Chapter 8: Cardiac Ultrasound

KEY IMAGES – PLAX, PSSA, A4C

Parasternal long axis (PLAX)

Correct plane has LA, MV, LV, LV outflow tract, AV, aortic root, septum, RV, RA, descending aorta.

Video 08-01: Parasternal long axis view (PLAX)

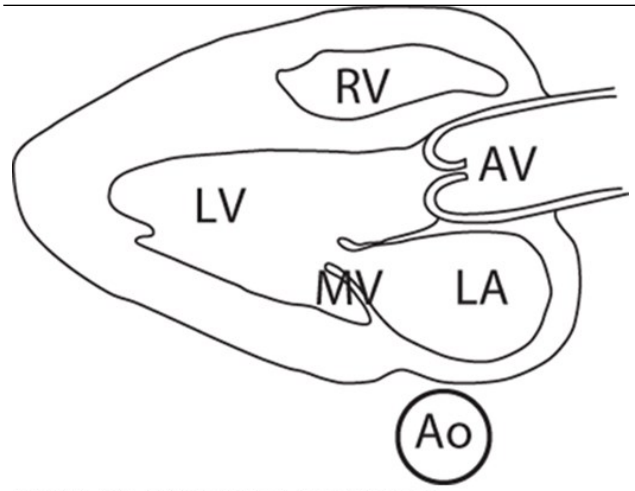
In the parasternal long axis window, it is important to identify all of the relevant anatomy to ensure that the correct plane is being evaluated. That includes the right ventricular outflow tract (near the top of the screen), the intraventricular septum, the left ventricle, the mitral valve, the left atrium, the aortic valve, and the descending aorta (near the bottom of the screen)

Play Video

PLAX-labeled anatomy

Ao = aorta; AV = aortic valve; LA = left atrium; LV = left ventricle; MV = mitral valve; RA = right atrium; RV = right ventricle; TV = tricuspid valve.

Figure 8-1



Hand position

Indicator dot toward right shoulder, 3rd to 5th intercostal space, as close to sternum as possible.

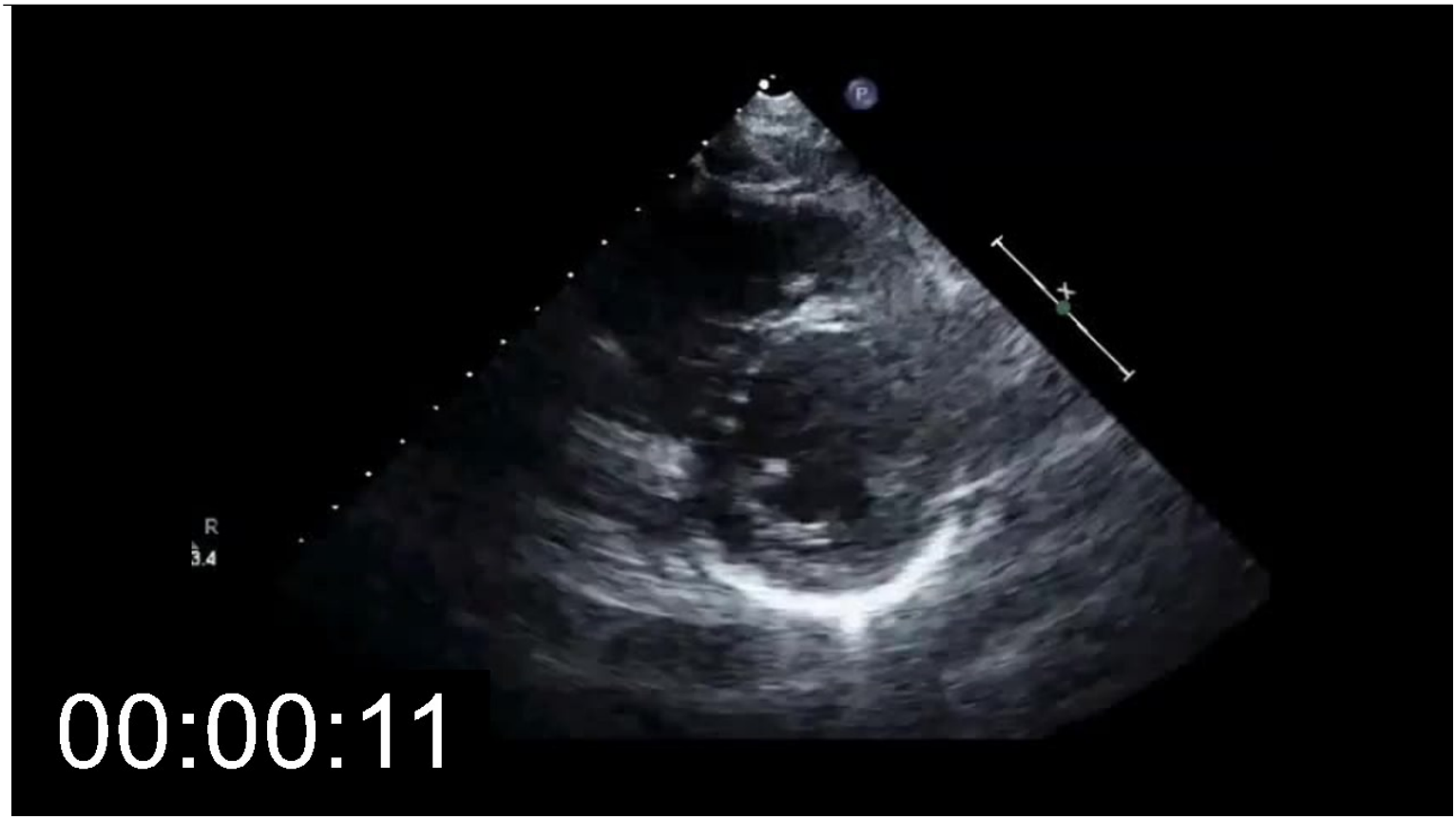
Figure 8-2

Parasternal short axis (PSSA)

Fan from apex to base to find LV, RV, pap, cordae, MV, AV, aortic root; RV, TV, RA, pulmonic valve.

Video 08-02: Parasternal short axis view (PSSA)

This parasternal short axis video is taken at the level of the papillary muscles. The crescentic right ventricle can be seen on the left side of the screen. The concentric circle of the LV can be seen in the center of the scree, with the hyperechoic papillary muscles at 5 and 7 o'clock inside the LV. This is a normal heart with a normal ejection fraction. If the transducer is fanned toward the right shoulder (so the tail of the probe is angled toward the left hip), then the mitral valve could be evaluated, followed by the aortic valve. Fanning toward the left hip (tail toward the right shoulder) would allow visualization of the apex.



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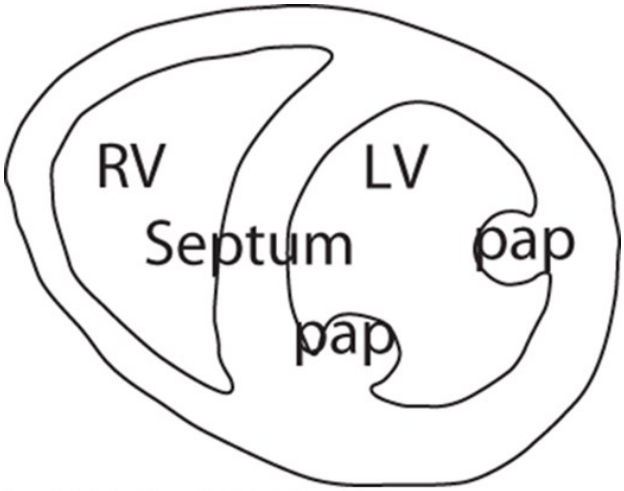
PSSA-labeled anatomy at level of papillary muscle (pap)

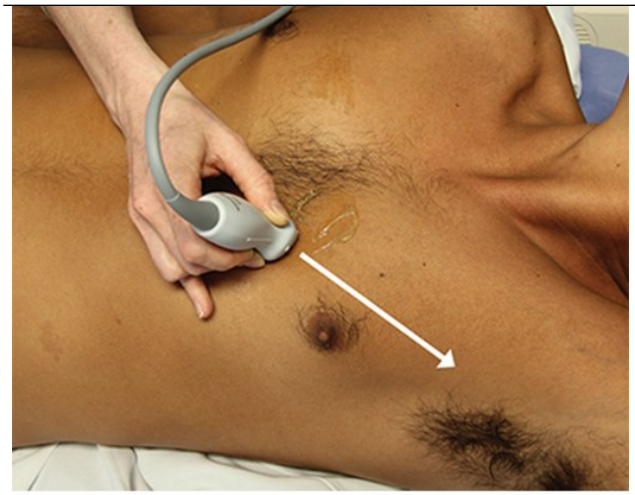
Figure 8-3



Hand position

Indicator toward left shoulder. This plane is 90 degrees clockwise in exact location of optimal PLAX view.

