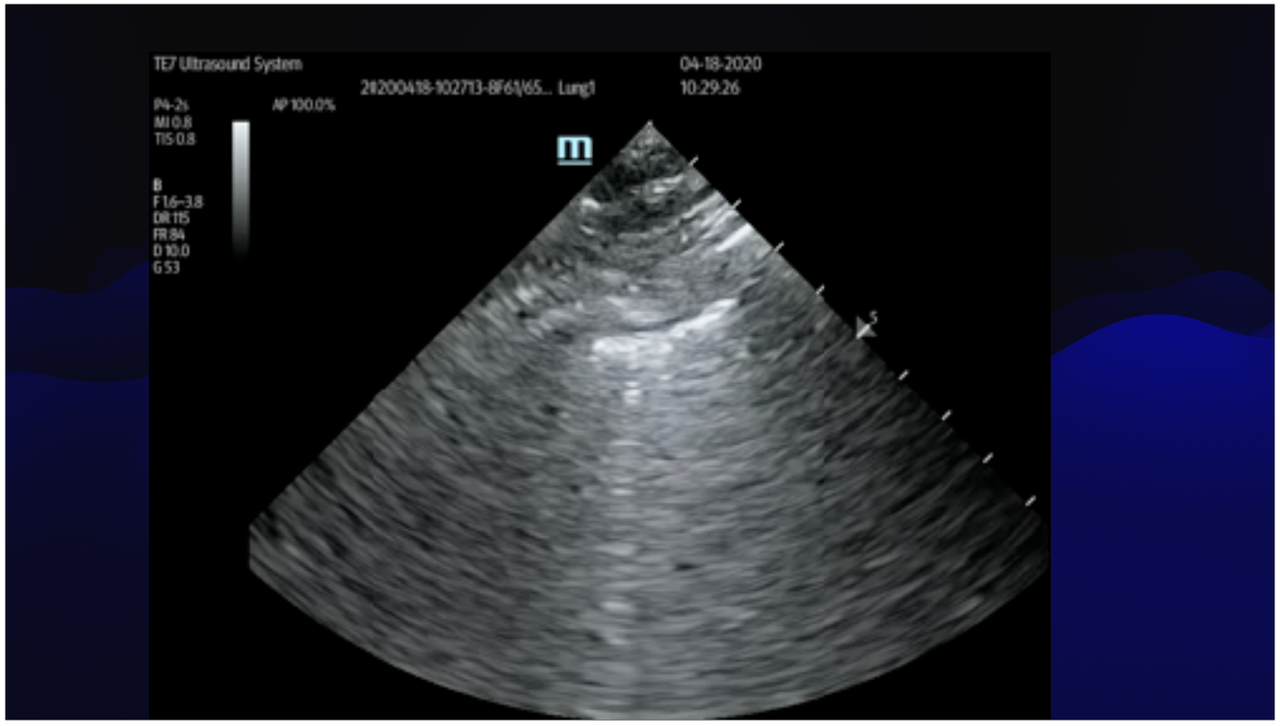
In this video, I have tagged all the important structures for your reference.



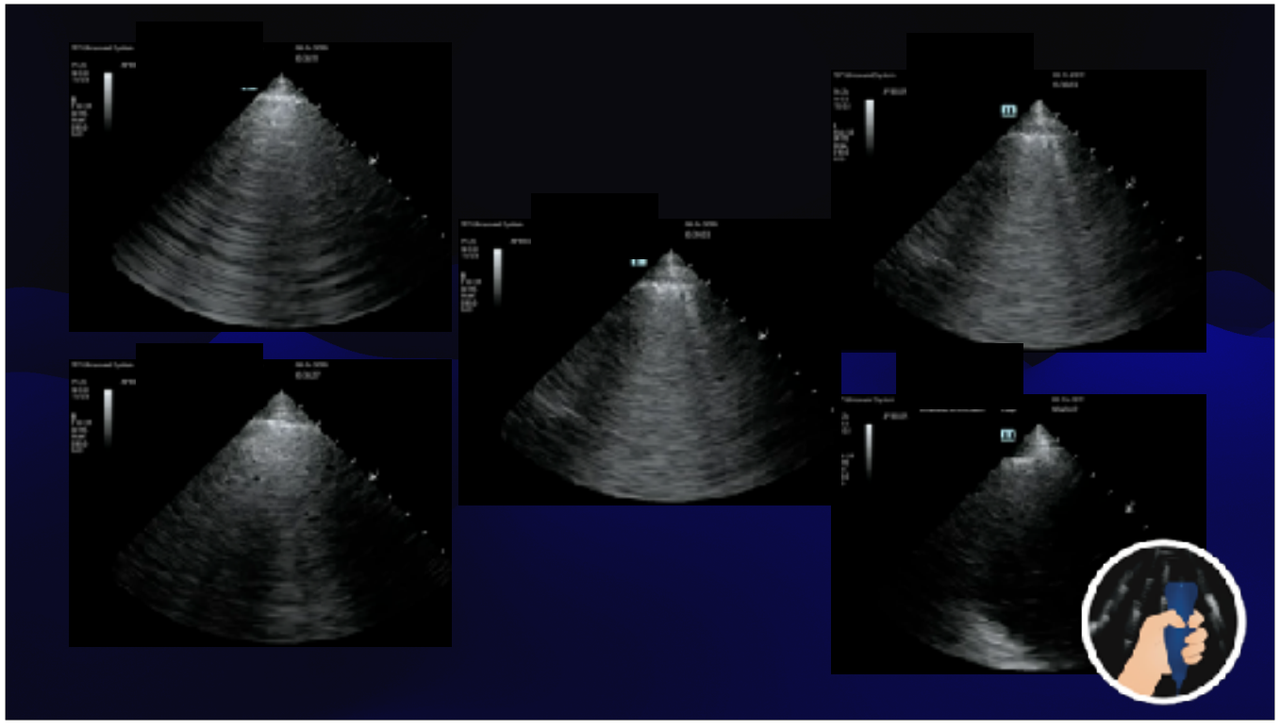
This is another video of B lines.



