Introduction to transthoracic echocardiography

Philips tutorial

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Contents

Introduction to transthoracic echocardiography

1 What is point-of-care echo?

Point-of-care (POC) echo is defined as a focused, goal-directed, transthoracic echo performed at the patient's bedside by the treating physician to answer specific clinical questions.

Advantages

- Fast
- Performed at the bedside
- Non-invasive
- Immediate information

Be careful

- Training and experience are crucial
- POC echo is a qualitative assessment, **NOT** a quantitative analysis

Point-of-care echo does not:

- Replace clinical examination
- Replace a comprehensive echocardiogram with quantitative analysis

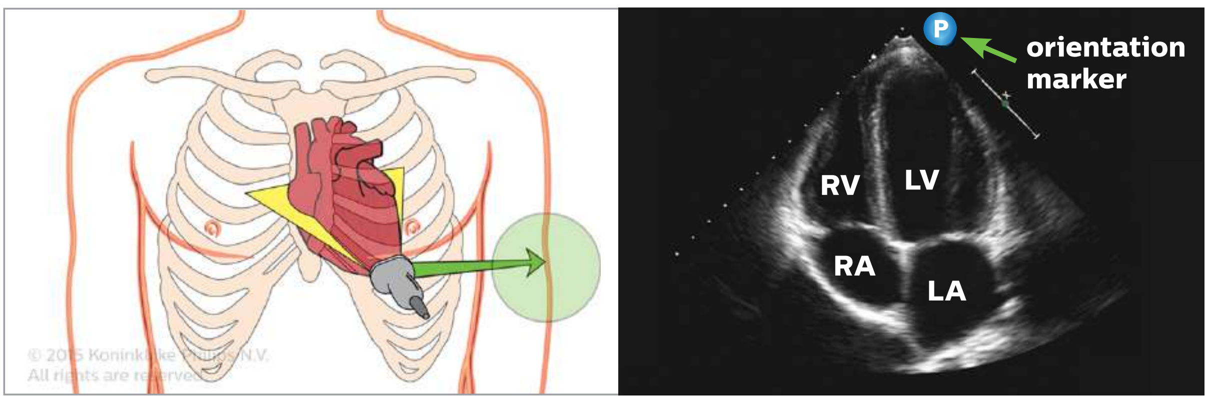
2 The basics

The transducer

The optimal transducer for transthoracic echo is a phased array. The typical frequency range for adult echo is 1–5 MHz.

Orientation of the ultrasound image for echo

- Every transducer has an orientation marker on one side (usually a notch, a groove or a ridge).
- The orientation marker on the transducer corresponds to the orientation marker on the ultrasound monitor.
- By convention, for echo, the orientation marker on the ultrasound monitor is located to the upper right of the ultrasound image.



In this example, the transducer orientation marker is pointing to the patient's left, thus the patient's left will be on the right side of the ultrasound image.

Transducer manipulation

Proper transducer placement and manipulation are required to optimize ultrasound images.

- The placement and manipulation of the transducer will differ with each patient depending on body habitus and the position of the heart in the chest.
- A subtle change in the transducer position and manipulation can have a significant impact on the quality of the image.

Getting started

Apply the gel, and then place the transducer on the patient's chest with the orientation marker aimed at the appropriate landmark (example: for the apical four-chamber view, the orientation marker will be toward the patient's left). Make sure that the transducer is making good contact with the skin.

Ultrasound gel is required for good conduction of ultrasound between the skin and transducer.

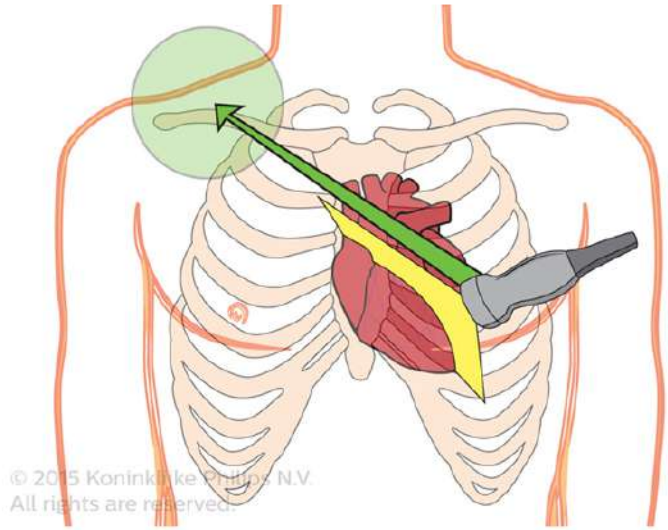
The transducer is the most fragile part of the ultrasound system. Damage can occur if the transducer is dropped or hit against a hard surface.