Figure 8-4



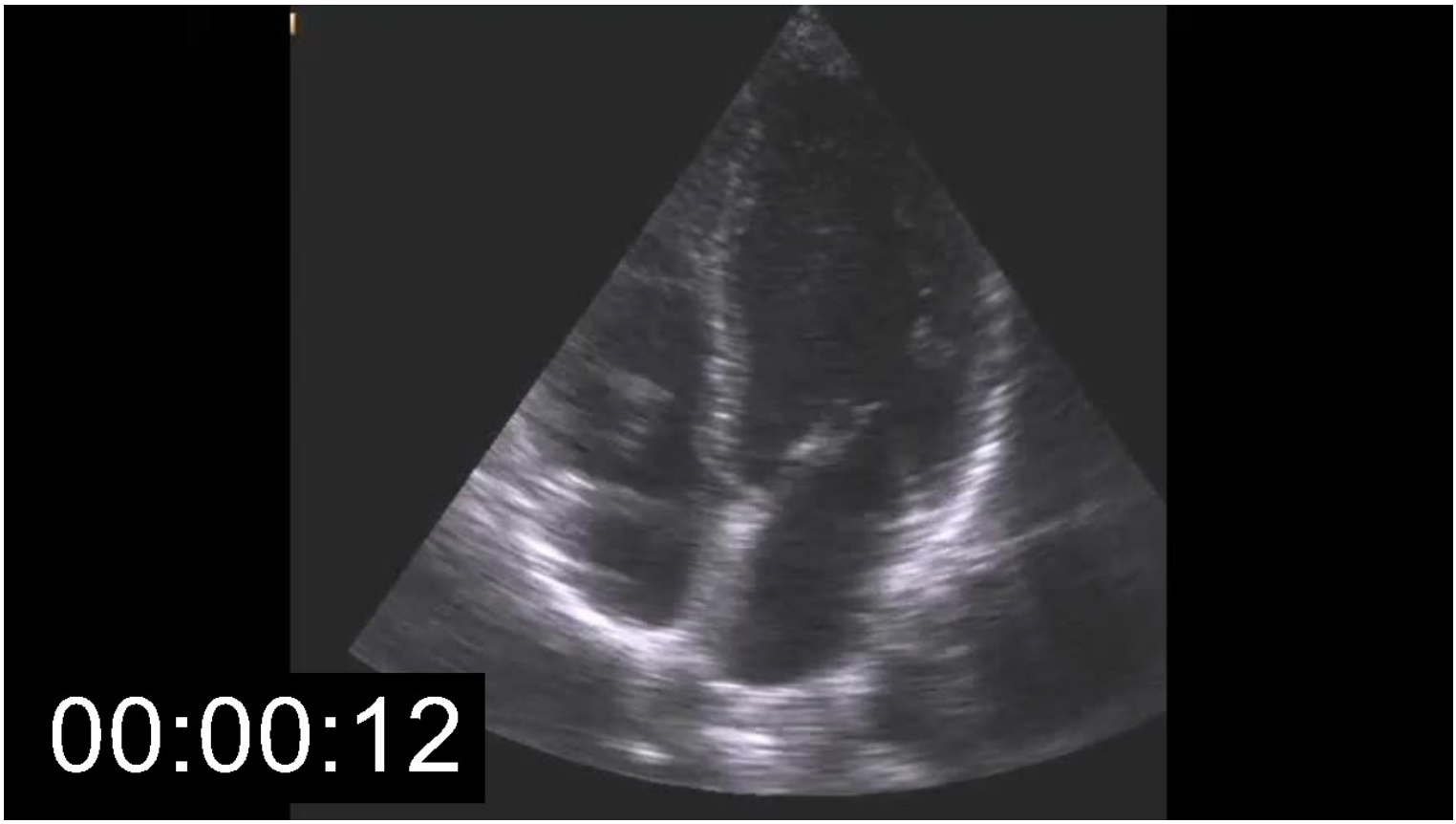
Source: C. M. Baston, C. Moore, E. A. Krebs, A. J. Dean, N. Panebianco:
Pocket Guide to POCUS: Point-of-Care Tips for Point-of-Care Ultrasound, 1st edition.

Apical four-chamber (A4C)

Identify LV, RV, MV, TV, LA, RA

Video 08-03: Apical four chamber view (A4C)

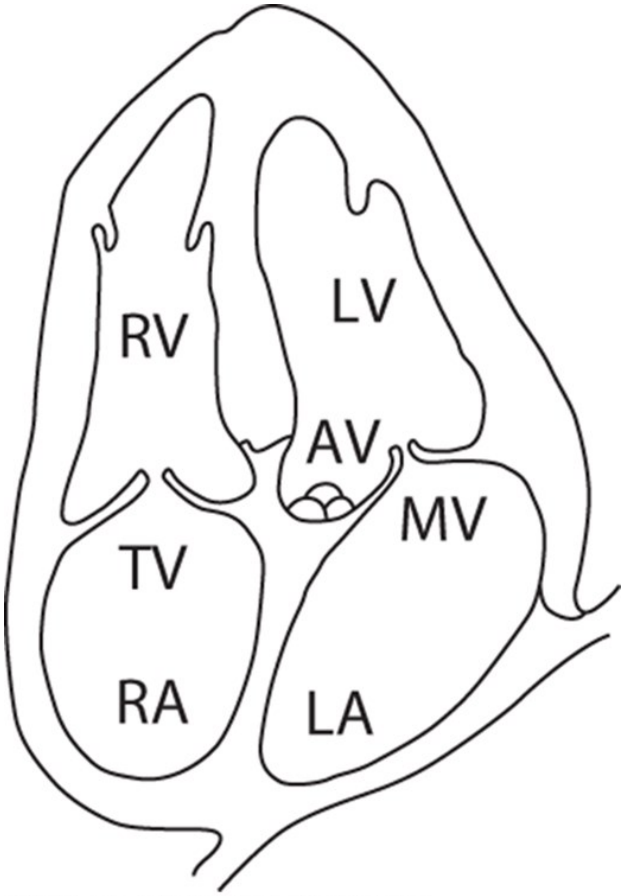
This normal ultrasound demonstrates all four chambers of the heart. On the left of the screen, the RV can be seen longitudinally. The moderator band is the hyperechoic lateral structure inside the RV cavity. The tricuspid valve opens and closes at the bottom of the RV. Deep to that is the right atrium. To the right of the right atrium is the left atrium, and through the mitral valve is the LV. During several cardiac cycles the aortic valve can be seen next to the anterior leaflet of the mitral valve. Also, outside of the bright pericardium can be seen some mirror artifact.



Play Video

A4C-labeled anatomy

Figure 8-5



Hand position

Indicator toward left axilla. Slide from PSSA toward the point of maximum impulse (PMI) until septum is vertical, then fan until all anatomy is visible.

Figure 8-6

ACQUISITION TIPS

- Use plenty of gel. Start with position described for each view, and then slowly slide in small concentric circles until the heart is seen. Gradually adjust angle of probe until relevant anatomy comes into view.
- For views other than inferior vena cava (IVC), firm pressure usually improves images.
- Positioning in left lateral decubitus position usually improves all views except subxiphoid.
- Adjust gain to see endocardium. This is an exception to the idea of titrating gain to make fluid appear black; echo prioritizes visualization of endocardium and valves.
- Cardiologists have the screen indicator dot located on the upper-right side of the screen by convention. Emergency medicine has it on the left side. The important thing is that the images you acquire have the same appearance as above.
- Many patients may not have all cardiac windows; however, most key findings of the focused cardiac exam can be obtained even with limited views.
- Patients with poor subxiphoid views often have good parasternal views and vice versa.

PLAX

- Adjust depth so that the descending aorta is visible.
- The correct scanning plane has the MV and AV visibly opening and closing.
- If the MV leaflets are not visibly opening, the scanning plane may be too far left or right. This can be fixed by fanning toward left shoulder or right hip.
- The LV apex is usually not visible on the PLAX view, but if only great vessels are seen, either move or rock probe toward apex (away from the sternum) to see more of LV cavity.
- If LV cavity does not appear to open or close all the way, adjust by fanning and rotating.
- Axis varies greatly: more transverse for patients with abdominal pannus or enlarged hearts; more cephalocaudal for patients with hyperaerated lungs (e.g., positive-pressure ventilation [PPV] chronic obstructive pulmonary disease [COPD]) or underfilled hearts.

PSSA

- The PSSA plane is exactly 90 degrees from the optimal PLAX plane. Rotate the probe 90 degrees clockwise without changing the PLAX footprint.
- If in doubt, subtly rotate and fan the probe to make the papillary muscles appear symmetrical and the LV appears like a donut (unless there is an LV aneurysm).
- If RV not visible, rock to right and/or fan toward base to bring it into view.
- To assess all levels of the PSSA, fan from apex to base to evaluate anatomy, relative size, and function of all structures. You may need to use several rib spaces.

A4C

- Probe can simply be placed on PMI (usually just below nipple on males), or slide from PSSA to PMI while maintaining orientation.
- For individuals with large breasts, lift up the breast and place the probe at the PMI.
- Ensure indicator is appropriately pointed to patient's left axilla.
- This view is susceptible to foreshortening of ventricles—often indicated by small or absent atria. This is usually fixed by sliding closer to apex and fanning more cephalad. The probe should be pointing at the right shoulder (not the spine or left scapula).
- If AV is visible, this is the apical 5-chamber view—useful to confirm L/R orientation. Fan inferiorly to return to apical 4-chamber view.
- If MV or TV are not opening, rotate until the entire valve motion is visible.

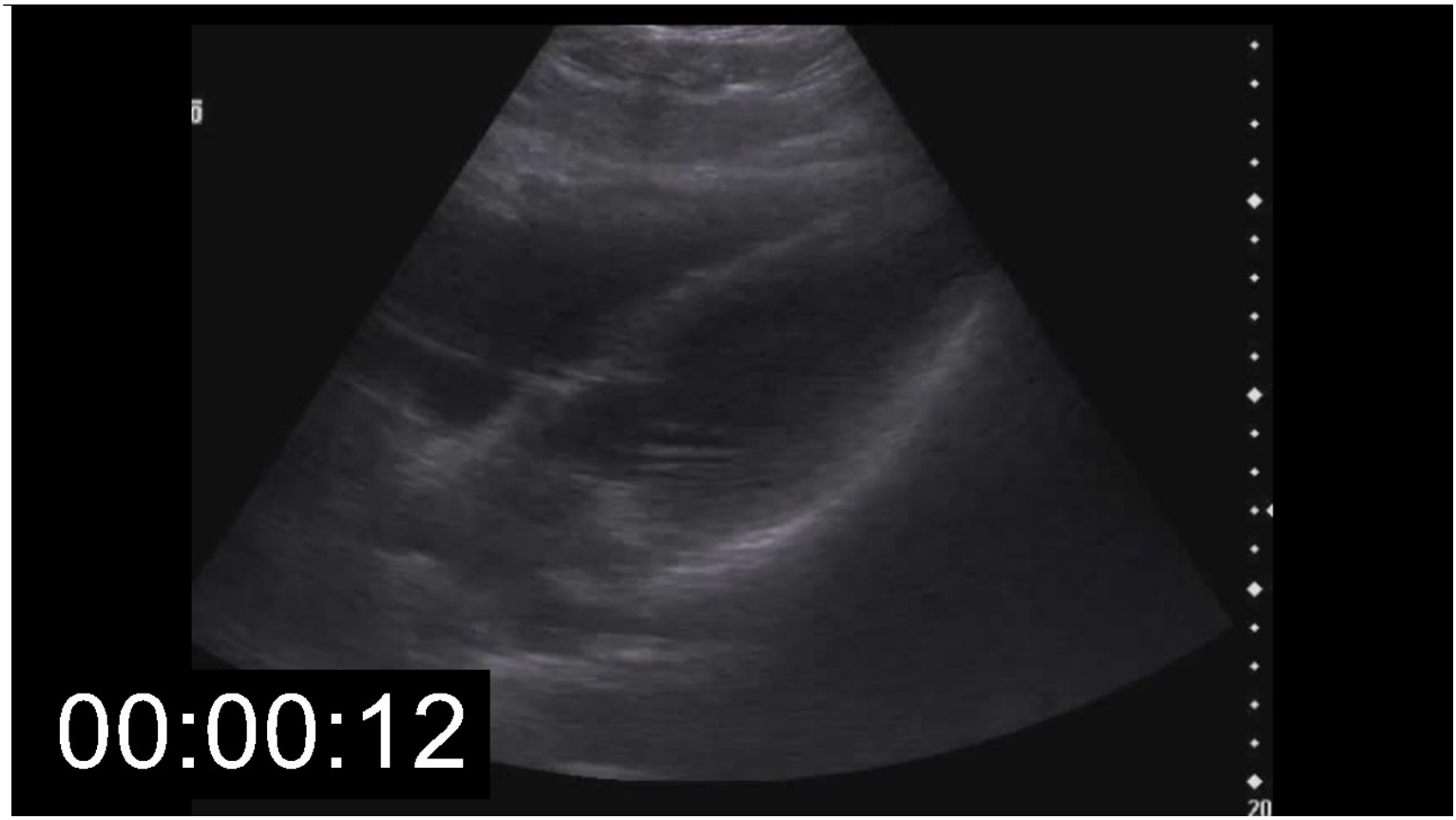
KEY IMAGES – SUBXIPHOID AND IVC

Subxiphoid four chamber (Subx4C)