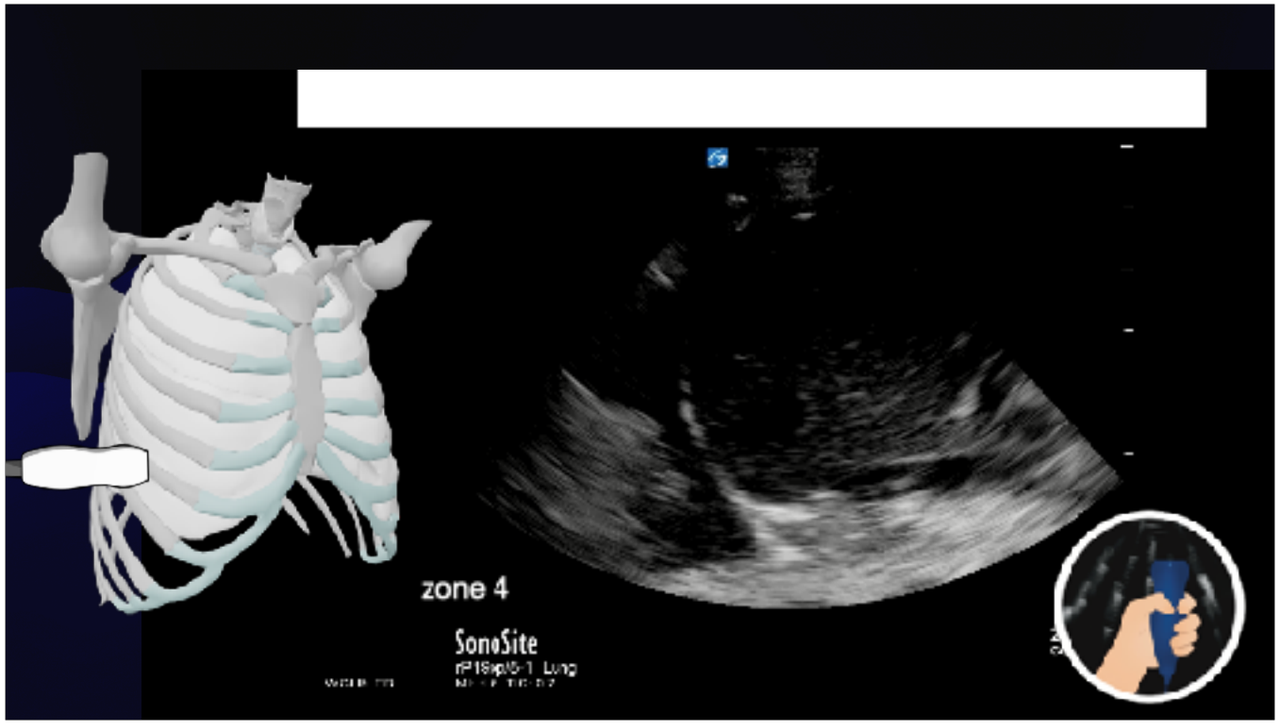
Sometimes, there may be so many B lines that the lung appears white. This phenomenon is often referred to as white lung.
I want you to observe the pleural line. In this case, the pleural line appears “shredded”, which is because a large amount of fluid and air is creating this illusion. This is very common in pneumonia.



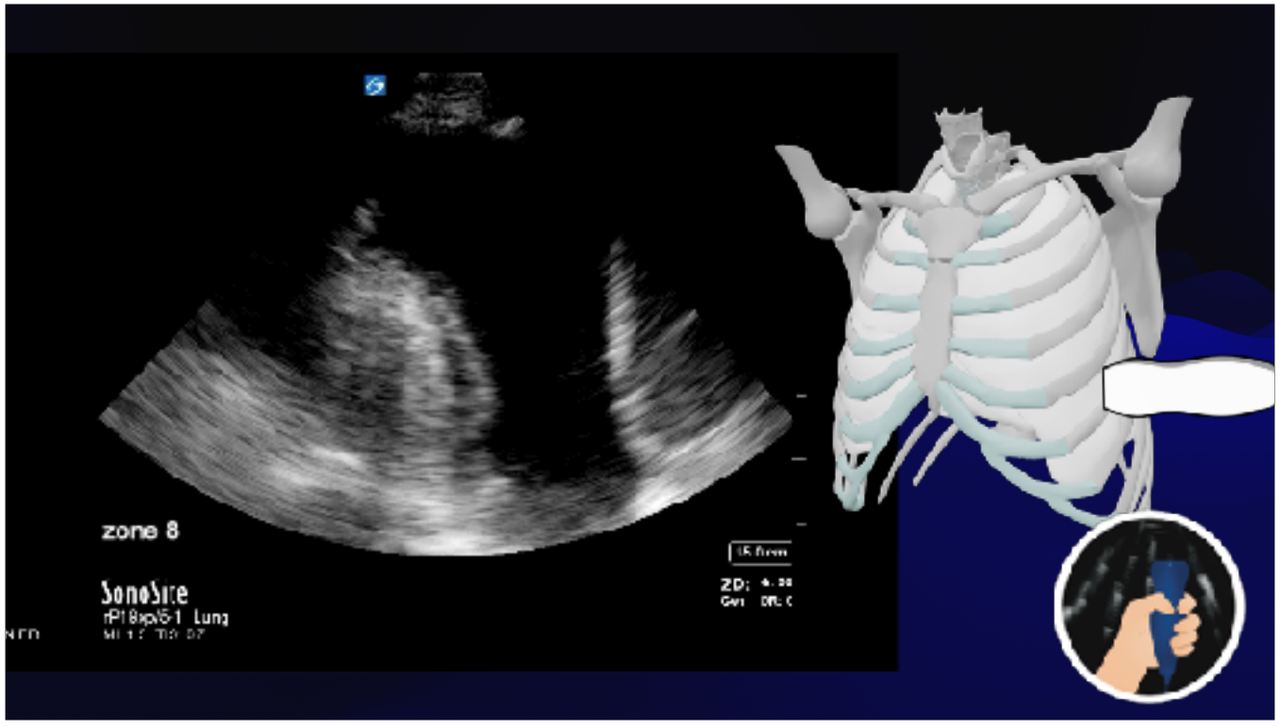
This is another case of shredded pleura with B lines. This is secondary to a bacterial pneumonia. Note the solid B lines associated with the pleural shredding.