Use the following techniques to adjust the transducer

Locate the ultrasound "window" on the patient's chest. Adjust transducer manipulation step by step and with small movements.

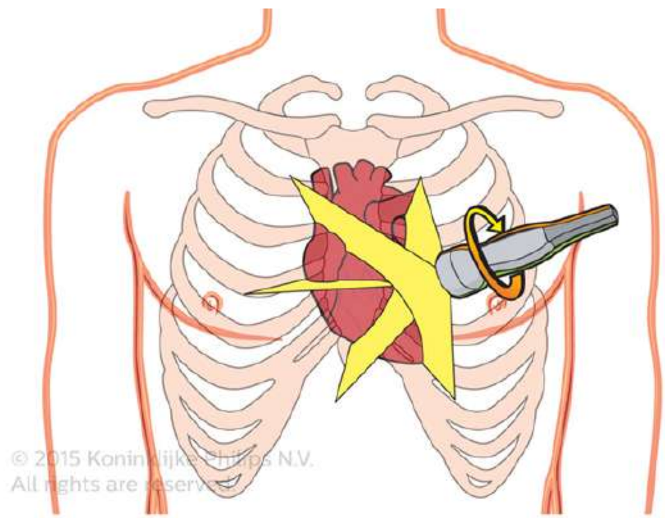
Align

Place the transducer so the ultrasound beam is aligned with the anatomy.



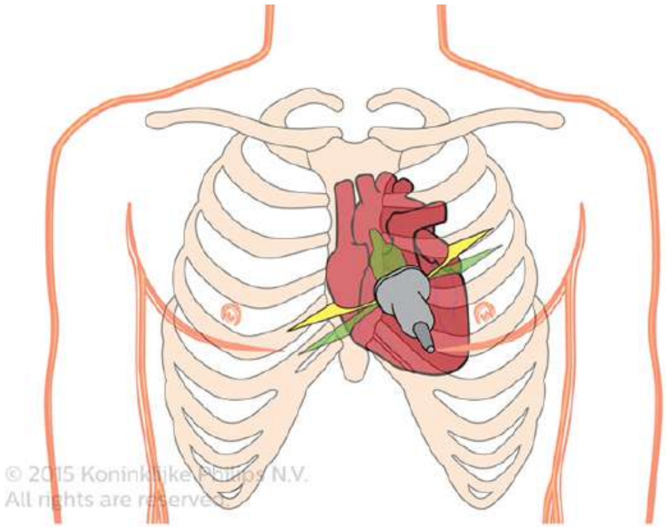
Rotation

Clockwise or counter-clockwise rotation of the transducer is required to change views and to optimize the image.

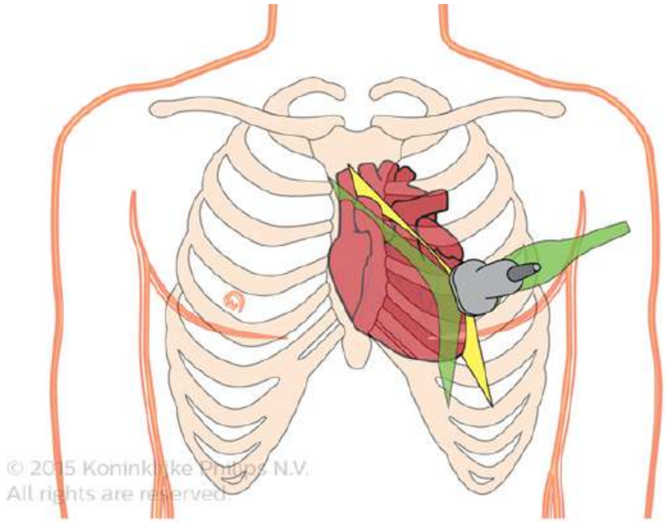


Tilt

Tilt the transducer to identify and optimize the anatomy of interest.



Tilt may be up/down or side-to-side depending on the ultrasound view.