Identify liver, LV, RV, LA, RA, MV, TV

Video 08-04: Subxiphoid view

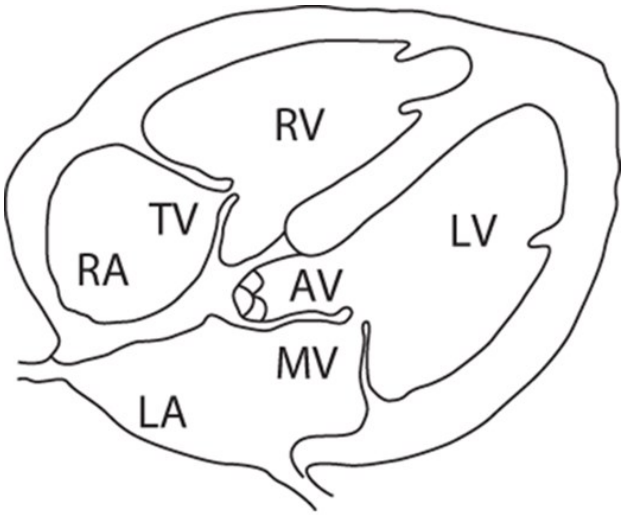
Starting with a view of the liver and IVC, this video fans superiorly until the 4 chamber view of the heart can be seen. The liver is still visible at the top of the screen with the bright hyperechoic pericardium defining the border between the liver and the right ventricle. The left ventricle is deep to the right ventricle, and the left and right atria can be seen to the left side of the screen. At several points the aortic valve can be seen allowing blood to exit the left ventricle. This video shows a normally functioning heart with no pericardial effusion.



Play Video

Subx4C-labeled anatomy

Figure 8-7



Hand position

With patient supine, flatten on epigastrium (may need overhand grip). Indicator to patient left.

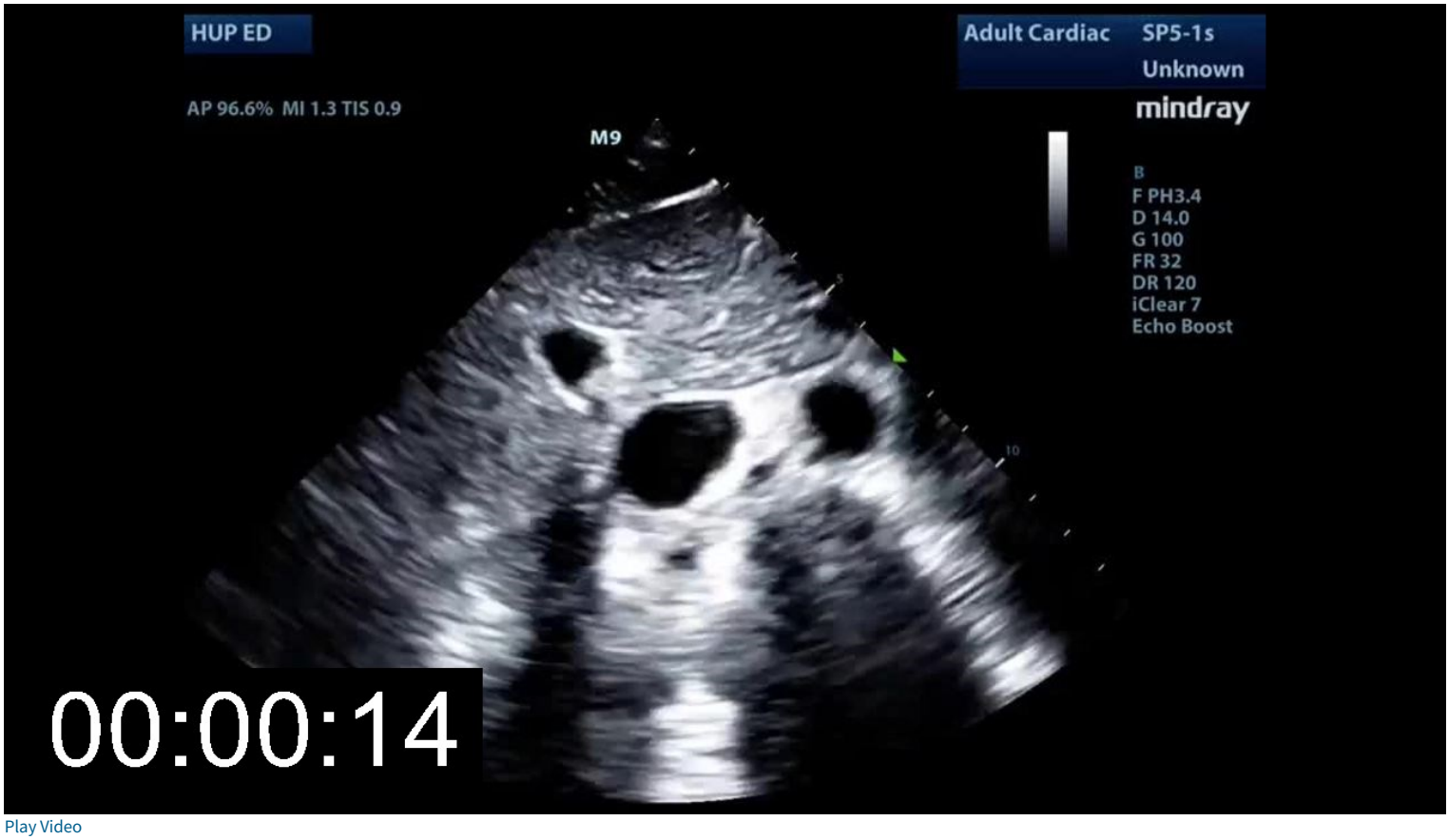
Figure 8-8

IVC in transverse view

Identify IVC, aorta, hepatic veins (rabbit ears), and spine.

Video 08-05: Transverse view of the Inferior Vena Cava (IVC)

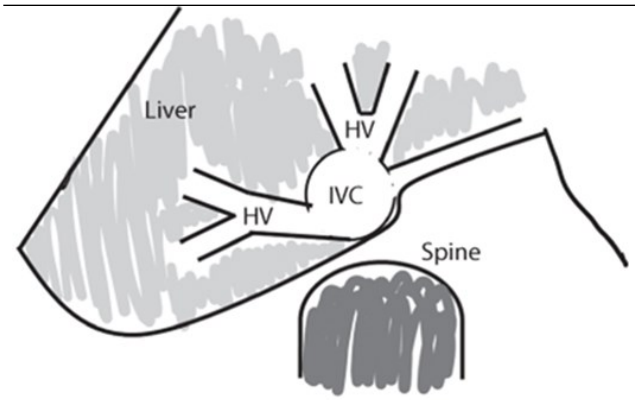
This video demonstrates the IVC and aorta in the transverse view. The aorta can be seen on the right side of the screen, directly in front of the spine with acoustic shadow. The IVC is to the left of the aorta, inside the heterogenous liver. A single hepatic vein can also be seen moving toward the large IVC. It can be seen that both the IVC and the aorta are pulsatile, so that is not a useful way to differentiate them.



Play Video

IVC transverse-labeled anatomy

Figure 8-9



Hand position

Fan down from RA through confluence of hepatic veins.

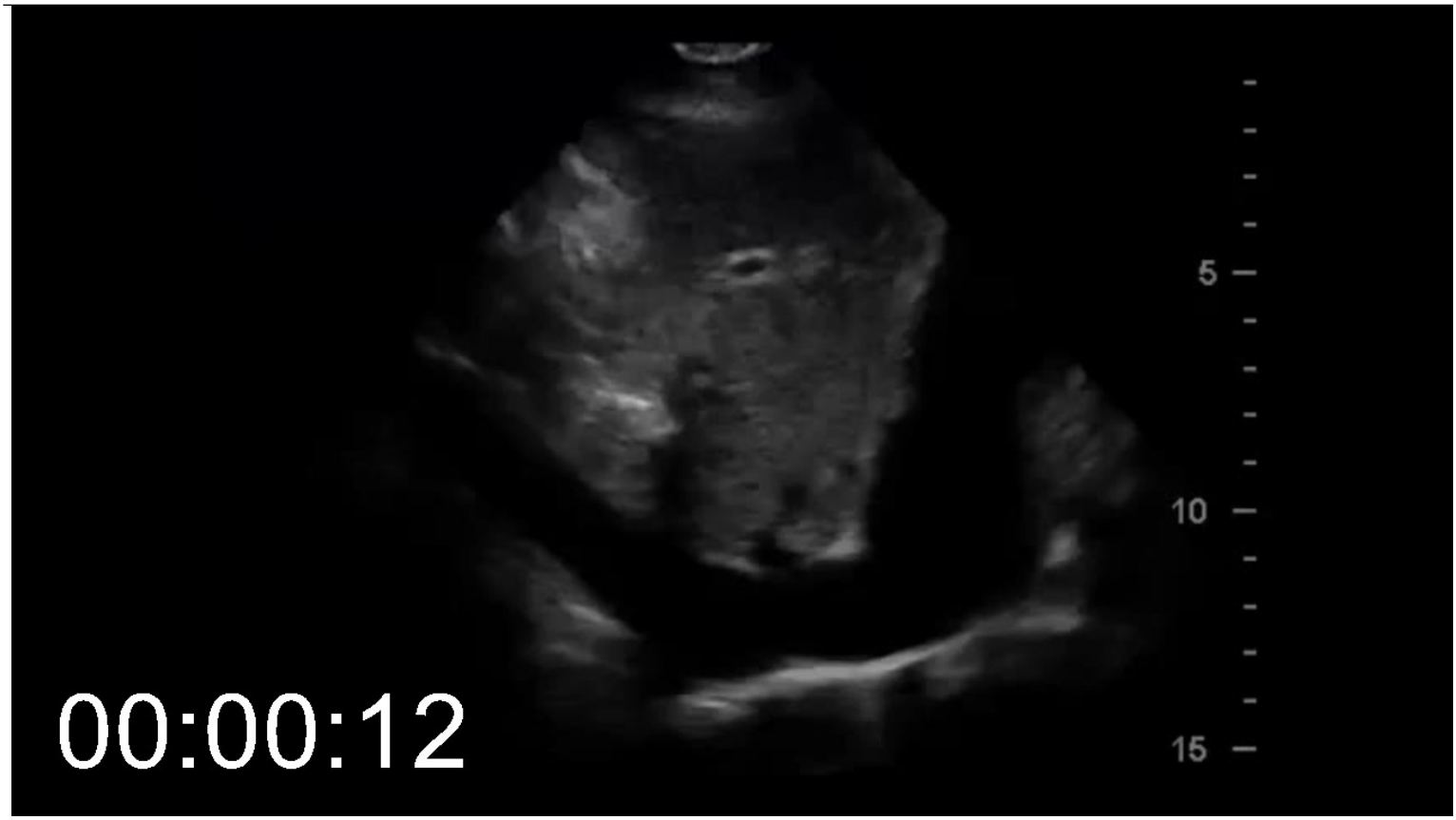
Figure 8-10

IVC in longitudinal view

Identify IVC, hepatic veins, RA

Video 08-06: Longitudinal view of the inferior vena cava (IVC)