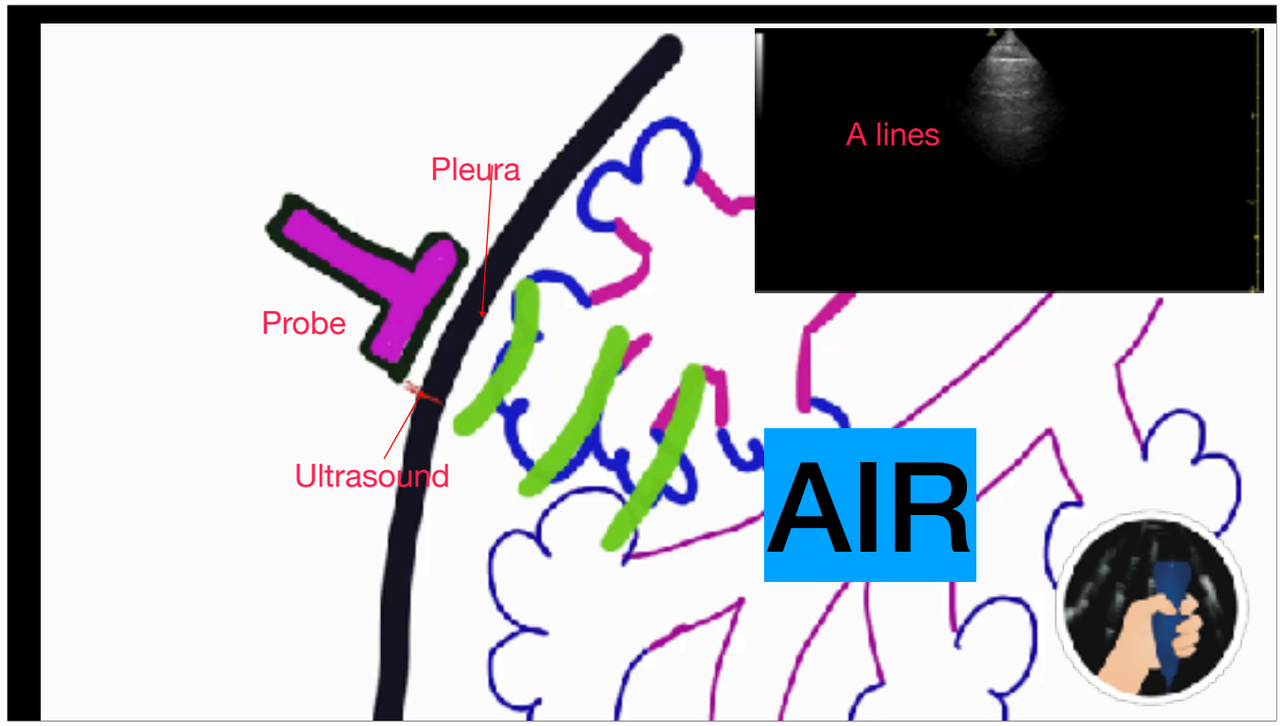
Here, we have multiple videos of the same patient demonstrating B-lines. This is a case of ARDS, and the patient was intubated and ventilated. It is crucial to evaluate the pleural space and rule out the presence of an effusion. In the video at the bottom right, you can see the liver moving in and out of the ultrasound field. You can see that the air or the lung is being projected when the liver is out of the field. This is called the curtain sign and is a very good sign that there is no pleural fluid.



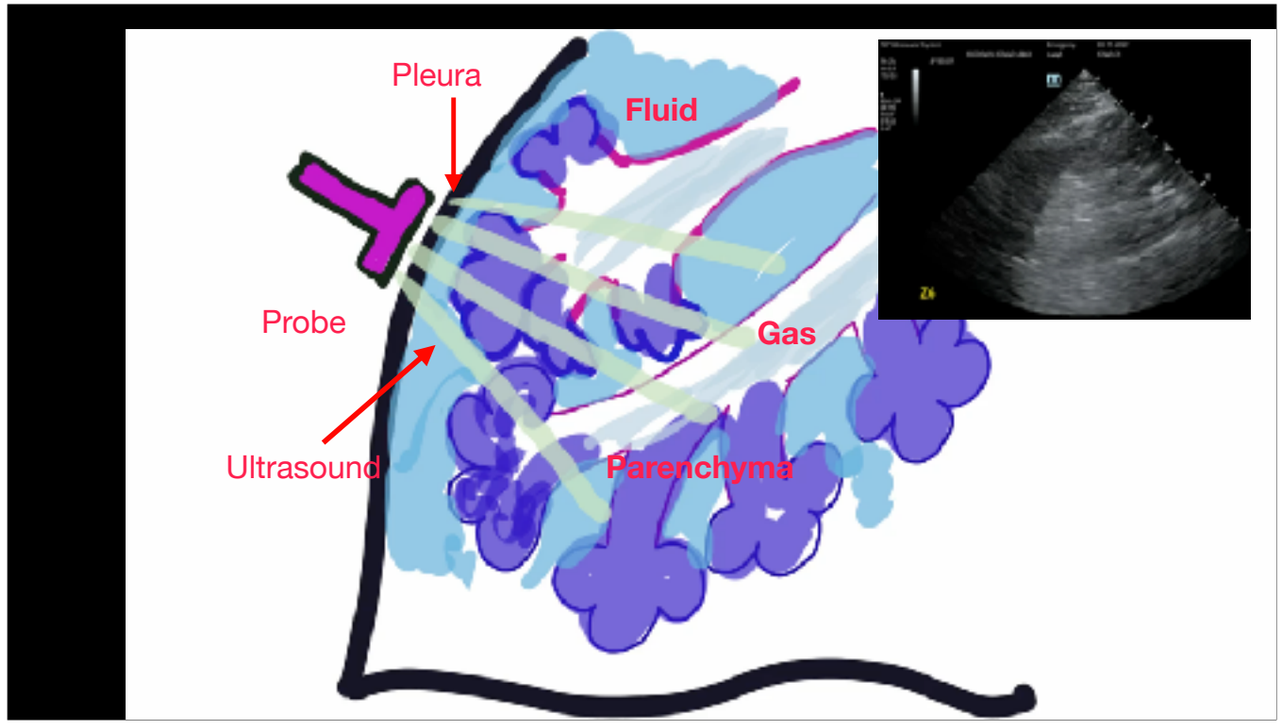
Demonstrating the diaphragm is necessary. This is to evaluate for pleural effusion. This is a case of pleural effusion of the right side of the chest. The pleural effusion is small. You can see the diaphragm and fluid above it.



