Basic Echocardiography in the Intensive Care Unit: A Practical Guide for Anaesthetists and Intensivists Part 1

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KEY POINTS

- Focused echocardiography acts as a dynamic extension of the clinical examination, allowing real-time bedside assessment and serial evaluation of haemodynamic status in critically ill patients.[1]
- A systematic approach using 4 standard views—parasternal long-axis, parasternal short-axis, apical 4-chamber, and subcostal—allows focused assessment of volume status and common causes of circulatory failure, including ventricular dysfunction and tamponade.
- Optimising image quality by careful probe positioning, appropriate machine settings, and ergonomic patient and operator positioning is critical for accurate image acquisition and interpretation, particularly in the technically challenging intensive care unit environment.[2]
- Focused echocardiography training is available through structured programmes such as Focused Ultrasound in Intensive Care, which ensure safe and standardised application of focused echocardiography in critical care.[3]
- Findings from focused echocardiography should always be interpreted within the clinical context and other investigations.[1]

INTRODUCTION

- Haemodynamic instability is a common and life-threatening problem in the intensive care unit (ICU), and rapid identification of its underlying cause is essential for effective management.
- Transthoracic echocardiography (TTE) has become a valuable tool for anaesthetists and intensivists, offering real-time, non-invasive assessment of cardiac function, preload status, and potential obstructive pathologies at the bedside.
- Unlike formal comprehensive echocardiography, focused TTE in critical care is goal directed. It aims at answering specific clinical questions, such as: Is there a pericardial effusion? Is the left ventricle (LV) or right ventricle (RV) failing? Is the patient hypovolaemic? These focused questions can often be answered using a limited number of standard views, supporting timely clinical decisions in unstable patients.[1]
- The increasing availability of portable ultrasound (US) machines, along with structured training pathways, has enabled non-cardiologists to perform focused TTE safely and effectively. In the UK and Europe, Focused Ultrasound in Intensive Care (FUSIC) supports clinicians in acquiring the skills needed to perform and interpret these scans at the bedside.[1,3]

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TAKE ONLINE TEST

- This 2-part tutorial provides a practical guide to basic TTE for anaesthetists and intensivists. It focuses on image acquisition, interpretation, and troubleshooting of the 4 key views: parasternal long-axis (PLAX), parasternal short-axis (PSAX), apical 4-chamber (A4C), and subcostal.
- The aim is to support confident, consistent bedside use of TTE to aid in the assessment and management of critically ill adults.
- This tutorial, part 1 of 2, will focus on the basic principles of TTE as well as the PLAX and PSAX views.

ULTRASOUND MACHINE BASICS

- Focused TTE is typically performed using a phased array probe (low frequency, 2-5 MHz) and the cardiac preset, which optimises image quality for moving cardiac structures.[1]
- Most ICU US machines are designed for point-of-care use, with simplified interfaces and features such as auto-optimise or auto-gain functions to assist with image acquisition.
- Essential controls
  - Depth: Adjust so the heart occupies most of the screen.
    - Parasternal and apical views: Start at 12-16 cm.
    - Subcostal and inferior vena cava (IVC) views: Often require 16-20 cm.
    - Reducing depth improves resolution; increasing depth allows visualisation of deeper structures like the IVC or pericardial fluid.
  - Width (sector width): Adjust the image width to include only the structures of interest—typically the ventricles and valves.
    - Narrowing the width improves temporal resolution and frame rate, which enhances assessment of dynamic cardiac motion.
    - A wider sector may be needed to visualise extracardiac structures (e.g., pericardial or pleural effusions) but may reduce image quality for functional assessment.
  - Gain: Adjust gain so that blood appears black (anechoic) and myocardium and valve structures are clearly visible. Use the auto-gain function if available.
  - Focus: Place the focal zone at or just below the structure of interest—usually, the ventricular wall or valve annulus ensures adequate temporal resolution.
  - Freeze or cine loop: Use freeze to pause the image when a clear view is obtained. The cine loop function allows scrolling back through several cardiac cycles to select the best frame, especially useful in arrhythmias, poor windows, or when capturing dynamic pathology.
  - M-mode (motion mode): M-mode displays motion over time along a single US line, creating a wavelike tracing. It is used for simple, repeatable measurements such as:
    - Tricuspid annular plane systolic excursion (TAPSE)in the A4C view;
    - IVC diameter in the subcostal view;
    - Ensure the cursor is aligned perpendicular to the structure before activating M-mode.
  - Store and save: Save stills or short clips to document findings or for training portfolios such as the FUSIC Heart logbook.
- Electrocardiography (ECG) integration
  - Some US machines display an ECG trace on screen. This helps time image acquisition or measurements to the cardiac cycle, for example, aligning TAPSE with systole or identifying end diastole during valve assessment. We will revisit this in relevant sections.
- Image orientation
  - The probe marker (a ridge or dot on the probe handle) corresponds to the left side of the US screen.
  - A simple rule of thumb:
    - Notch to the right shoulder: PLAX view.
    - Notch to the left side: Apical and subcostal views.
    - Rotate notch cephalad: Subcostal IVC view.

Confirm correct orientation using known anatomical landmarks, especially when switching machines or presets.

EQUIPMENT, SETUP, AND ERGONOMICS

- Effective scanning in the ICU depends on the proper setup of the machine, patient, and operator. Small adjustments can make scanning easier and improve image quality.[2]
- Machine and bedside setup
  - Place the machine on the patient's left side (for right-handed users), with the screen at eye level.
  - Adjust the bed and machine height to keep your scanning arm relaxed and wrist neutral.
  - Ensure the machine is plugged in and have gel and wipes ready. Reduce glare if needed by dimming overhead lights.
  - In all ICU patients, ensure the probe is cleaned before and after each use, and use a probe cover if required, particularly in patients with transmissible infection risk.