Ergonomics and set-up

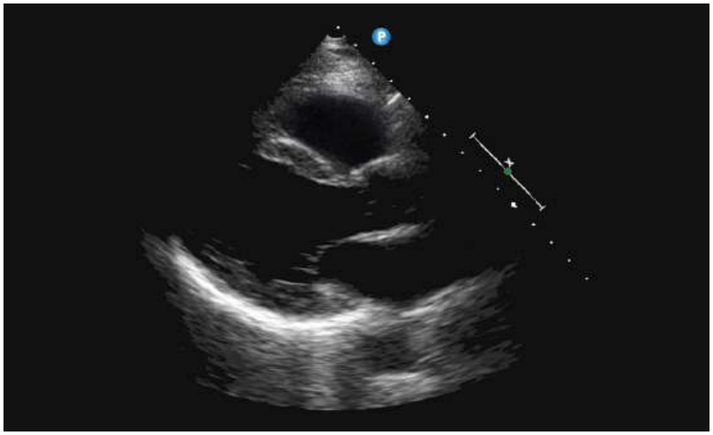
- Stand at the level of the patient's shoulders facing the ultrasound system.
- Adjust the height of the patient's bed and the ultrasound system so you are in a comfortable position while scanning.
- Scan either with your left or right hand; it is recommended to always use the same hand (this will help you to acquire better and more consistent scanning skills).

The patient

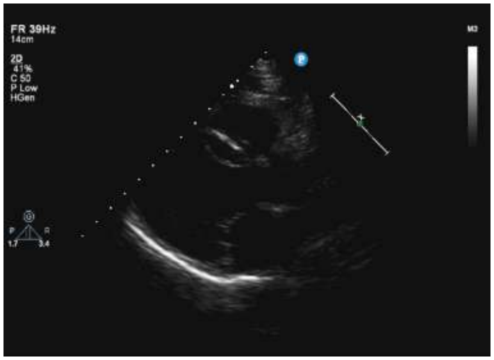
- The patient should be supine.
- If possible, turn the patient onto his or her left side for the parasternal and apical views – this will bring the heart closer to the chest wall. The patient can be supported by placing one or more pillows behind the right shoulder if necessary.
- Abduct the patient's left arm – this will open the intercostal spaces.

Using gain

Optimal gain

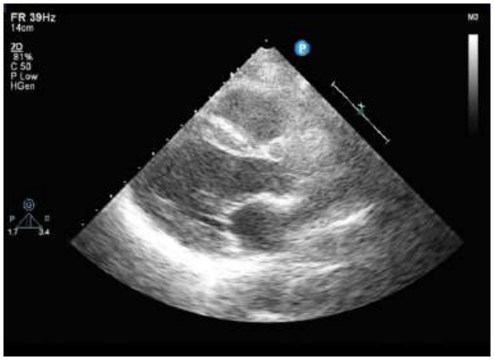


The **"gain"** controls the amplification of the displayed images. With an **"optimal gain"** setting, the cardiac structures will be shades of gray and the blood will be almost black.



Under gained

An image that is **"under gained"** will result in an image that is too black and some of the anatomical information will be missing.

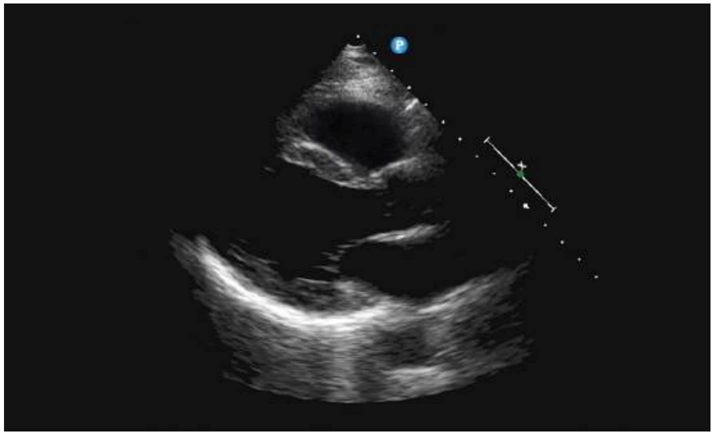


Over gained

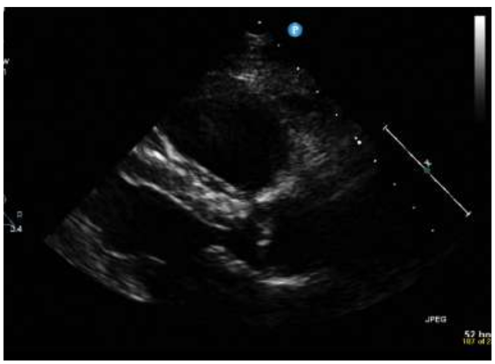
An image that is **"over gained"** will result in an image that is too white and some of the anatomical detail will be lost.