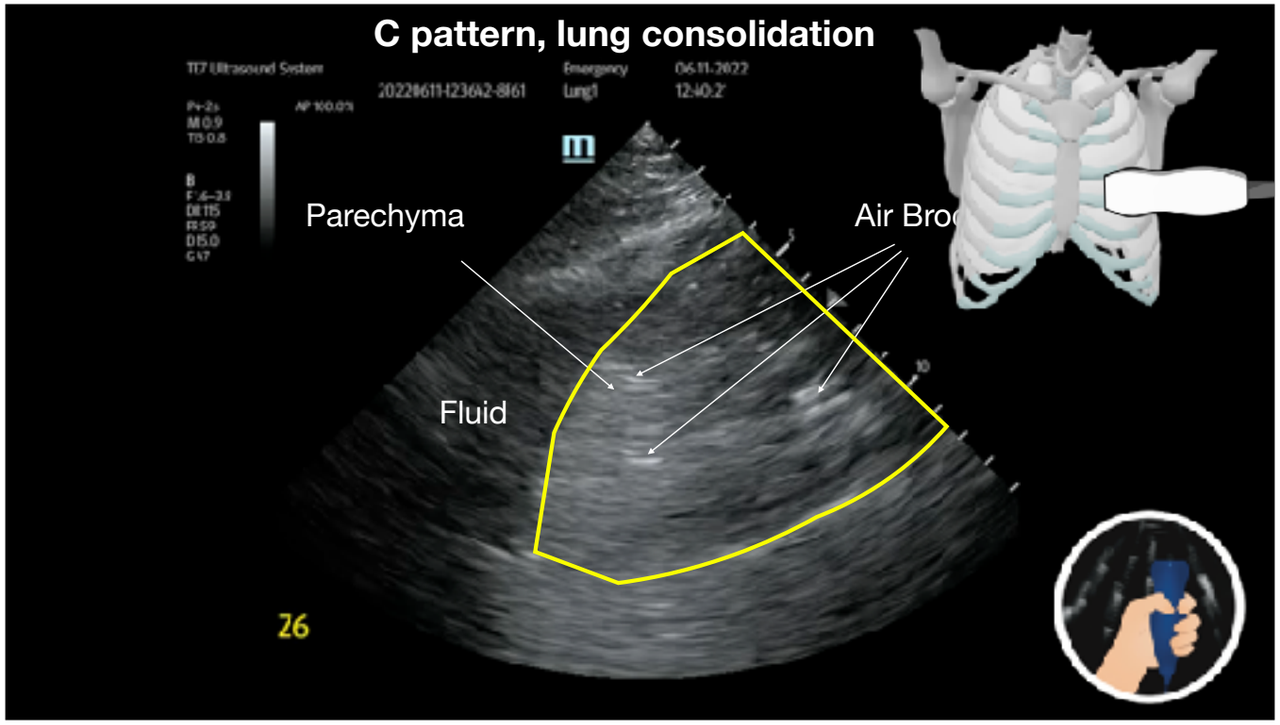
This is a case of left pleural effusion. In this case, the pleural effusion is large enough that you can see the pericardium and the heart with a small pericardial effusion.
This is a larger pleural effusion.



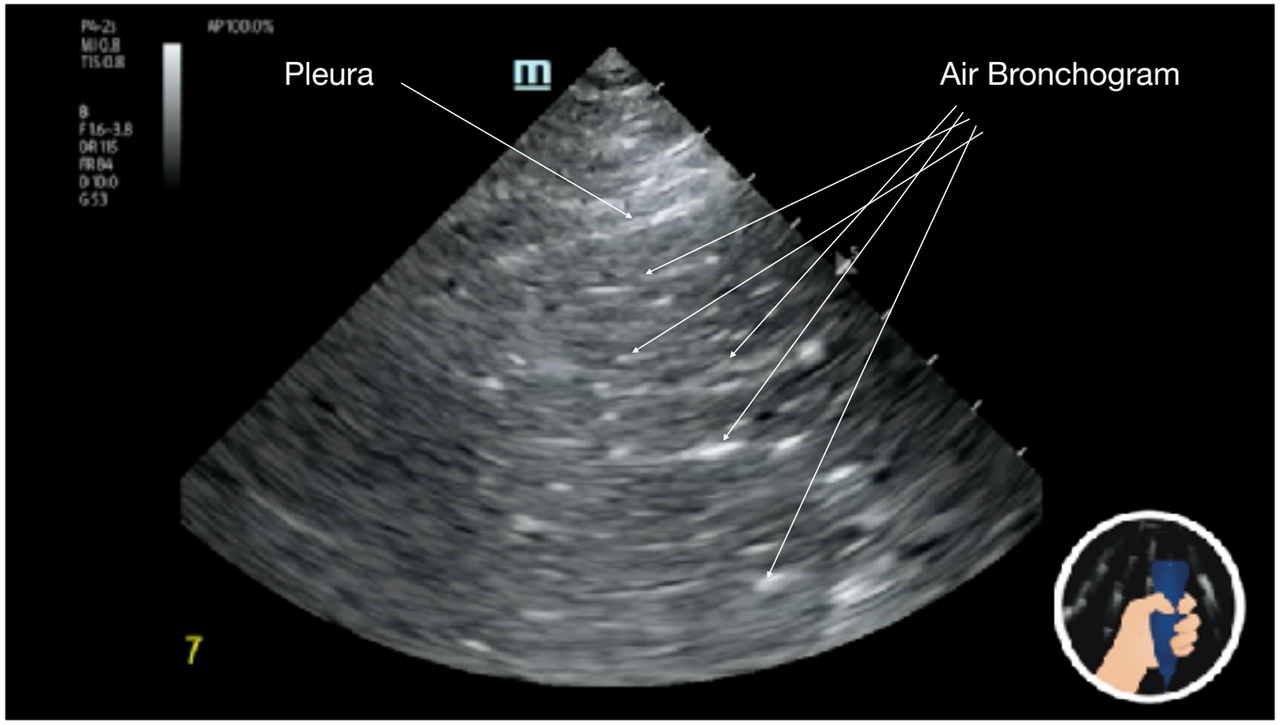
Before we discuss consolidation, I want to provide a quick reminder on how A lines occur. A line is a reverberation from the pleura, which acts as a mirror. You can see that the ultrasound is unable to penetrate beyond the pleural space due to gas.