- Patient positioning
  - Aim for a semirecumbent or left lateral position to optimise parasternal and apical views.
  - In ventilated or supine patients, the subcostal view is often the most accessible starting point.
  - For apical views, elevating the head of the bed to 30°-45° can help bring the apex into view.
- Operator ergonomics
  - Stand close to the bed and reposition the patient or bed as needed to avoid straining.
  - Drape the probe cable over your forearm or the bed rail to prevent it from pulling on your wrist.
  - Use your non-dominant hand to adjust machine settings.
  - Reposition regularly and avoid prolonged awkward postures to reduce strain.
- Challenging scenarios
  - If standard views are limited, start with the subcostal view.
  - Placing a towel or wedge under their right shoulder to provide a slight left tilt can improve parasternal windows.
  - High positive end expiratory pressure (PEEP) in a mechanically ventilated patient can affect cardiac function and image acquisition.
  - Applying optimal pressure on the probe can improve the image quality.
  - If image quality remains poor, consider repeating the scan later when the patient is repositioned, less agitated, or clinically more stable.

SUGGESTED SCAN SEQUENCE

Following a consistent scan sequence improves efficiency and helps ensure important views are not missed (Table). In most ICU patients, a transthoracic exam typically begins with the PLAX view then progresses through a standard sequence,[2] as depicted in Figure 1:

(1) PLAX—typically the starting point for most transthoracic scans.
(2) PSAX—acquired by rotating the probe 90° clockwise from the PLAX position.
(3) A4C—acquired by moving the probe to the cardiac apex, typically near the point of maximal impulse.
(4) Subcostal 4-chamber—often the most accessible view in supine or ventilated patients.[3]
(5) IVC—assessed from the subcostal window by rotating the probe so the marker points cephalad (12:00) and angling slightly to the patient's right to follow the IVC into the right atrium.

Figure 2 outlines the LV wall segments visualised in each view. Using the coloured lines as a map of the imaging planes, the segments being assessed can be identified and described.

PARASTERNAL LONG-AXIS VIEW

Purpose

The PLAX view (Figure 3) provides a rapid bedside window to assess LV function, pericardial effusion, valvular structure, and the aortic root. It is typically the first transthoracic view obtained in focused echocardiography and is particularly valuable in shocked or unstable ICU patients.

How to Obtain the View

- Place the probe in the third or fourth left intercostal space, just lateral to the sternum.
- Point the probe marker towards the patient's right shoulder (approximately 10:00-11:00).
- Begin with a depth of 14-16 cm, reducing once the heart is centred.
- Tilt or slide the probe slightly to optimise the image.

A slight left lateral position, if tolerated, can improve image quality by bringing the heart closer to the chest wall.

View	Probe Position	Key Structures	Purpose
PLAX	Left third-fourth ICS, parasternal	LV, RV, LA, MV, Ao	Global function, pericardial effusion
PSAX	Rotate 90°, same spot	LV cross-sections	Wall motion, RV pressure overload
A4C	Apical point	4 chambers	Function, valvular assessment
Subcostal 4C	Subxiphoid	4 chambers	Effusion, fluid status
IVC	Subxiphoid long axis	IVC, RA	Fluid responsiveness

Table. Summary of standard views in focused echocardiography. A4C, apical 4-chamber; Ao, aorta; ICS, intercostal space; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; MV, mitral valve; PLAX, parasternal long-axis; PSAX, parasternal short-axis; RA, right atrium; RV, right ventricle

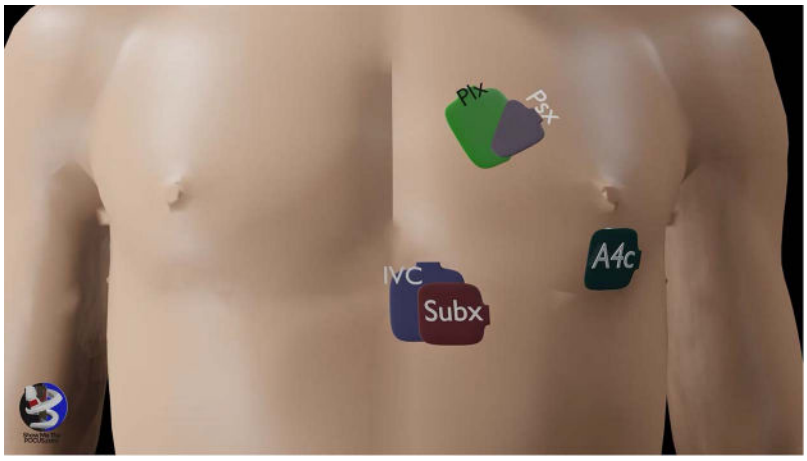

Figure 1. Surface model with probe positions.[4]

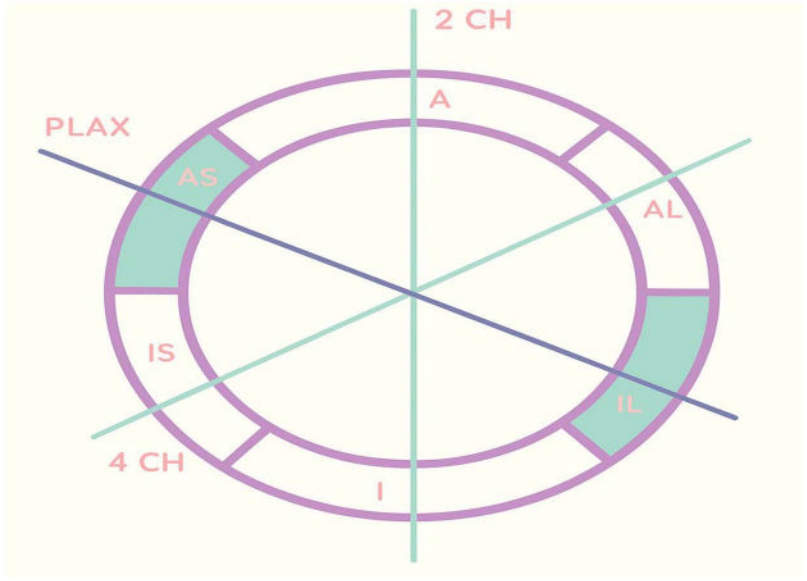

Figure 2. Orientation of the left ventricular (LV) wall with each echo view.