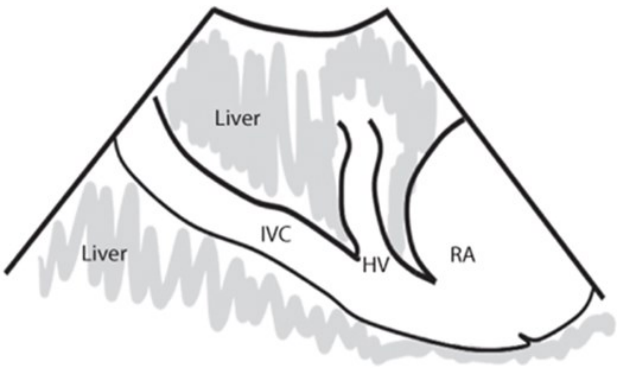
By rotating the probe so that the indicator is cephalad, the IVC can be seen as a long anechoic tube running across the screen and ending in the right atrium. This is confirmed to be the IVC by the presence of a hepatic vein draining into it, as well as the presence of liver on both the near and far sides as well as the right atrium on the right side of the screen. This IVC (mine) collapses completely with a sniff, but represents a normal intravascular volume.



Play Video

IVC longitudinal-labeled anatomy

Figure 8-11



Hand position

Rotate probe so indicator is cranial and length of IVC is seen across screen.

Figure 8-12

Source: C. M. Baston, C. Moore, E. A. Krebs, A. J. Dean, N. Panebianco:
Pocket Guide to POCUS: Point-of-Care Tips for Point-of-Care Ultrasound, 1st edition.

ACQUISITION TIPS

Subx4C

- The subxiphoid is often the best view for patients with COPD/asthma or those on PPV.
- Patient ideally supine. Use an overhand grip and slide up from abdomen to xiphoid. Aim sound waves at left shoulder.
- If bowel gas is obstructing view, try firm pressure. If that doesn't work, use the liver as a sonographic window by sliding to the patient's right and, if necessary, onto the rib cage.
- Use the patient's respirations to move the heart toward your probe. If the patient can cooperate, it can be helpful to ask the patient to take a deep breath and hold.
- The four-chamber plane is very susceptible to false ratios of chambers due to subtle misalignment. Use very small motions when adjusting image.
- This window can also be used to get short-axis views of the heart:
  - Rotate the probe 90 degrees clockwise without sliding.
  - The short-axis plane provides views of all structures from apex to base (akin to PSSA).

IVC—General

- The IVC should be assessed in transverse and longitudinal planes.
- Visualizing IVC usually requires much less pressure than other cardiac views.
- The IVC variability is assessed during the normal respiratory cycle. A forced sniff is not necessary and may be misleading because it is an unpredictable amount of force.
- Both the IVC and aorta are pulsatile; this feature cannot be used to identify the IVC.
- If obesity or bowel gas prohibits visualization of the subxiphoid window, the right intercostal view is more reliable, but technically more challenging. Start in the rib space below the right nipple or more posteriorly and image through the liver.

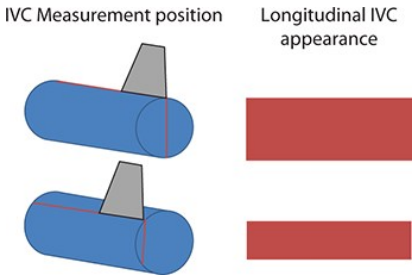
IVC—Transverse

- The transverse plane allows a view of IVC morphology (flat, oval, or round), shows the aorta in the same image as the IVC, and lateral motion of the IVC with inspiration will not be mistaken for collapse.
- The anatomy to determine appropriate depth is the dark shadow of the vertebral body.
- The aorta enters the abdomen caudal to the IVC and gives off the celiac and superior mesenteric arteries anteriorly.
- The confluence of the hepatic veins (rabbit ears) confirms IVC.
- A pitfall of the transverse plane is that extrinsic structures (e.g., the liver, abdominal masses) can cause IVC narrowing. To address this, use long *and* transverse planes.

- Scanning the IVC above the hepatic vein confluence visualizes the RA, not the IVC.

IVC—Longitudinal

- The IVC will be patient right of the aorta.
- In the longitudinal view, the hepatic veins entering the IVC are the most reliable marker to differentiate aorta from IVC. Continuity with the RA can also be used.
- If the IVC does not go all the way across the screen, try subtle rotation.
- The IVC may move laterally with respiration, causing this view to come off axis. This results in an inaccurate measurement of collapse (see figure). The solution is to assess the IVC in both longitudinal and transverse planes.



INTERPRETATION – LEFT VENTRICULAR EJECTION FRACTION (LVEF)

- Left ventricular ejection fraction (LVEF)
  - Aggregate visual estimate from multiple views. Don't trust a single view or plane.
  - Fractional shortening method:
    - A decrease of linear LV diameter by one-third or more correlates with normal EF.
    - This can be done in PSSA or PLAX, but PLAX is more prone to imaging axis errors.
  - The E-point septal separation (EPSS) can also help estimate LVEF.
    - In a well-aligned PLAX view, zoom in on the anterior leaflet of the mitral valve.
  - Measure the minimum distance between the anterior leaflet of the mitral valve and septum. M-mode can be helpful for this measurement:
- With practice, it is possible to recognize grossly abnormal valves or valvular function or grossly asymmetric wall motion, although this is not part of basic cardiac ultrasound.
- Hypertrophy and dilated cardiomyopathy can be inferred by abnormal wall thickness (septum or free wall) and end-diastolic diameter (measured at level of mitral tips).
  - Normal LV end-diastolic wall thickness is 6 to 12 mm.
  - Normal LV end-diastolic diameter is 40 to 60 mm (correlates with height).

Diameter in end diastole

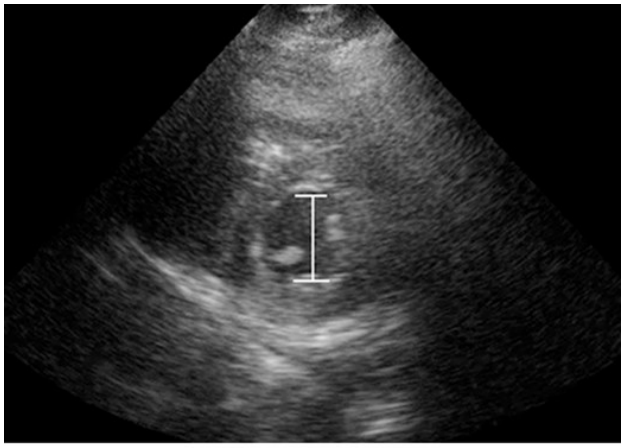
Video 08-07: High Ejection fraction PSSA

This video demonstrates a heart with a normal to elevated ejection fraction in the parasternal view. The leaflets of the mitral valve are visible at the beginning of the clip, but the LV chamber still decreases in diameter more than 50%, when 1/3 corresponds to a normal LVEF. Also of interest in this video is the small pericardial effusion, as well as the crescentic right ventricle.

Play Video

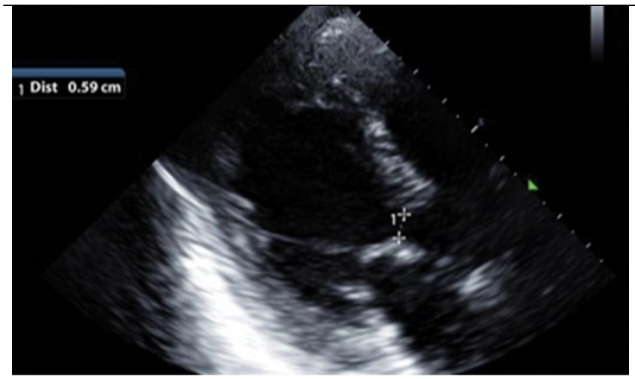
Diameter in end systole

Figure 8-13



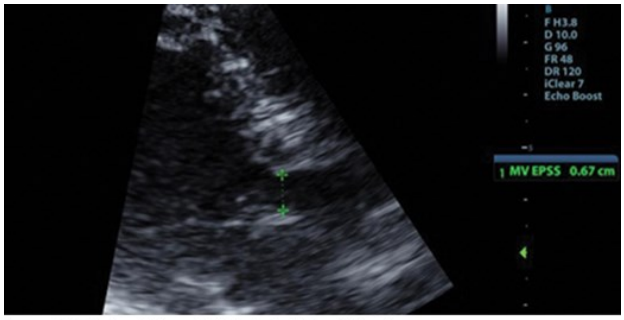
Zoomed out

Figure 8-14



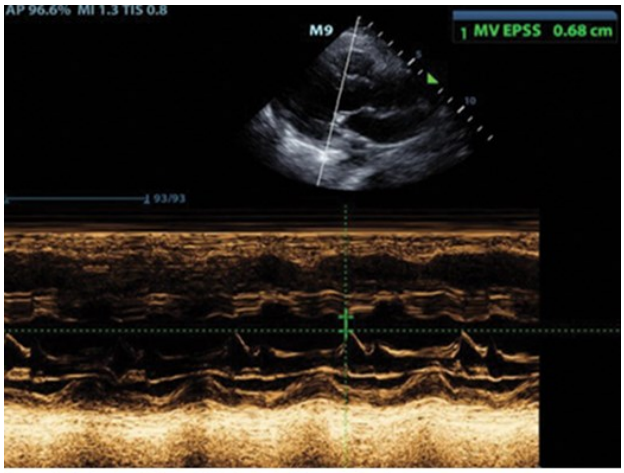
Zoomed in

Figure 8-15



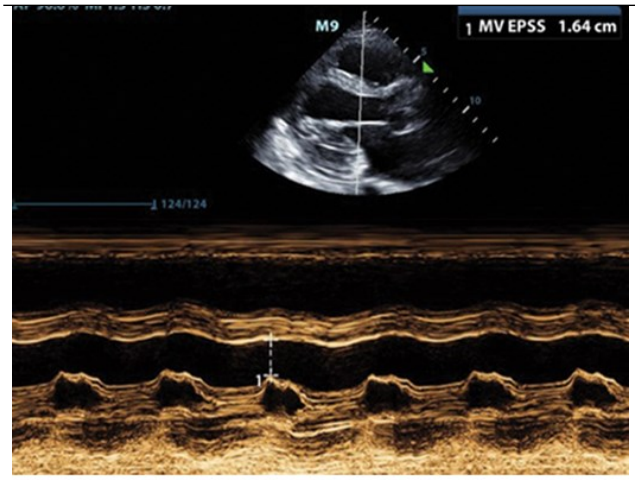
Normal

Figure 8-16



Abnormal—high EPSS, low LVEF

Figure 8-17



	Interpretation
<7 mm	Normal LVEF
7–10 mm	Borderline/unclear
>10 mm	Probably decreased LVEF (or valvular disease)