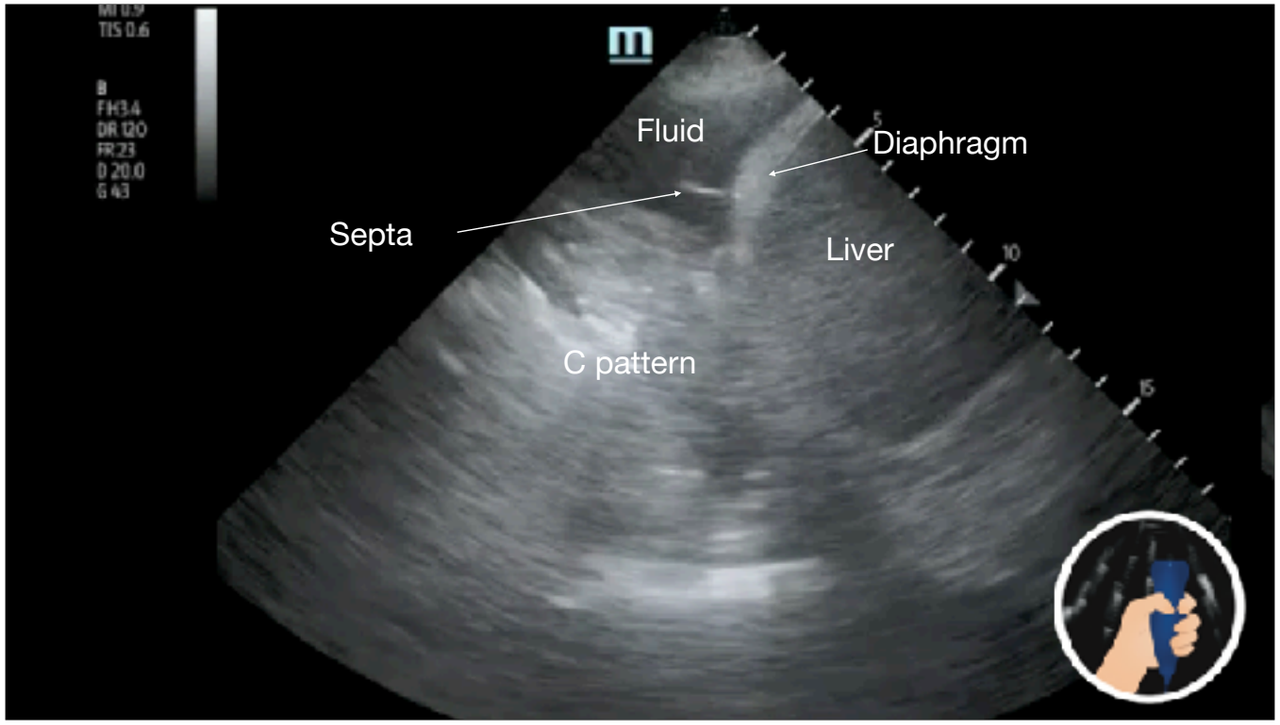
When there is fluid or consolidation, one can see the lungs and/or the fluid, since there is now an ultrasound window.
You can see the ultrasound going through the mix of gas and fluid in the alveoli and small airways. The presence of gas will cause specking, creating the illusion of echotexture. Here is an illustration of a consolidated lung.
Consolidation is also called “C pattern.”