Key Findings and Visual Cues

In the PLAX view (Figure 4), anterior structures (closest to the probe) appear at the top of the screen, with posterior structures displayed progressively deeper. The following description proceeds from anterior to posterior, as visualised in standard image orientation.

- RV outflow tract (RVOT)
  - Seen anterior to the LV.
  - The RV free wall, seen as the most anterior structure on the screen, should be clearly identified and assessed for motion to ensure it is not akinetic.
  - RVOT size should be visually compared with the ascending aorta (which lies just beneath it in this view); they should be of similar calibre.
  - Gross RVOT dilation may suggest right heart strain, but a full RV assessment requires an apical view.
- LV function
  - In the PLAX view, the anteroseptal wall (nearest the interventricular septum) and the inferolateral wall (posterior wall of the LV, near the pericardium) can be assessed.

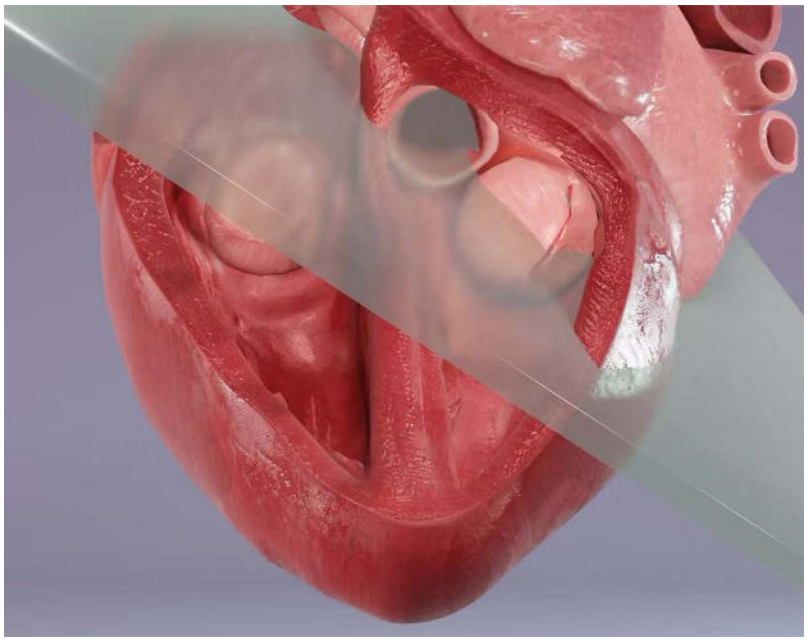

Figure 3. Three-dimensional (3D) animation of heart showing ultrasound (US) plane parasternal long-axis (PLAX).[4]

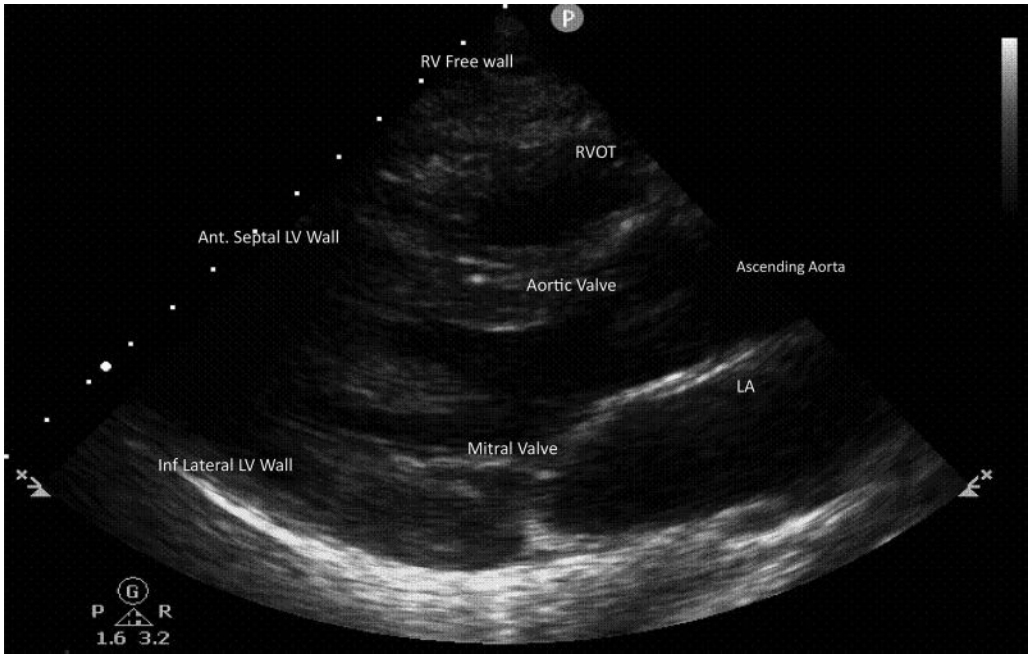

Figure 4. Normal parasternal long-axis (PLAX) labelled.[4]

- Assess for wall thickening of at least 50% during systole, not just inward movement. Notably a segment may appear to move due to being tethered by adjacent normal segments, even if it is not contracting itself (as in regional wall motion abnormalities).
- Normal: Symmetrical wall thickening >50% and coordinated inward motion.[5]
- Hyperdynamic: A small, vigorously contracting LV, often seen in hypovolaemia or distributive shock.
- Poor contraction: Globally reduced wall motion, typically seen in cardiogenic shock or postarrest.