Using depth

Optimal depth

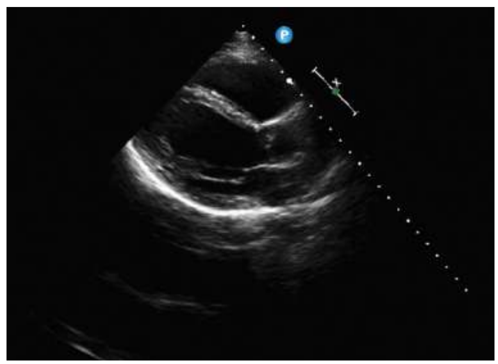


The **"depth"** control increases or decreases the field of view. It is very important to have the appropriate depth setting for each view.



Insufficient depth

Insufficient depth will not display all of the anatomy that is of interest.

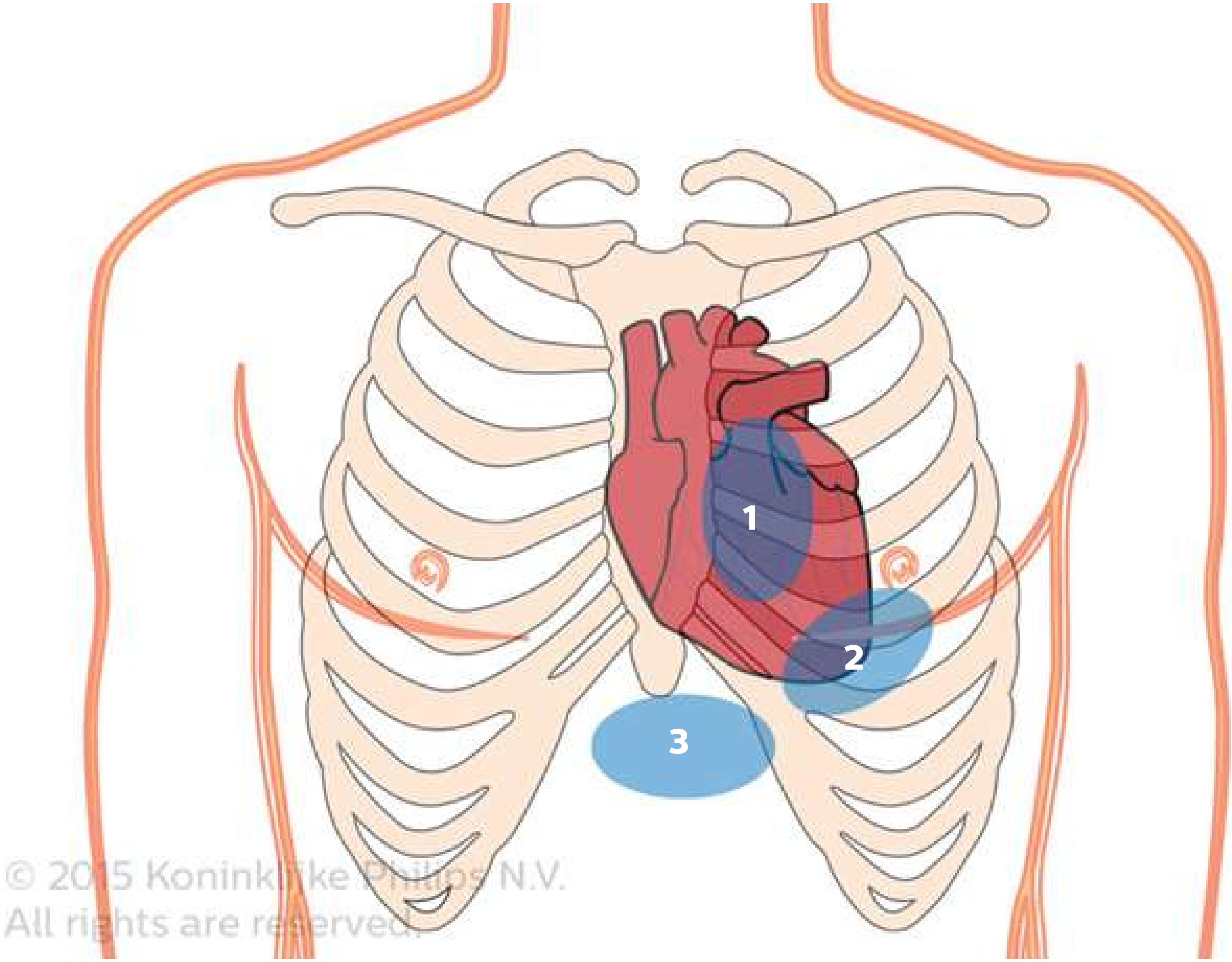


Excess depth

Excess depth may not allow the visualization of details needed.