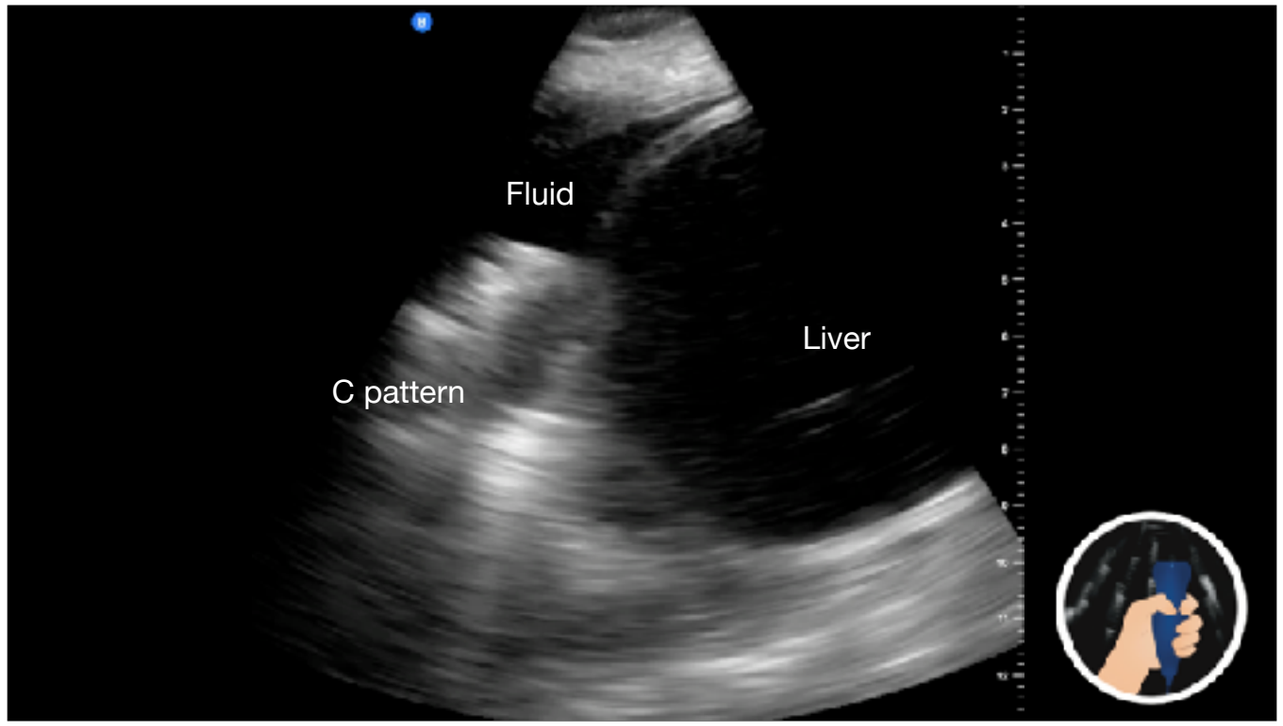
This is the video from the last slide.
Note the speckling in the lung; this is gas in the airway, called an air bronchogram. This lung is consolidated and is located over area 6 on the left side. You can see that the lung is pulsating, as we discussed before, this sign is called the lung pulse. There is also fluid around the consolidated lung. This patient has consolidation with pleural effusion secondary to bacterial pneumonia.



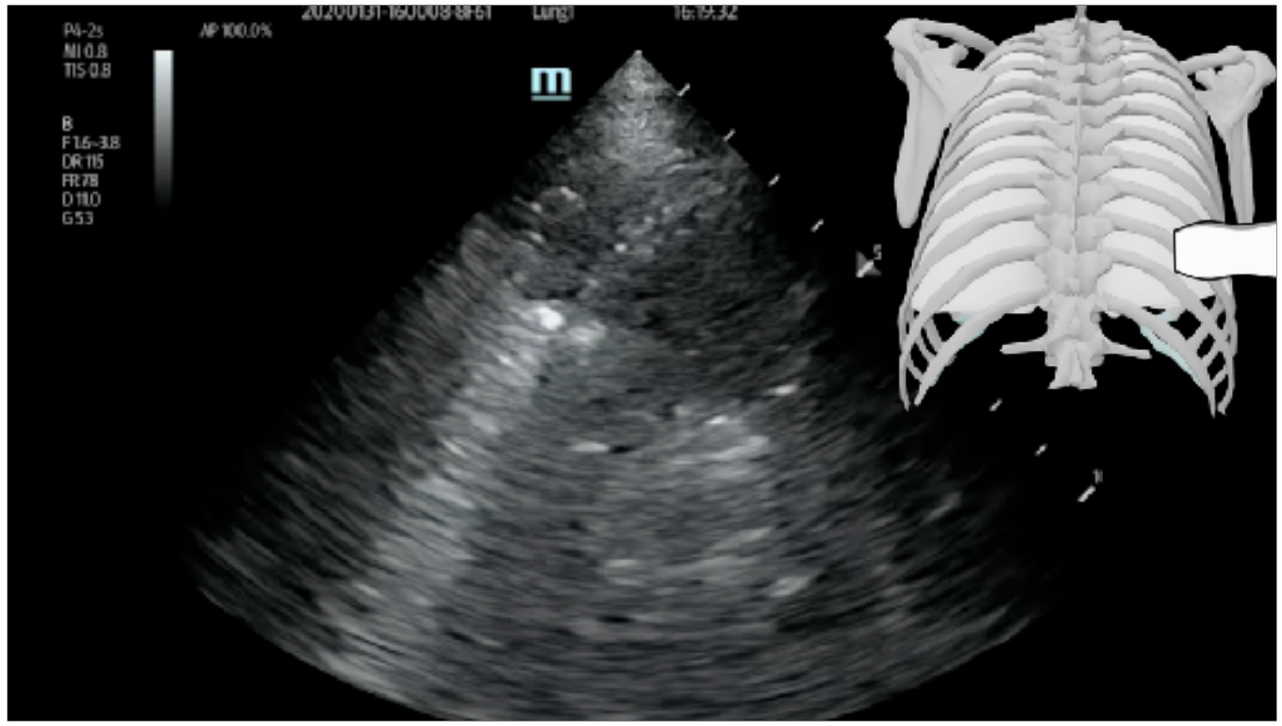
In this video, we see area 7 on the left side. We can see a consolidated lung coming in and out of our field. You can also notice that the patient is likely tachypneic, and you can again see the consolidated lung transmitting the cardiac beat or lung pulse.
With some attention, it is very easy to see that the airway contains fluid and gas. Some authors also refer to this pattern as “hepatization” because of its similarity to the liver.