- LV internal diastolic diameter (LVIDd; Figure 5)
  - Estimate of volume status.
  - Freeze the PLAX view at end diastole when the LV is fullest (R wave on the ECG tracing, aortic valve closed), and use callipers to measure across the LV cavity from inner wall to inner wall: at the level of the tips of the mitral valve leaflets.
  - An LVIDd < 4.0 cm suggests low preload or hypovolaemia, in the absence of LV hypertrophy.[5]

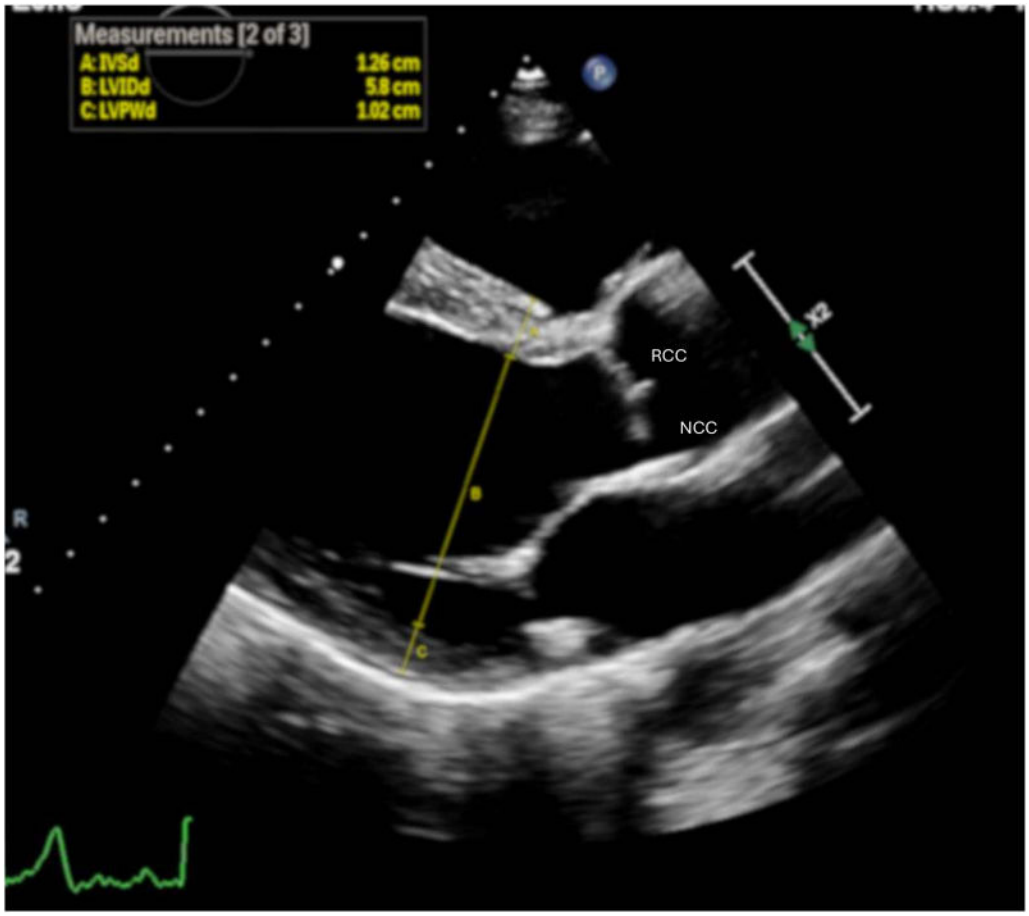

Figure 5. Parasternal long-axis (PLAX) showing location of measurement for left ventricular internal diastolic diameter (LVIDd; yellow line), right coronary cusp (RCC), and non-coronary cusp (NCC).

- Aortic valve
  - Seen in long axis, the right coronary cusp (RCC) appears at the top of the screen (anterior), and the non-coronary cusp (NCC), also called the posterior cusp, appears at the bottom of the screen (posterior).
  - Assess leaflet thickness (should be thin and mobile) and coaptation—the cusps should meet cleanly in the centre during diastole. Incomplete closure may suggest regurgitation.[2]
  - The aortic root is also visible in this view: A diameter >4.0 cm suggests dilatation.
  - Rarely, a dissection flap may appear as a mobile, linear echogenic structure within the aortic root.
- Left atrium (LA)
  - The LA is a posterior structure; it should be similar in size to the ascending aorta, which lies anteriorly.
  - The descending aorta appears as a round structure, posterior to the heart and pericardium (thin, bright echogenic line posterior to the LV, separating the heart from surrounding structures).
- Pericardial effusion (Figure 6)
  - Appears as a black (anechoic) stripe between the posterior wall of the LV and the pericardium.
  - Larger effusions may become circumferential.
  - In hypotensive patients, always assess for signs of tamponade, particularly RV diastolic collapse—pressure from a pericardial effusion compresses the RV free wall during diastole, when the RV is normally relaxed and most vulnerable. Best seen in the subcostal view.[6]
- Distinguishing effusion from other findings
  - Pleural effusion: Lies posterior to the descending aorta (Figure 7).
  - Pericardial effusion: Lies anterior to the descending aorta and often appears to hug the heart.[6]
  - Pericardial fat:
    - Brighter and more textured than fluid (not anechoic).
    - Found only anterior to the heart.
    - Does not shift with patient position: Unlike fluid, it remains fixed.