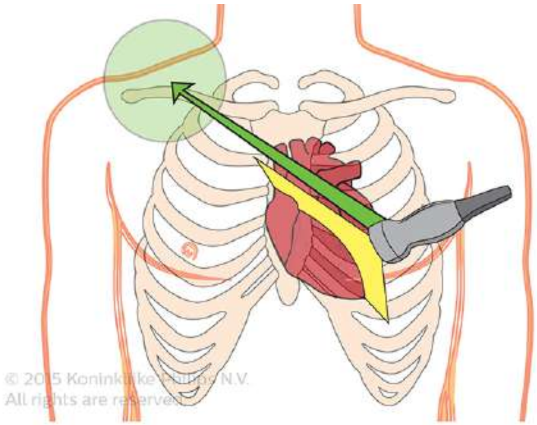
3 Transthoracic echo views

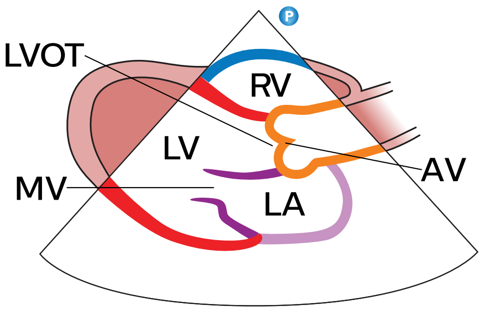
Main transthoracic echo (TTE) windows



1. Parasternal window
2. Apical window
3. Subcostal window

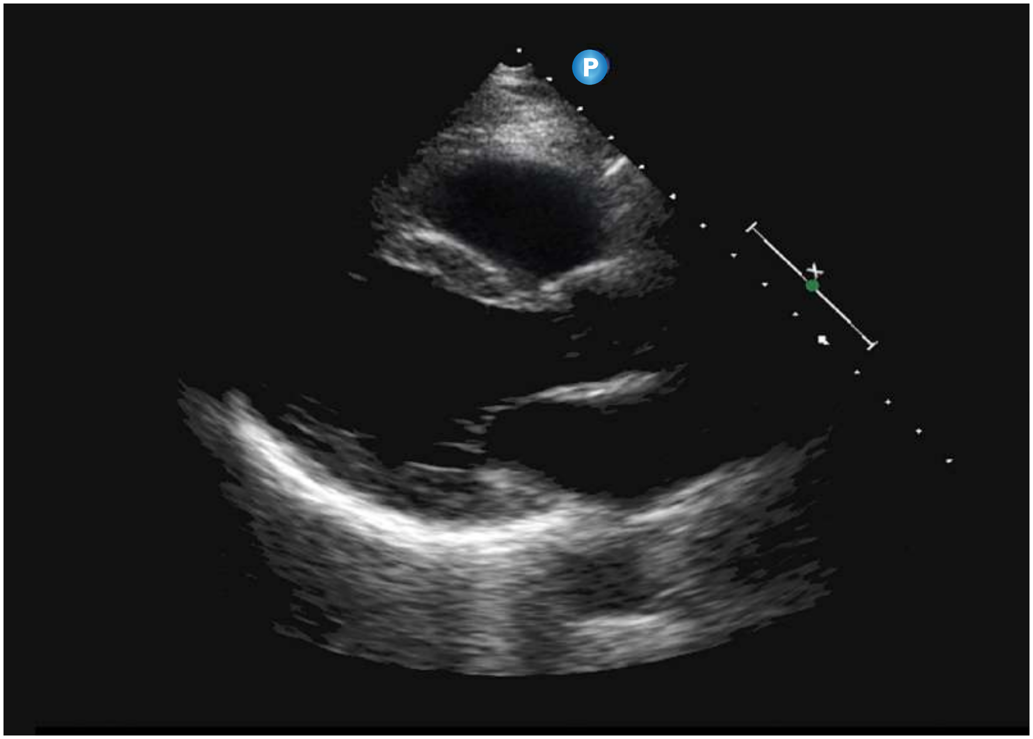
Parasternal long-axis



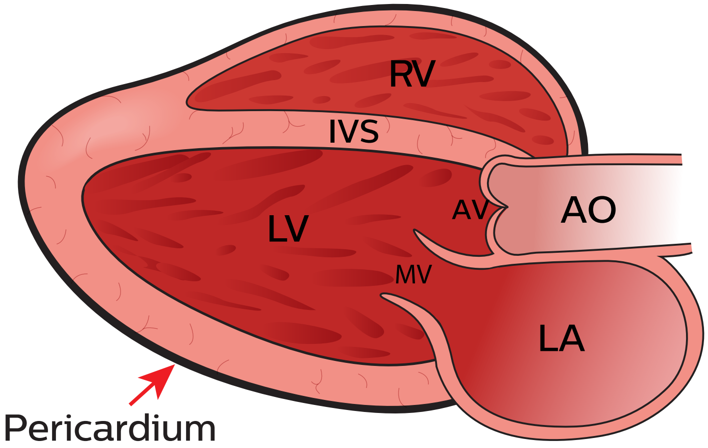


- Transducer is placed in 3rd–4th intercostal space.
- Transducer orientation marker is pointing toward the patient's right shoulder (~10 o'clock).
- Depth 12–16 cm.
- For assessment of a pericardial and pleural effusion use a depth of 20–24 cm.

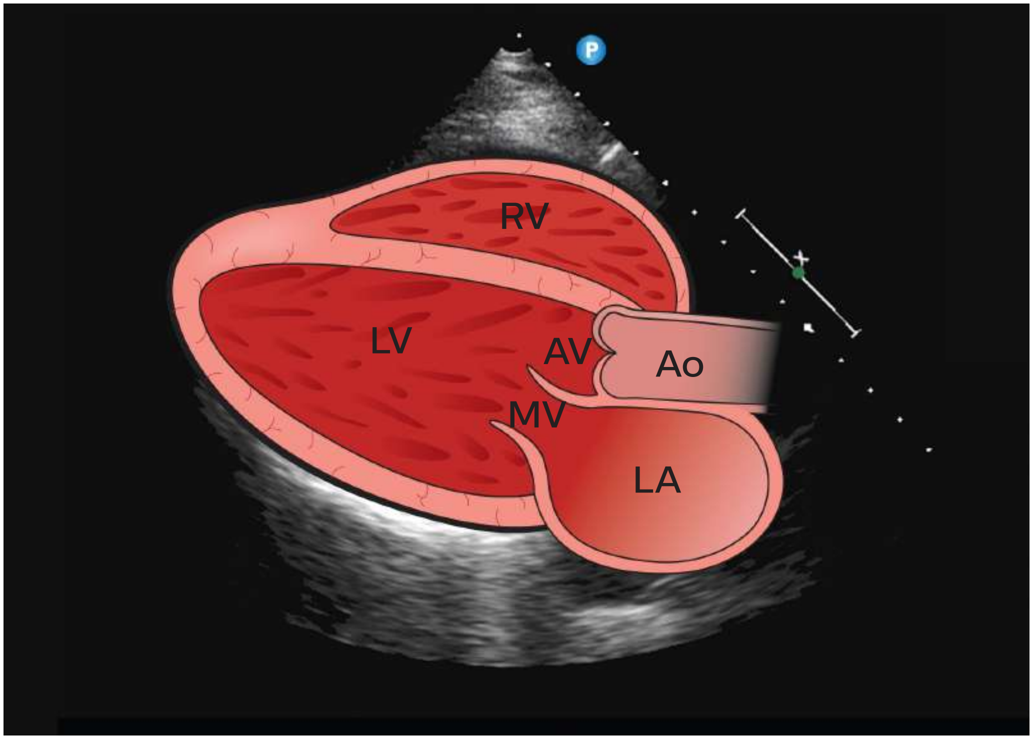
Structure	**Assessment**
RV (right ventricle)	size and function
LV (left ventricle)	size and function
AO (ascending aorta)	size
AV (aortic valve)	motion, opening and calcification
MV (mitral valve)	motion, opening and calcification
Pericardium	pericardial fluid



Parasternal long-axis view – right side of the image is cephalad. The pericardium is a strong echo reflector and appears as a bright white echo.



Parasternal long-axis



Parasternal long-axis view with overlay. RV = right ventricle; LV = left ventricle; Ao = ascending aorta; AV = aortic valve; LA = left atrium; MV = mitral valve.