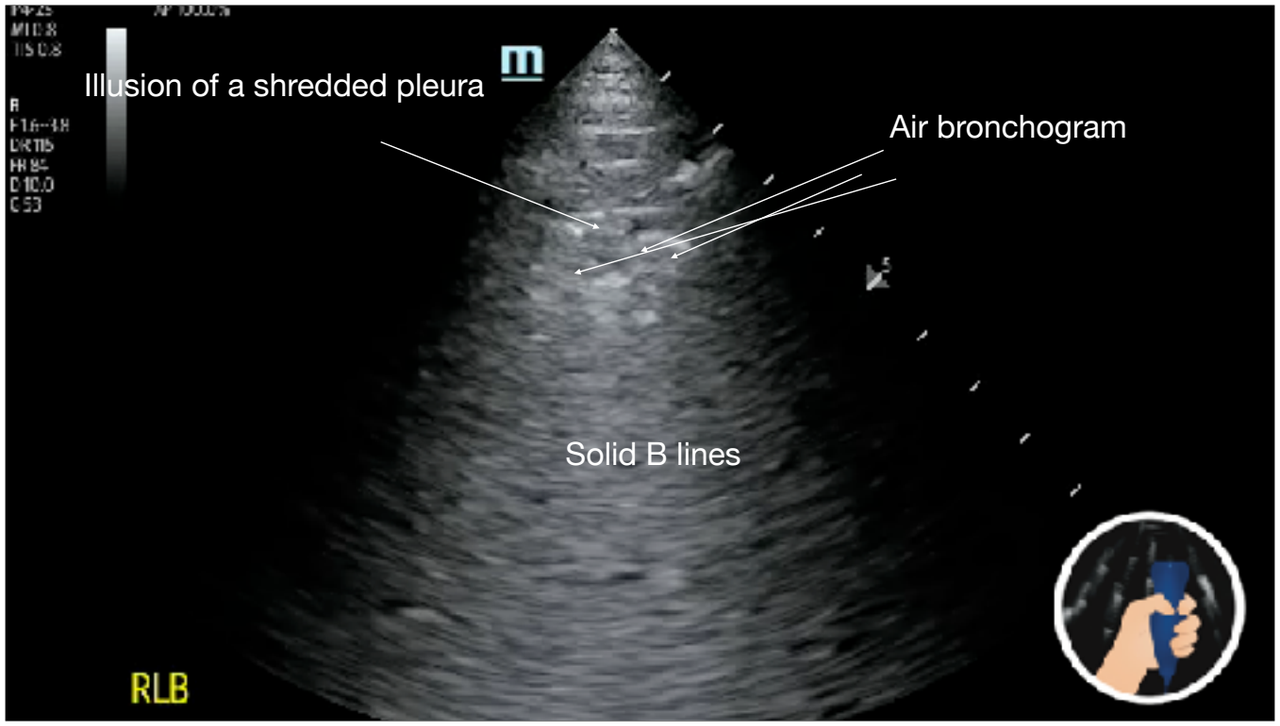
This is a video obtained with abdominal settings of a pleural effusion with a septum, which is characteristic of empyema. We can also see the diaphragm, the liver, and the consolidated lung in the video. The bright echogenic lines in the lung are an air bronchogram.



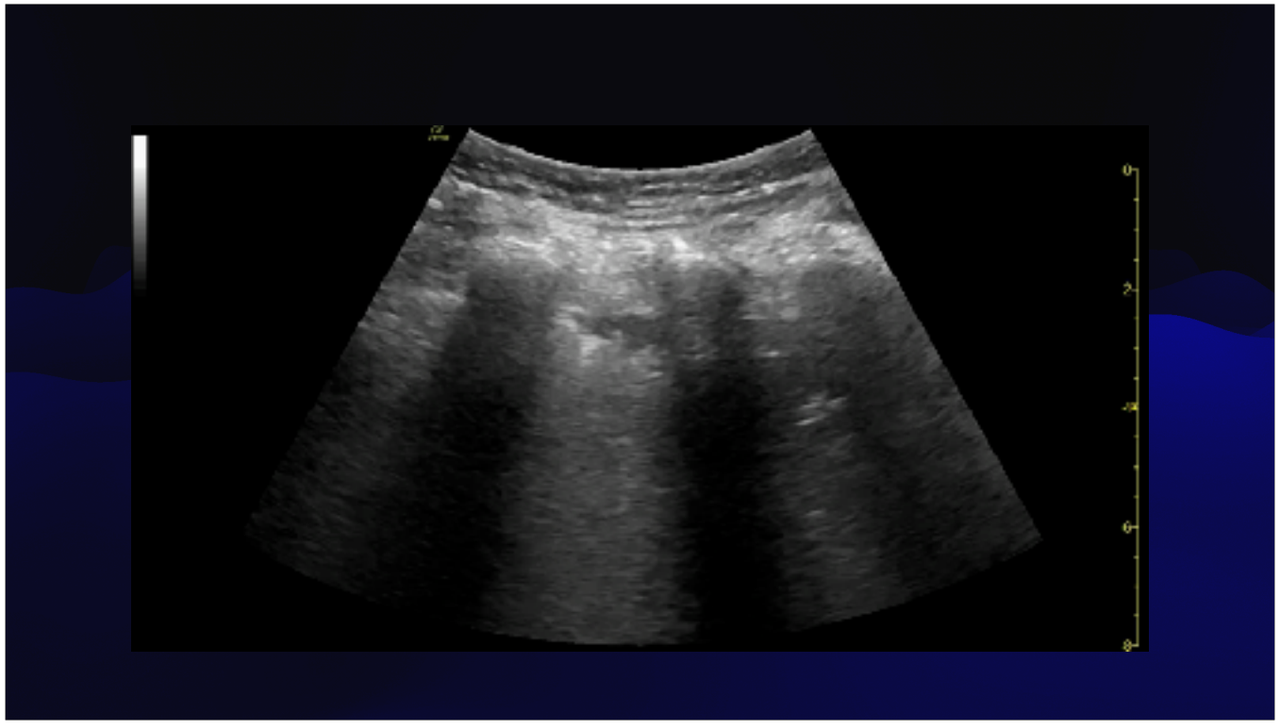
This video was obtained with a butterfly ultrasound. You can see the liver, a small pleural effusion, and the lung consolidated.