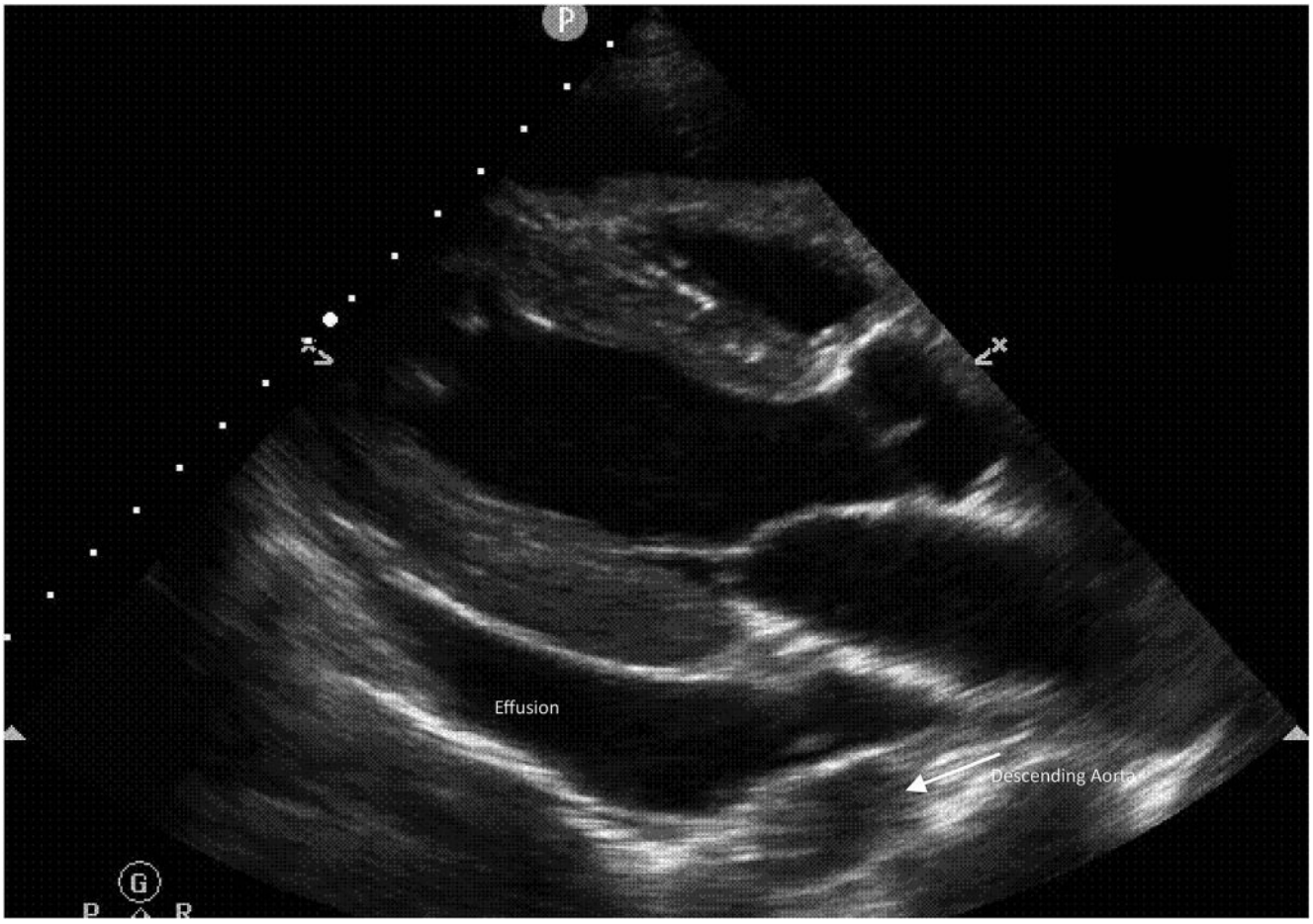

Figure 6. Parasternal long-axis (PLAX) with pericardial effusion and right ventricular (RV) diastolic collapse.[4]

Troubleshooting

- Slide up or down the left sternal border to find the best window between ribs.
- Tilt or rotate the probe to avoid foreshortening (when the LV looks short and round due to an off-axis image).
- If the tricuspid valve or RV inflow is seen in the PLAX view, the image is off axis.[2]
  - Correct by angling the probe tail slightly down (towards the patient's right hip), along the probe's long axis.
- Adjust depth and gain to centre the LV and enhance contrast.
- If the view remains limited, use the subcostal view and return to PLAX later.

Once PLAX is optimised, rotate the probe 90° clockwise (marker towards left shoulder) to obtain the PSAX view.

PARASTERNAL SHORT-AXIS VIEW

Purpose

The PSAX view provides cross-sectional images of the heart at different levels (Figure 8). It is essential for assessing global and regional LV function, detecting signs of RV pressure overload, and reviewing valve morphology.

How to Obtain the View

- Start from a good PLAX view at the level of the LV.
- Rotate the probe 90° clockwise so the marker points to the left shoulder—the first view should be the midpapillary level.
- Keep the same depth setting initially.