INTERPRETATION – EFFUSION, RV, IVC

- Evaluation of pericardial effusion versus cardiac tamponade:
  - Pericardial effusions are best seen in subxiphoid view, but evaluate in all views.
  - In PLAX, pericardial effusions appear between heart and descending Ao, while pleural effusions extend behind Ao.
  - Look for signs of tamponade physiology
    - IVC plethora (most sensitive).
    - RV diastolic collapse (most specific).
    - RA diastolic collapse (intermediate sensitivity and specificity).
    - MV or TV inflow velocity variation (an advanced technique).
  - Epicardial fat can be a fake-out for a pericardial effusion, but is usually located just in front of the RV, and is often more echogenic than simple fluid.
- Evaluation for RV failure:
  - Signs of pressure or volume overload
    - RV dilation to greater than LV diameter (A4C).
    - Flat septum/D-sign (PSSA).
    - RV violates rule of one-thirds (PLAX).
    - Paradoxical septal motion (septum bulges into LV in diastole).
    - Decreased tricuspid annular plane systolic excursion (TAPSE) (advanced).
    - RV diastolic thickness >5 mm suggests hypertrophy from chronic process, while thickness <5 mm suggests an acute process, such as pulmonary embolus (PE).
    - McConnell's sign: RV free wall hypokinesis with apical sparing is seen in both acute and chronic RV failure.

- IVC interpretation:
  - While one of the easiest views to acquire, the IVC view is challenging to interpret, and the ability of the IVC to predict volume responsiveness is limited except at the extremes (a collapsed [<10 mm] or very plethoric [>2.5 cm and unchanging] IVC).
  - The most common serious error in IVC assessment is failure to identify a slit-like IVC and substituting the aorta. If only one is seen in the transverse plane, then it is the aorta, and the IVC is probably critically underfilled.
  - In spontaneously breathing patients, the IVC will collapse with inhalation, while in patients on PPV, the IVC will distend with inhalation.
  - The diagnostic performance is controversial and depends on tidal volume, respiratory effort, and abdominal pressure.

Pericardial effusion in PLAX

Video 08-08: Parasternal long axis view with pericardial effusion

In the parasternal long axis view, the pericardial effusion can be seen circumferentially around the heart, and running in between the left atrium and descending aorta. The other cardiac function appears intact.

Play Video

Pericardial effusion measured with arrows

Pleural and pericardial effusion in PLAX

Video 08-09: Pleural effusion in the parasternal long axis view

Pleural effusions in the parasternal view can sometimes be mistaken for pericardial effusions. This video of a large pleural effusion shows that pleural effusions go behind the descending aorta, while pericardial effusions (as seen in the other videos) go in between the descending aorta and the left atrium.

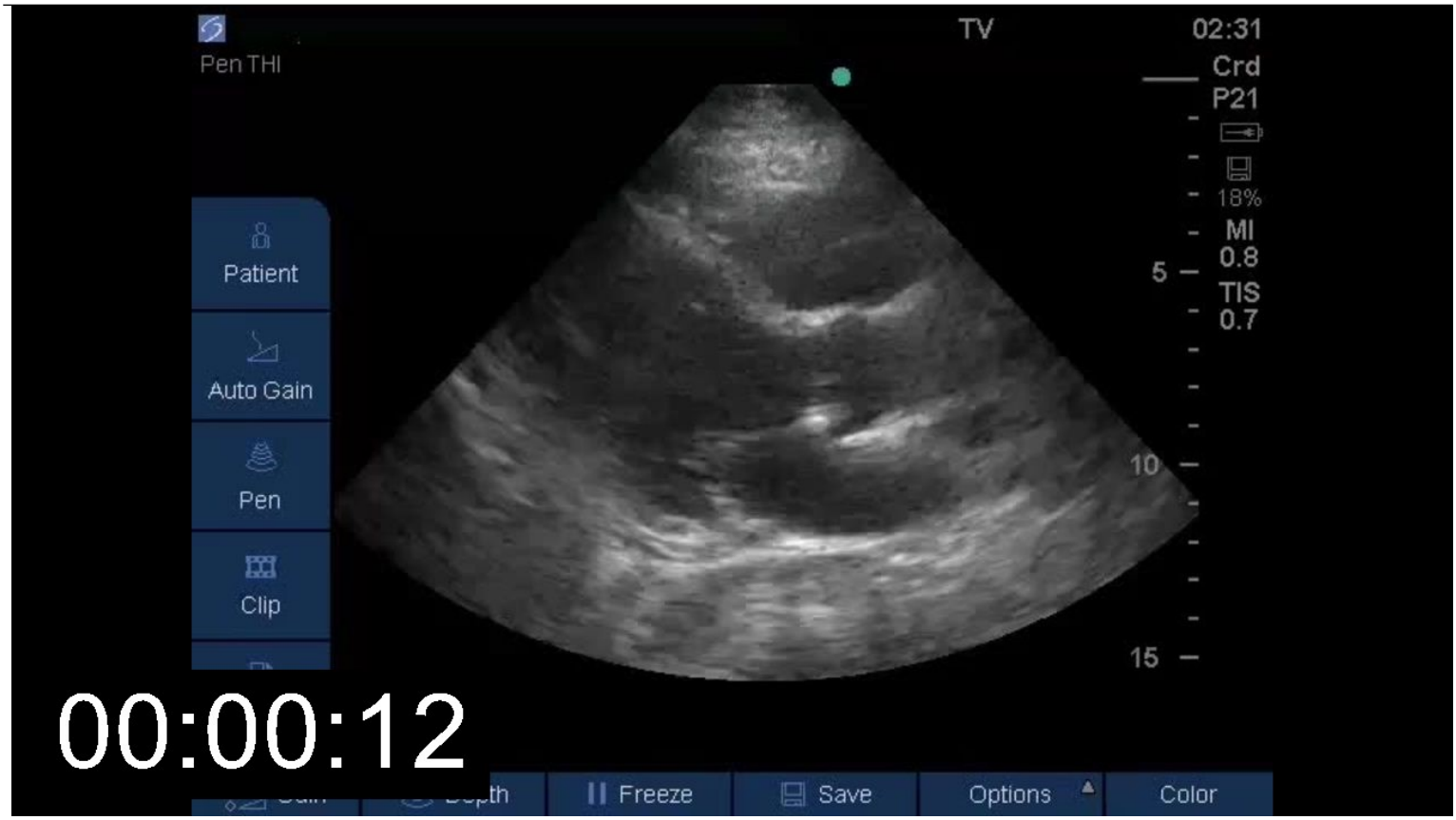
Play Video

Small pericardial effusion marked with arrow

EXAMPLES OF PATHOLOGY

Video 08-10: Low Ejection fraction in the parasternal long axis

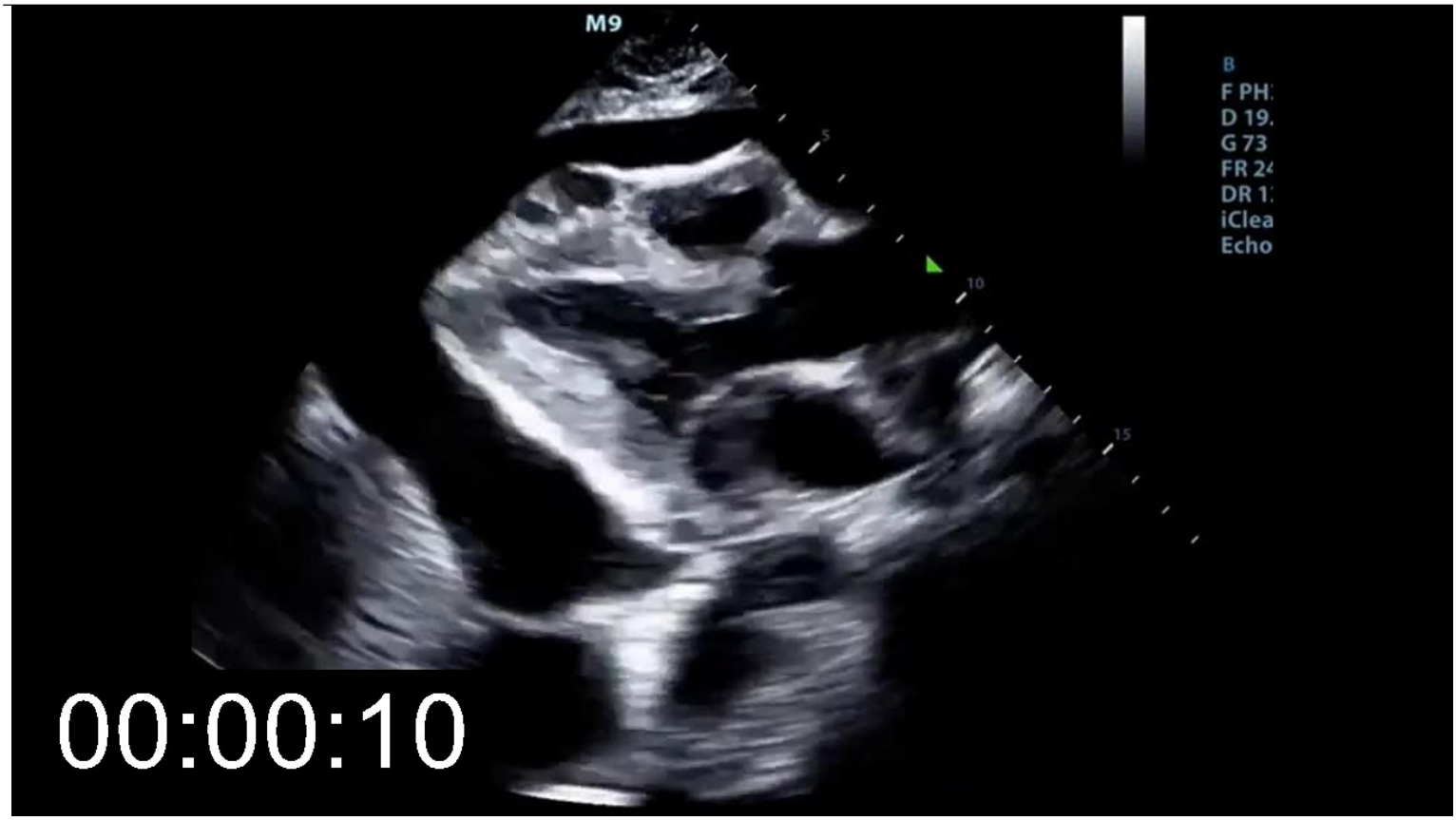
The walls of the LV cavity in this video of a patient with severe systolic heart failure can be seen barely thickening. In addition, the anterior leaflet of the mitral valve can be seen 2-3 cm from the septum, consistent with an elevated E point septal separation. Finally, the Right ventricular outflow track can be seen to be both dilated and with an impaired "wink" during systole.