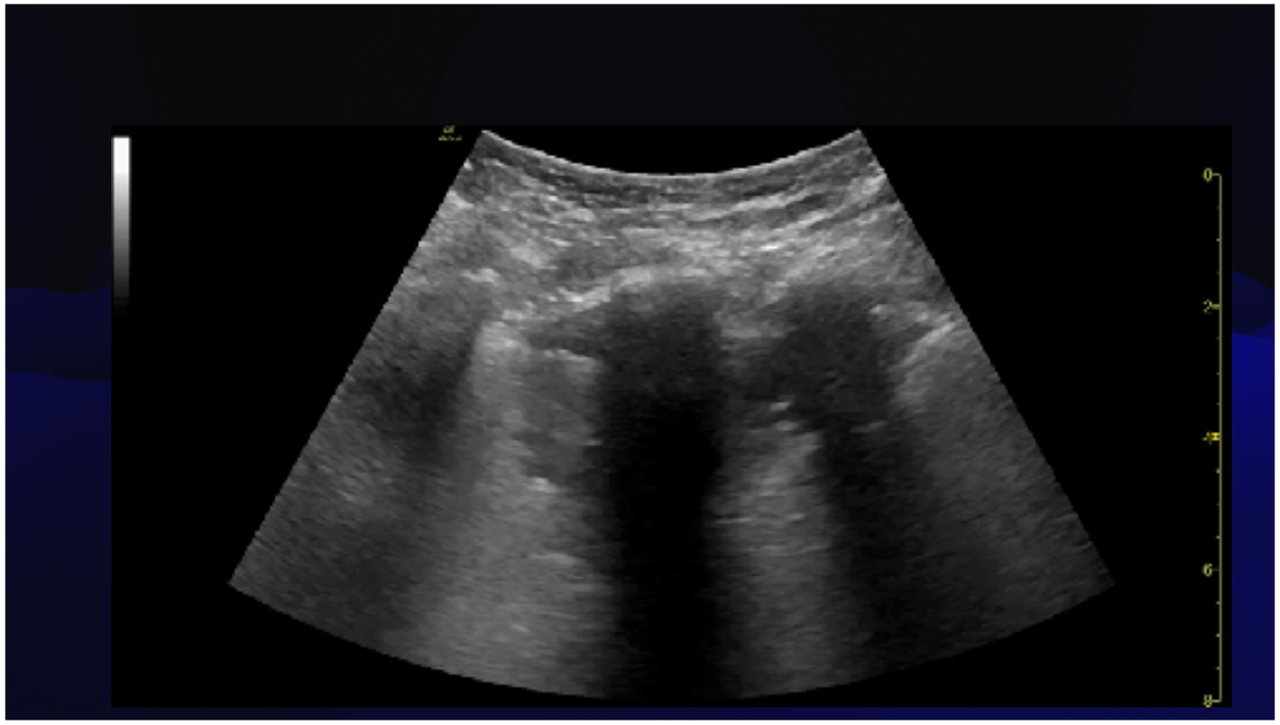
This is an ultrasound image of the base of the lung obtained via the posterior thorax approach. This patient presented to the emergency room with a fever, chills, and a cough. Along with shortness of breath, a physical examination revealed crackles in an area. The ultrasound probe in lung settings was applied directly over the area of findings and demonstrated a consolidated lung with an air bronchogram and minimal pleural effusion. He had some pleurisy. One can see the diaphragm and part of the liver, too. The patient was treated for bacterial pneumonia,



This is an ultrasound from the prior patient, but 2 intercostal spaces up. You can see the air bronchogram, solid B lines, and the illusion of a shredded pleura.

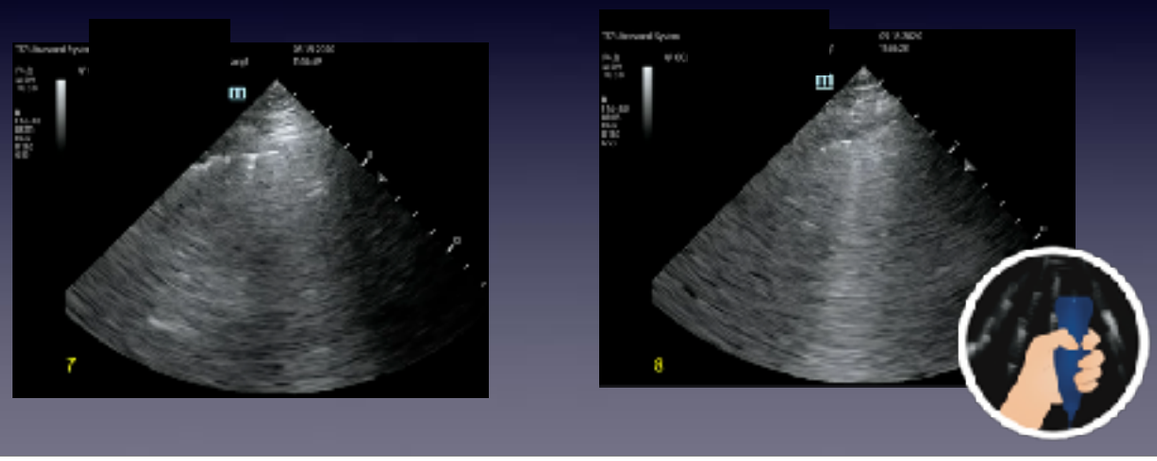


This video is from the left back of a patient who presented with fever, chills, and cough. You can see defects in the pleural space with a minimal air bronchogram. Some of the findings straddle the field. This patient was found to be positive for influenza A. Due to the timing and findings, he was treated for viral pneumonia. Viral pneumonias and atypical pneumonias can present in various areas of the lung in a similar manner.



This is an area of the right upper back of the same patient.

Covid B lines



COVID-19 was a fascinating time with some interesting findings.
The presence of B lines, shredded pleura, and consolidations in different areas of the same patient was the rule. I have not seen these findings since the beginning of the Omicron wave. However, as stated before, atypical and viral pneumonia can present with different types of disease simultaneously in completely different areas of the lung fields.
Normal lung auscultation, normal X-rays, and dramatic findings with the lung ultrasound and CT scans characterized COVID-19.