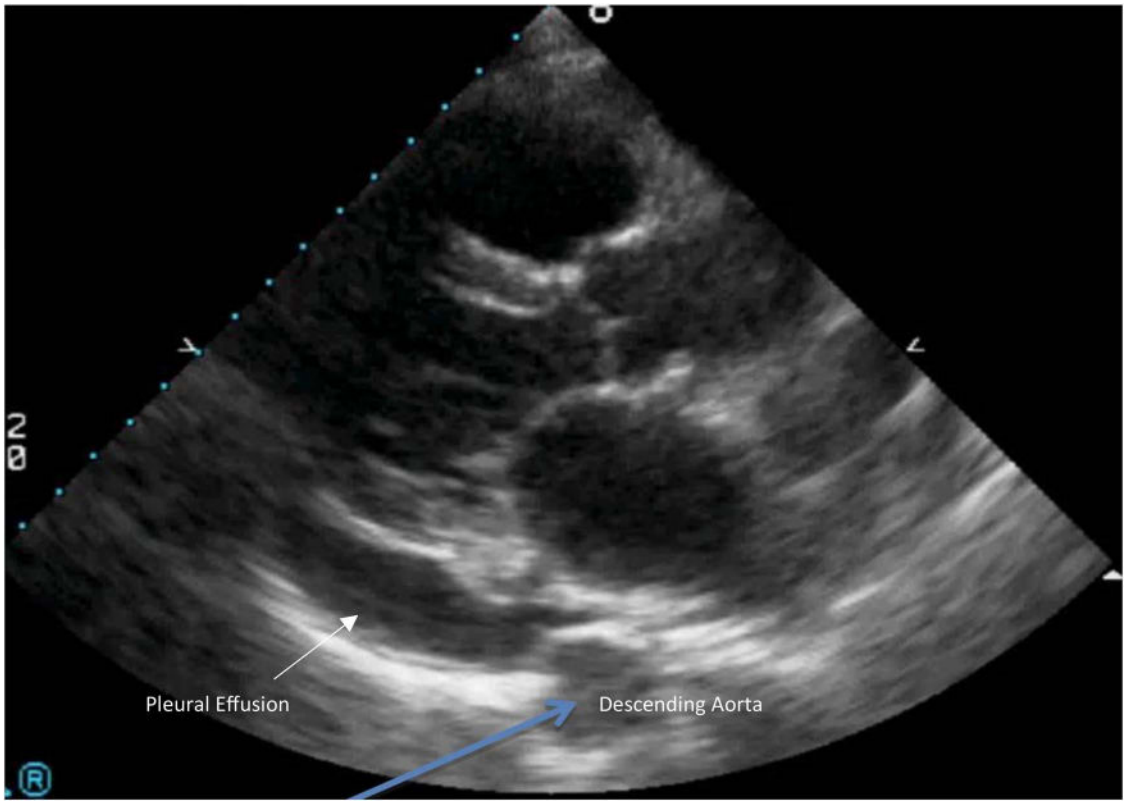

Figure 7. Parasternal long-axis (PLAX) with pleural effusion.

- To transition between levels:
  - Tail down (towards the left hip) → base of the heart → aortic and mitral valve levels.
  - Tail neutral → midpapillary muscle level.
  - Tail up (towards the right shoulder or chin) → apex.

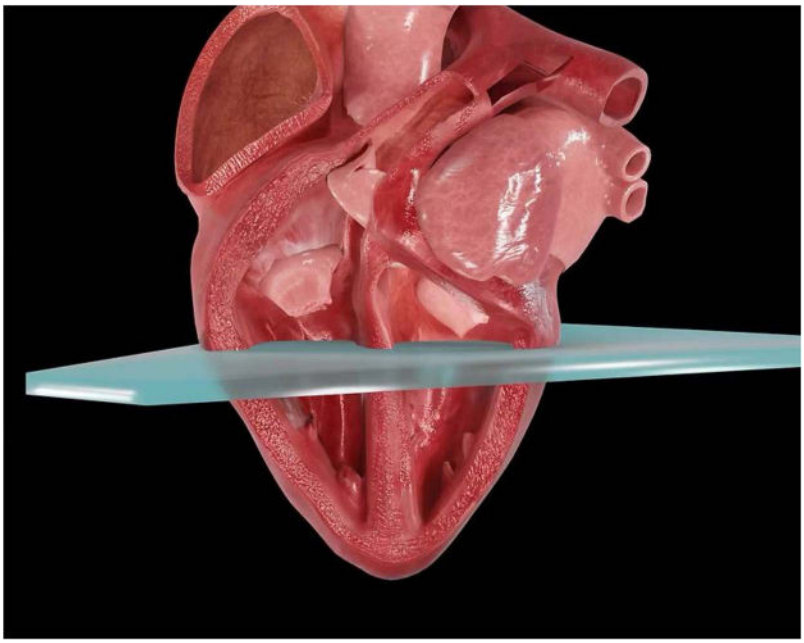

Figure 8. Three-dimensional (3D) animation of heart showing ultrasound (US) plane parasternal short-axis (PSAX).[4]

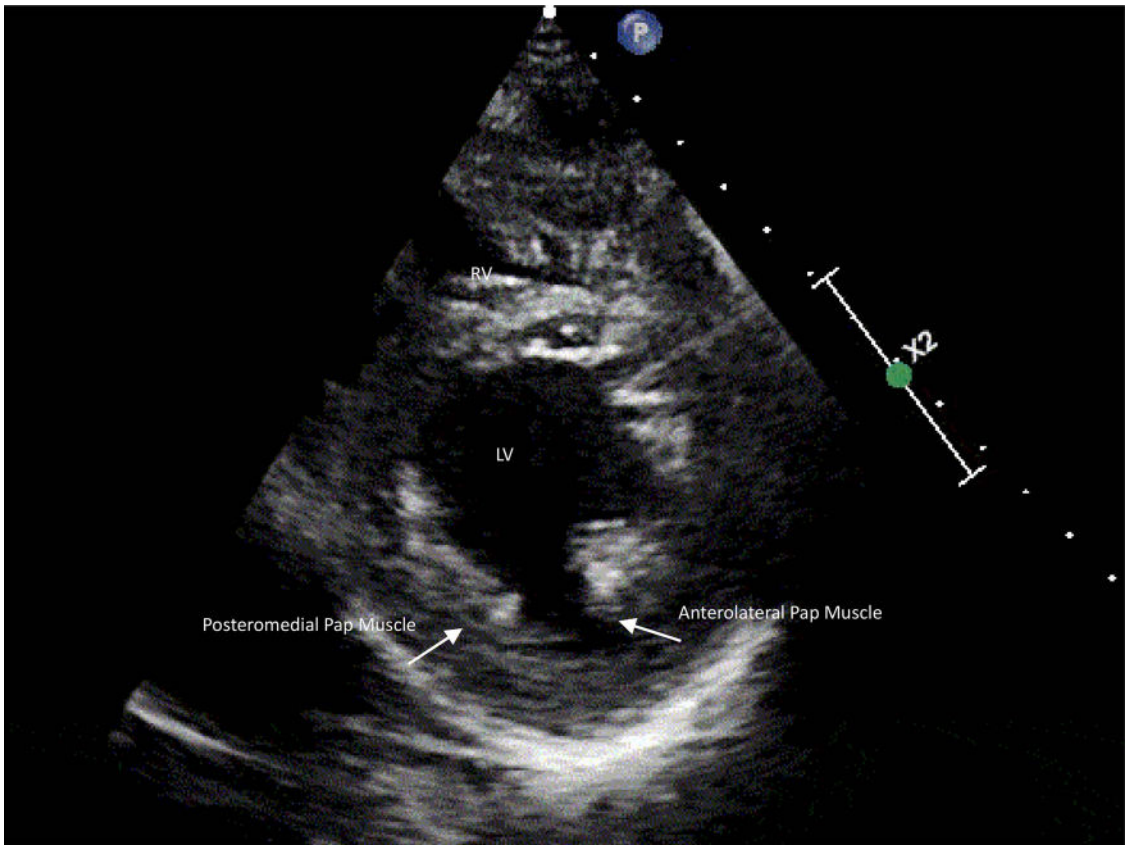

Figure 9. Parasternal short-axis (PSAX) midpapillary view.[4]

Key Findings and Visual Cues

Midpapillary Level

- Contraction is primarily radial[5]—assess that each wall segment is thickening during systole (Figure 9).
- Regional wall motion abnormalities—where 1 or more segments fail to thicken. The midpapillary view is most reproducible.
- Figure 10 shows the key segments and their common blood supply[6]:
  - Anterior/anteroseptal (LAD),
  - Anterolateral (circumflex),
  - Inferoseptal/inferior (RCA),
  - Inferolateral (circumflex or RCA).