[Video 1]

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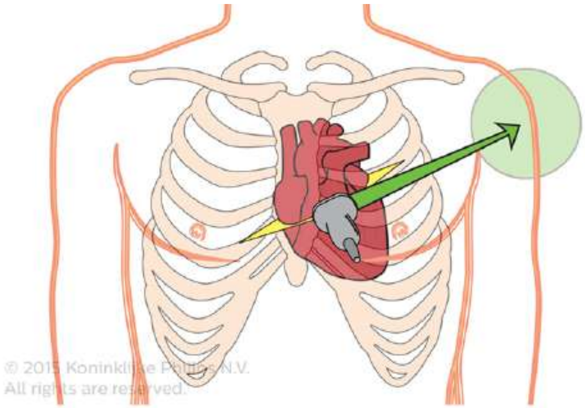
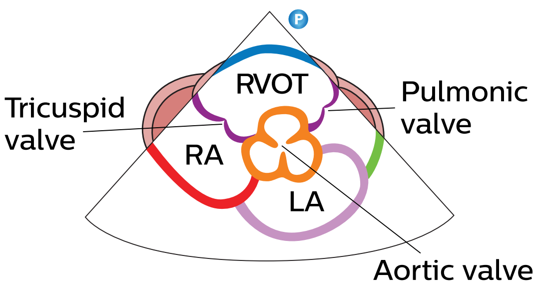
Parasternal long-axis view.

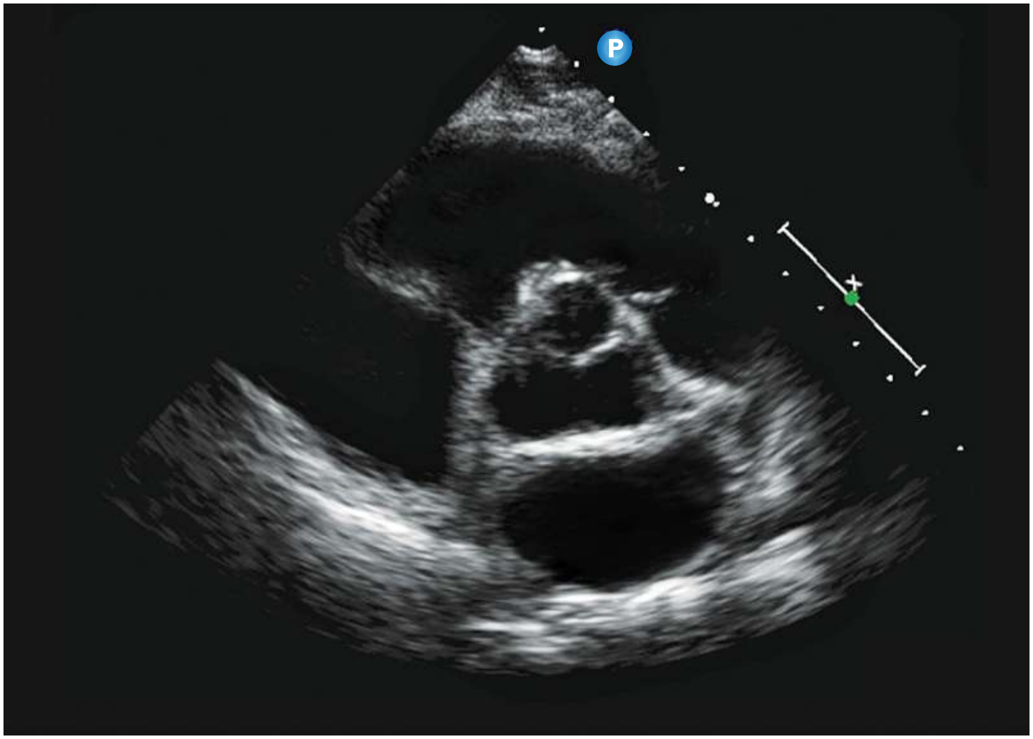
Parasternal short-axis – aortic valve level