Play Video

Video 08-11: Tamponade in the parasternal long axis view

In the parasternal long axis view, the pericardial effusion can be seen circumferentially around the heart, and running in between the left atrium and descending aorta. In contrast, this patient's pleural effusion runs deep to the descending aorta. Note the serpiginous motion of the right ventricular outflow track, a finding of tamponade in this patient.



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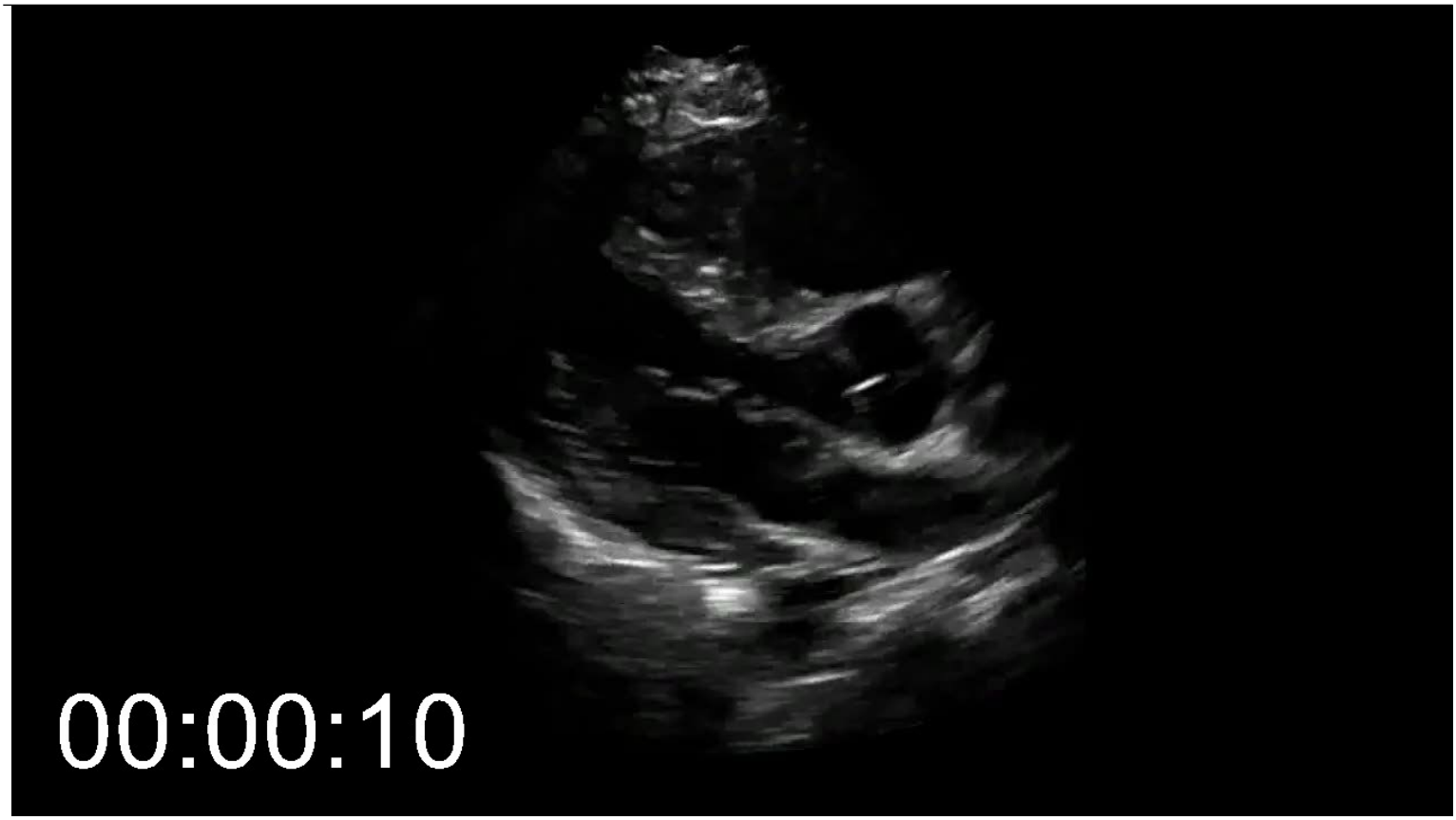
Video 08-12: Right ventricular enlargement in the parasternal long axis view

In this patient with chronic pulmonary hypertension, the right ventricle has dilated considerably. In the parasternal long axis view, that means that the right ventricular outflow track now appears larger in diameter than the aortic outflow track or the left atrium.



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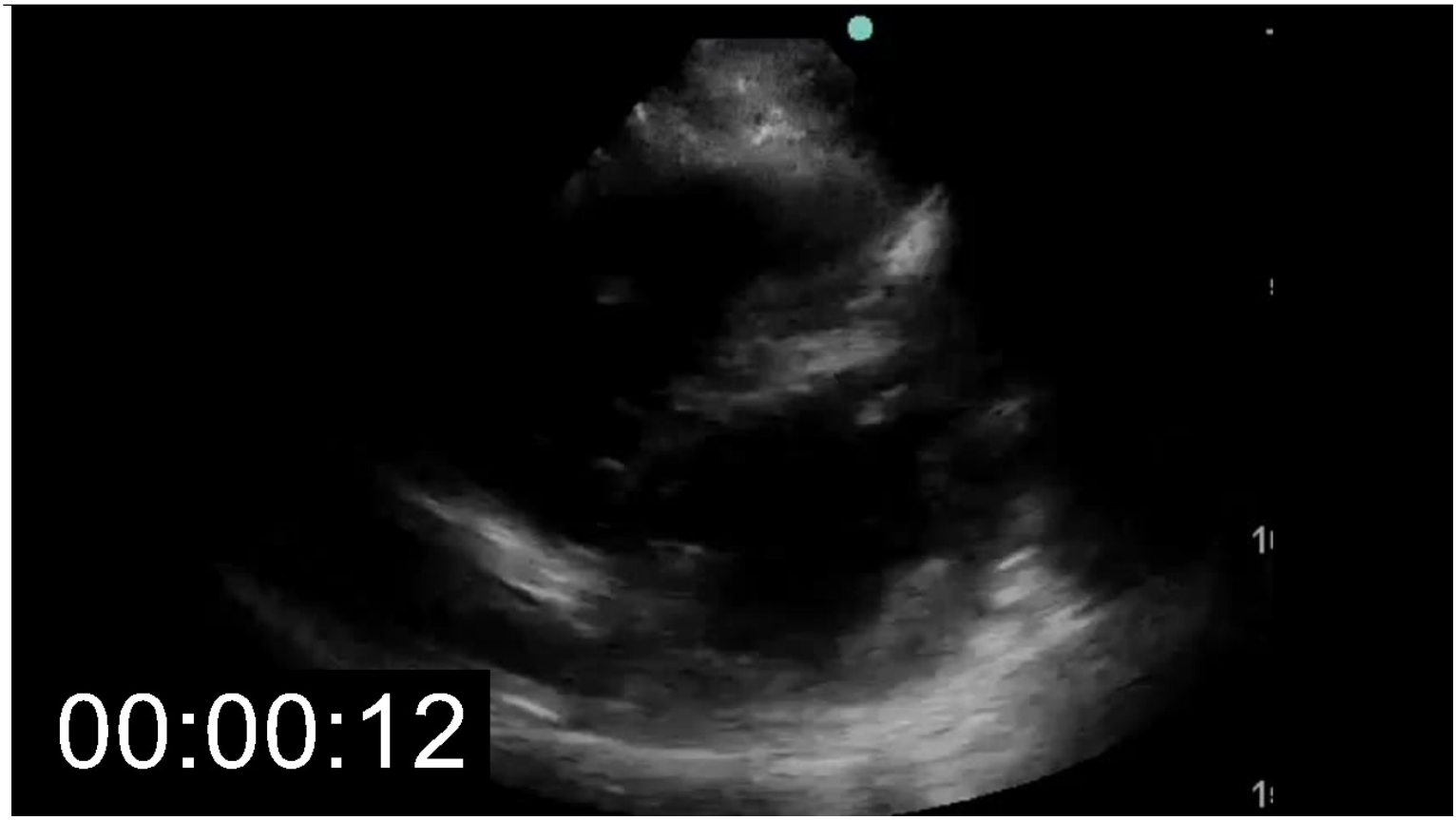
Video 08-13: Right ventricular enlargement in the parasternal short axis view

During every cardiac cycle for this patient with pulmonary hypertension, the intraventricular septum can be seen to flatten. This changes the shape of the left ventricle from a typical concentric circle to the letter "D" during diastole. This is a clear sign of pressure and volume overload to the right heart.

Play Video

Video 08-14: Low Ejection fraction in the parasternal short axis

The walls of the LV cavity in this video of a patient with severe systolic heart failure can be seen barely thickening. If one was to put a finger at the center of the LV cavity on the screen there is no danger of injury to the finger. By unidimensional fractional shortening, there is less than a 10 percent change.