Mitral Valve Level (Fish Mouth)

- This view is obtained by tilting the probe tail down from the midpapillary level (Figure 11).
- The anterior mitral valve leaflet appears at the top of the screen, and the posterior leaflet at the bottom.
- In diastole, the leaflets open into a characteristic fish-mouth shape, closing during systole.

Right Ventricle

- In the midpapillary PSAX view, the RV is seen anterior to the LV, wrapping around the top of the image.
- A D-shaped LV due to septal flattening suggests RV overload[7]
- Timing is key—use the ECG or visual cues to identify:
  - Systolic flattening → RV pressure overload (e.g., pulmonary embolism pulmonary hypertension).
  - Diastolic flattening → RV volume overload (e.g., tricuspid regurgitation, atrial septal defect)
- Confirm RV strain in another view (e.g., A4C) by checking RV size, TAPSE, and RA enlargement.
- Pitfall: An oblique image can falsely create a D-shaped LV—always ensure the LV appears circular, not ovoid.

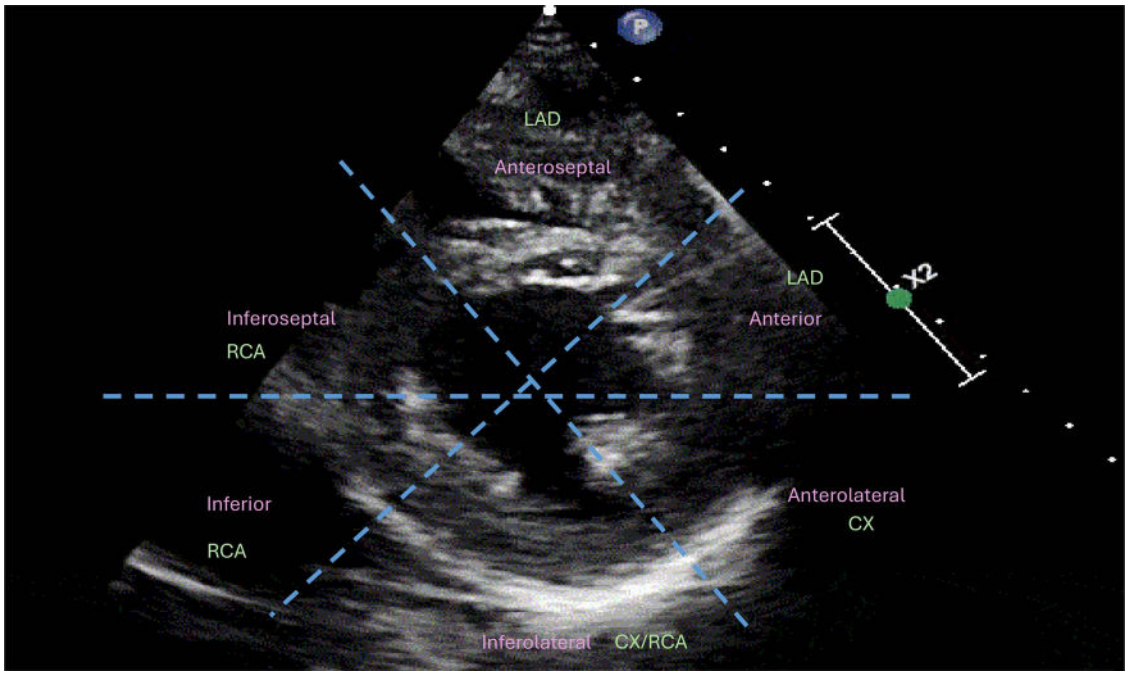

Figure 10. Parasternal short-axis (PSAX) with left ventricular (LV) walls labelled with most common blood supply pattern.

Figure 11. Parasternal short-axis (PSAX) at the level of mitral valve showing anterior and posterior mitral valve leaflets.

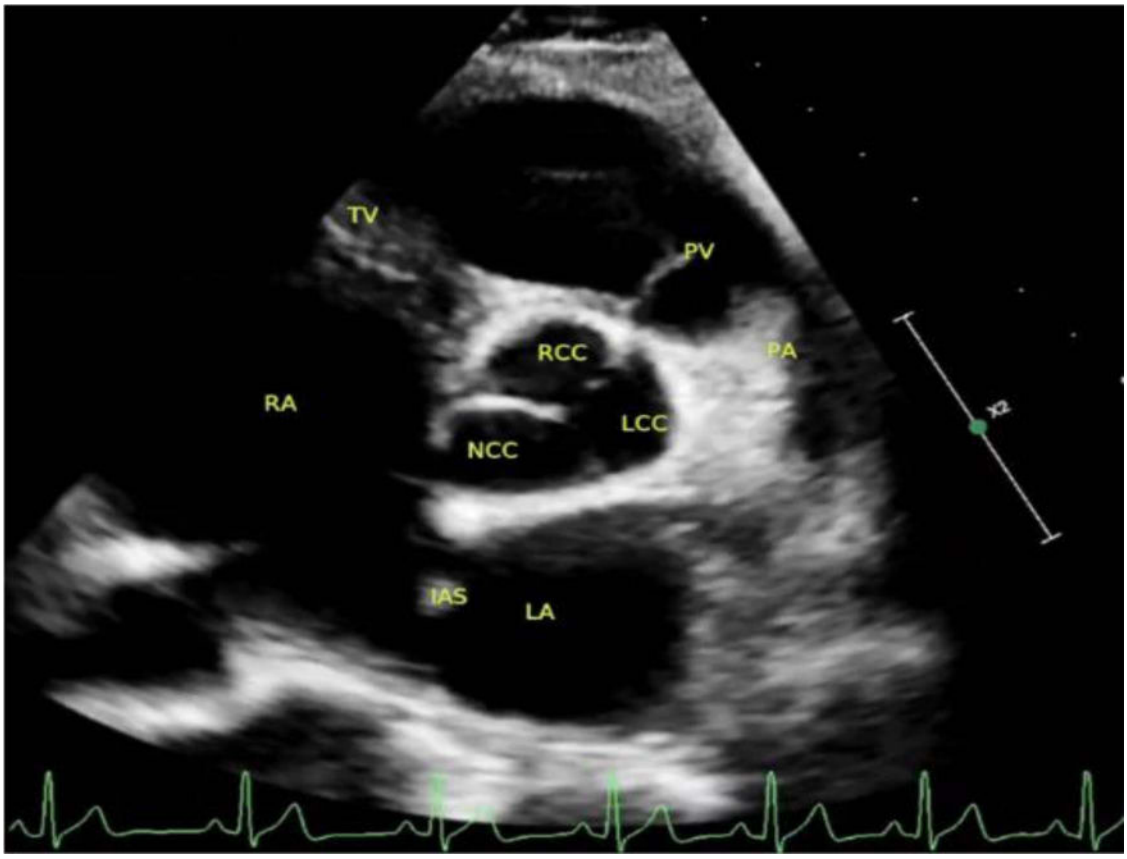

Figure 12. Parasternal short-axis (PSAX) at the aortic valve level.

Aortic Valve Level

- This view is obtained by tilting the probe tail further down from the mitral valve level (Figure 12).
- The aortic valve appears in short axis—in diastole, the 3 cusps form the classic Mercedes-Benz sign (3 symmetric cusps).
- Also shows the RVOT, RA, pulmonary valve, and sometimes the tricuspid valve.

Apex

- This view is obtained by angling the probe tail upwards from the midpapillary level.
- The LV appears as a small, circular cavity, and rotational myocardial motion confirms you have reached the true apex.[2]
- While not routinely included in focused exams, it can be valuable in detecting specific pathologies such as apical aneurysm, thrombus, or cardiomyopathy.

Troubleshooting

- Ovoid or distorted LV: Likely due to an oblique cut. Slide the probe slightly up or down or angle medially or laterally until the LV appears round, especially at the midpapillary level.
- D-shaped septum unclear: Confirm that you are at true midpapillary level with a circular LV—avoid overinterpreting apparent septal flattening in off-axis views. Off-axis flattening—try anticlockwise rotating to become on axis.
- Cannot distinguish valve levels: Use deliberate tail movements:
  - Tail down to reveal the aortic or mitral valve levels.
  - Tail neutral or slightly up for midpapillary.
  - Tail further up for apex.
- Papillary muscles not visible: May be too apical or basal—adjust tail position to refine to true midventricular level.
- RV appears enlarged, but LV is compressed: Check for correct gain and probe alignment to avoid overestimating RV size. Confirm in a second view before concluding RV strain.

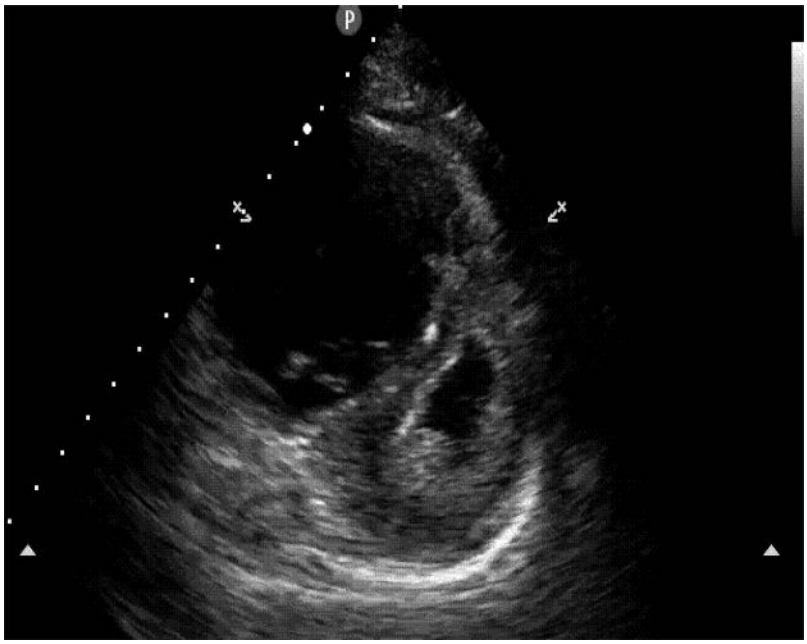

Figure 13. Parasternal short-axis (PSAX) with D-shaped septum.[4]

SUMMARY

Focused echocardiography serves as a dynamic extension of the clinical exam, allowing for real-time hemodynamic assessment in the ICU. This goal-directed tool helps clinicians answer specific questions regarding ventricular function, volume status, and potential tamponade. Success depends on a systematic approach and optimizing machine settings, such as depth and gain, to handle the challenging ICU environment. The Parasternal Long-Axis (PLAX) view is the standard starting point for evaluating the left ventricle, aortic root, and pericardium. It is particularly useful for identifying hypovolemia via the internal diastolic diameter and distinguishing pericardial from pleural effusions. Rotating the probe 90° from this position, displays the Parasternal Short-Axis (PSAX) view. This cross-sectional perspective allows for the assessment of regional wall motion and right ventricular pressure overload. A "D-shaped" left ventricle in this view is a hallmark sign of right heart strain as shown in Figure 13. Together, these views provide a foundational assessment of cardiac performance and fluid status. In the next tutorial, the Apical 4-Chamber (A4C) and Subcostal views will be discussed.

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