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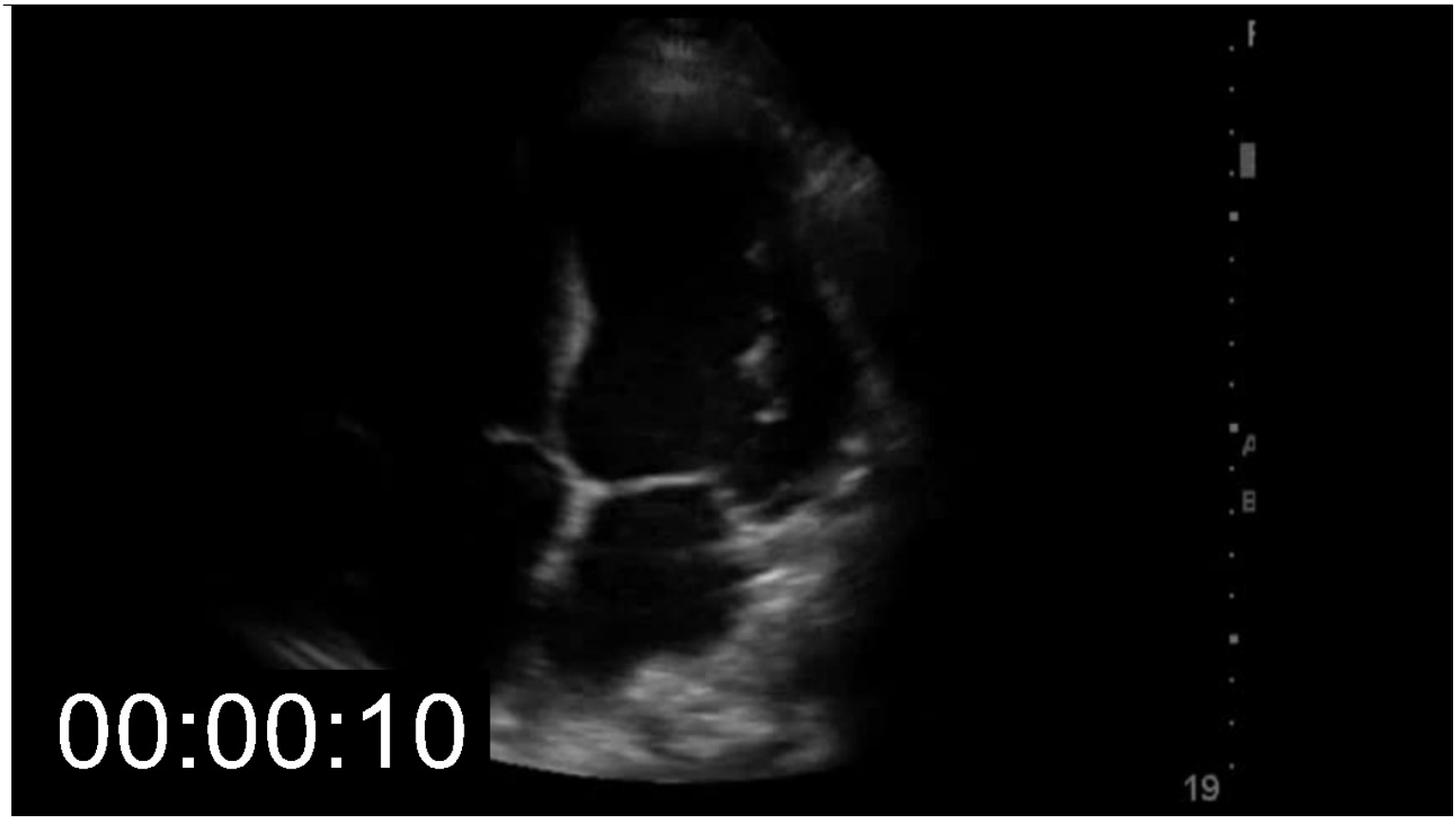
Video 08-15: Parasternal short axis view with a pericardial effusion

The anechoic space surrounding the heart in this parasternal view is a moderately large pericardial effusion. Also, deep to the heart can be seen a pleural effusion. Otherwise there is an elevated ejection fraction and a normal RV size.

Play Video

Video 08-16: Apical four chamber view (A4C) with a low ejection fraction

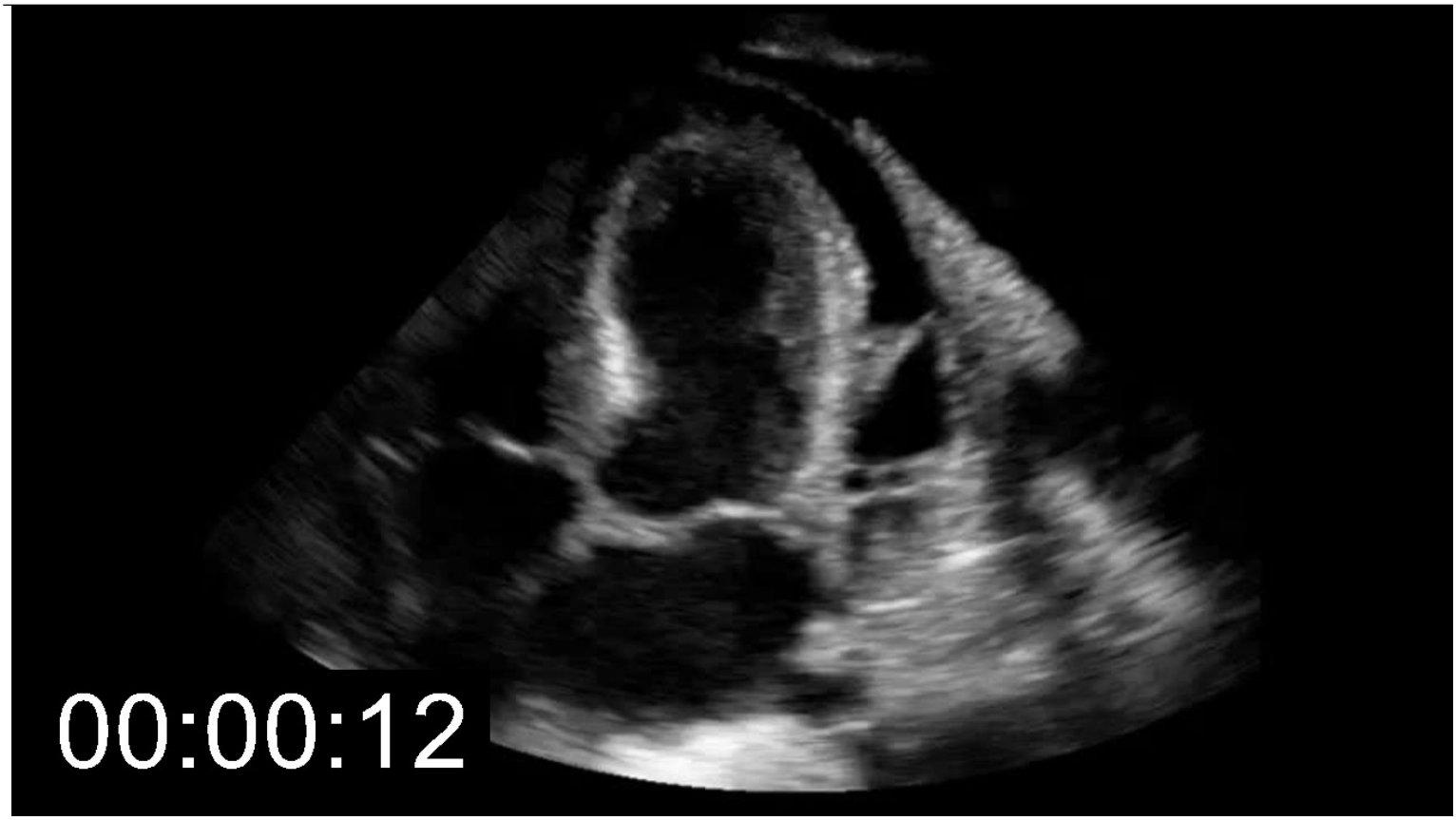
In the beginning of this video it is difficult to see the endocardium to make an assessment of the left ventricular function. Later the endocardium is visible but it barely moves or thickens in this patient with impaired systolic function.



Play Video

Video 08-17: Apical four chamber view (A4C) with a pericardial effusion

The anechoic effusion in this video can be seen surrounding the heart, but with several echoic tendrils bridging the fluid. These septations in a patient with a chronic effusion represent organization of the fluid and are seen in trauma after the blood has begun to clot, as well as infectious, malignant, and inflammatory effusions.



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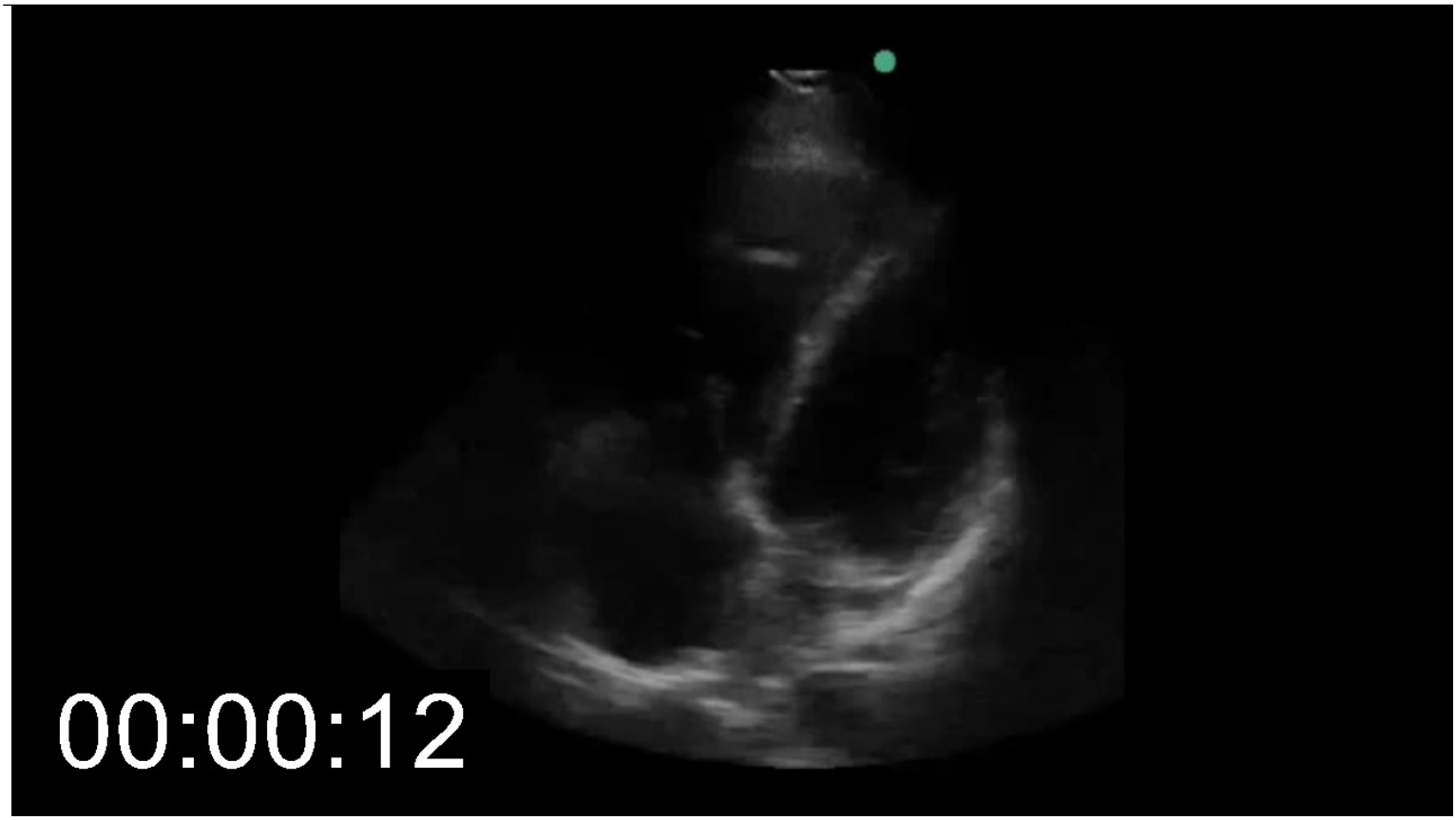
Video 08-18: Apical four chamber view with dilated right ventricle

In the apical four chamber view the right ventricle in a normal patient should have a diameter that is less than the diameter of the left ventricle. This patient with pulmonary hypertension has an RV that is clearly larger. In addition, the intraventricular septum can be see moving into the left ventricle during diastole, a finding call paradoxical septal motion. The right atrium can also be seen to be enlarged. In the RV, the echogenic structure is the moderator band, not a thrombus.



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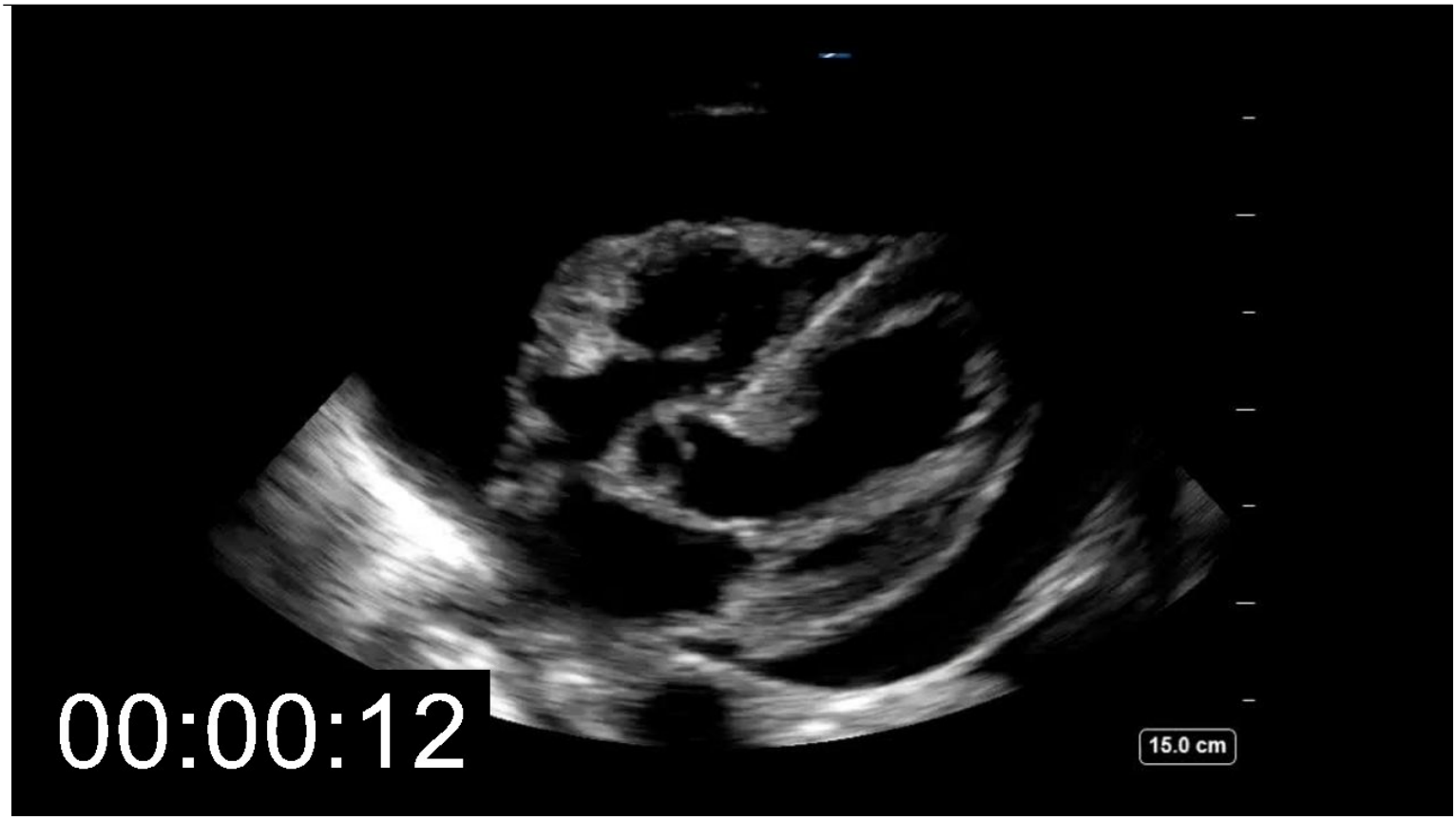
Video 08-19: Subxiphoid view with pericardial effusion

The very large effusion seen in this patient with an inflammatory effusion can be seen to cause some very mild collapse of the right atrium during systole, but the RV does not have diastolic collapse. Tamponade is a clinical finding, and the size of the effusion must be taken in combination with the time of accumulation when estimating pericardial pressures.



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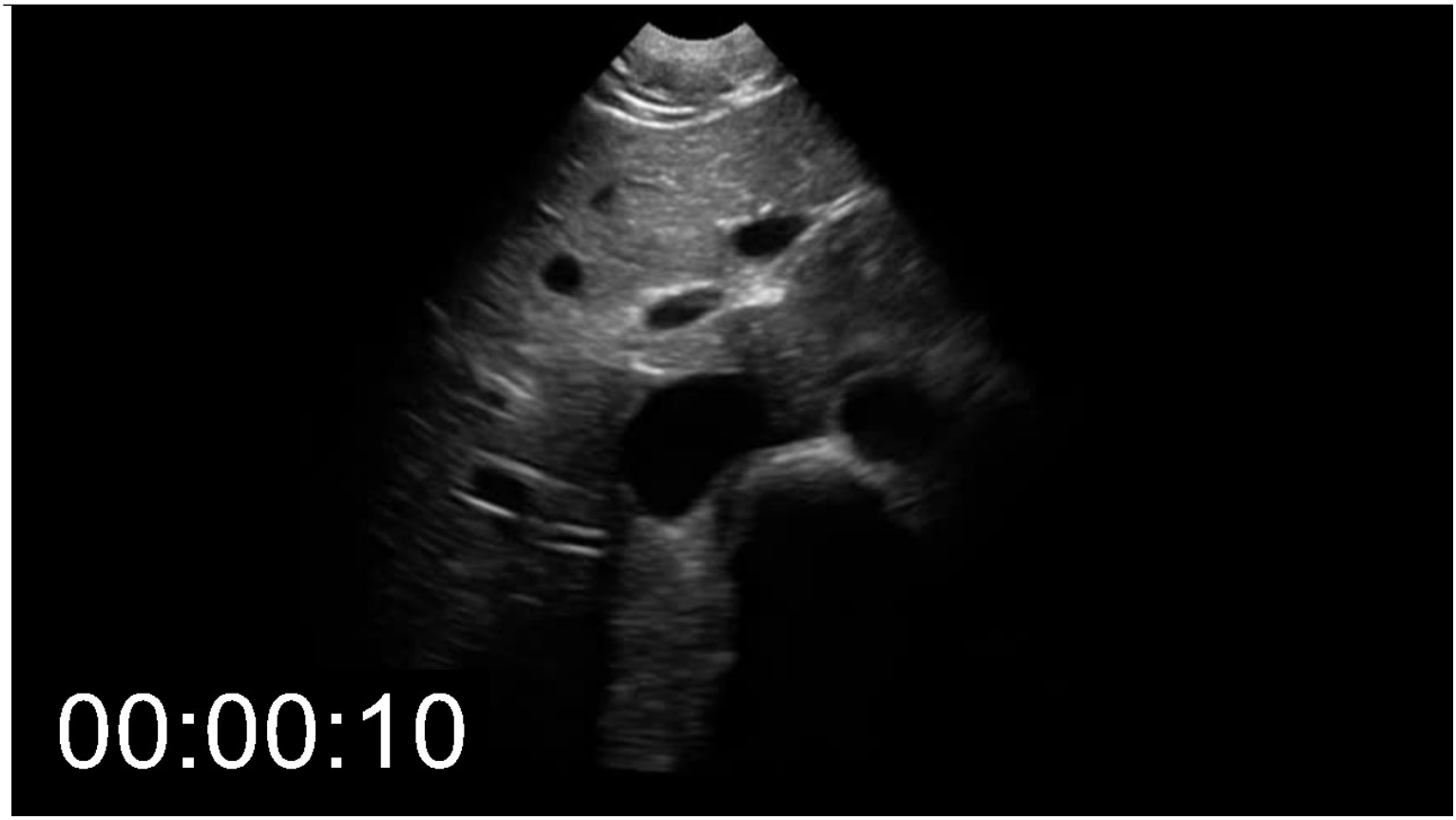
Video 08-20: Transverse view of a dilated inferior vena cava

This transverse view shows a very dilated IVC with dilated hepatic veins forming the "bunny ears" at the hepatic vein confluence near the beginning of the clip. The aorta can be seen on the right side of the screen in front of the lumbar spine.



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Video 08-21: Longitudinal view of a flat inferior vena cava

This longitudinal view of a profoundly hypovolemic patient almost appears to have no IVC at all. Careful scanning however, reveals an almost completely collapse IVC running into the right atrium and tiny hepatic veins draining into the IVC.

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