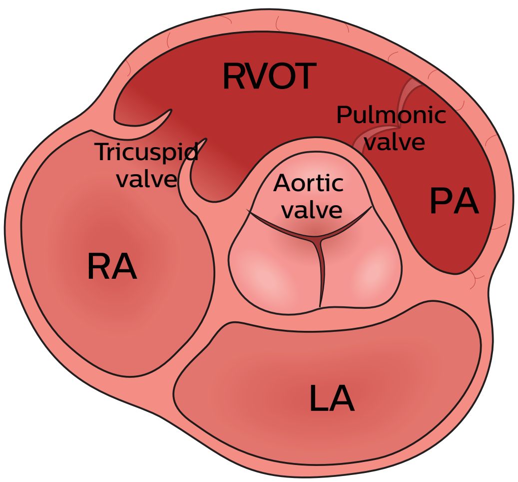


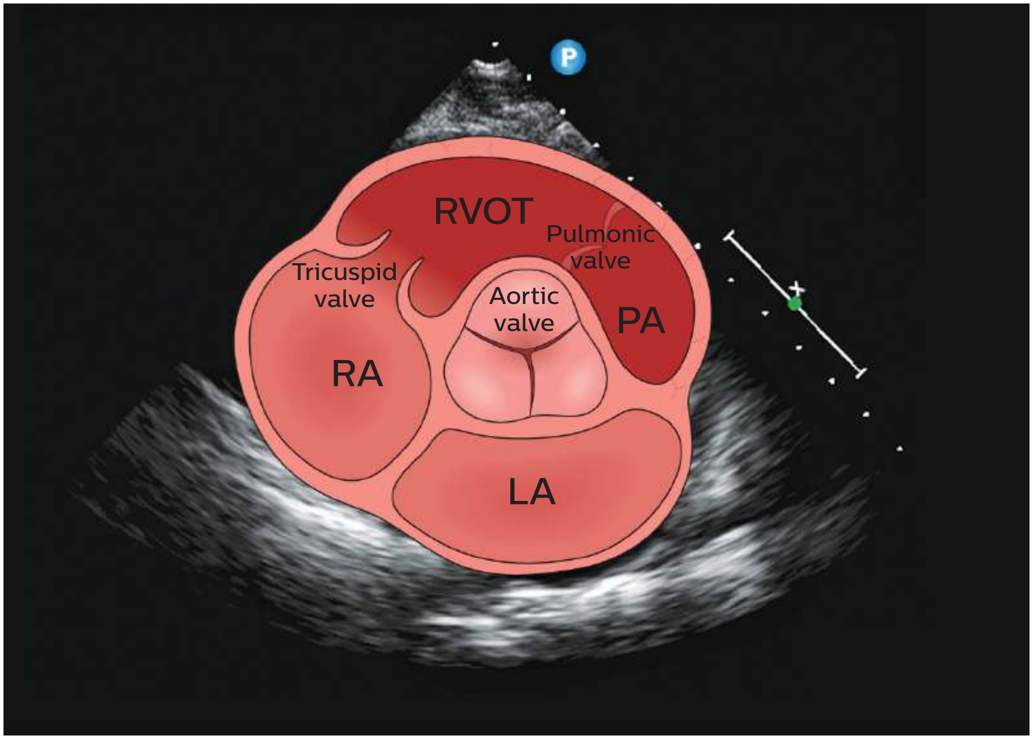
- From the parasternal long-axis view, rotate the transducer 90 degrees clockwise.
- Transducer orientation marker is pointing toward the patient's left shoulder (~2 o'clock).
- Tilt the transducer face slightly upward toward the patient's right shoulder.
- Depth 12–16 cm.

Structure	Assessment
Aortic valve	cusp opening and calcification
Tricuspid valve	motion and regurgitation
Pulmonic valve	motion and regurgitation
RA (right atrium)	better assessed in apical 4-C view
LA (left atrium)	better assessed in apical 4-C view



Parasternal short-axis view – aortic valve level.





Parasternal short-axis view with overlay at the aortic valve level. RVOT = right ventricular outflow tract; RA = right atrium; LA = left atrium; PA = pulmonary artery.

[Video 2]

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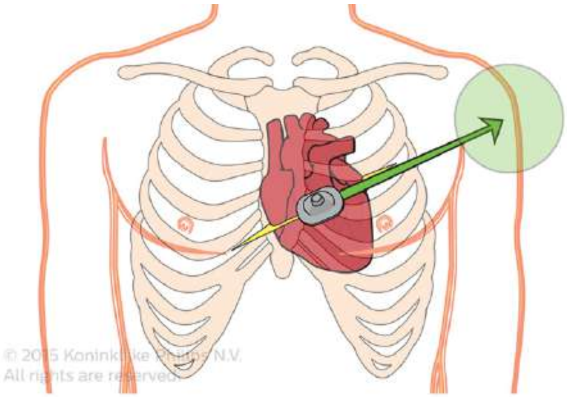
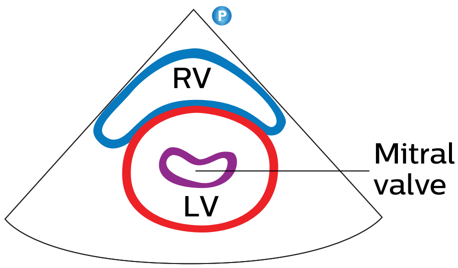
Parasternal short-axis view at the aortic valve level.

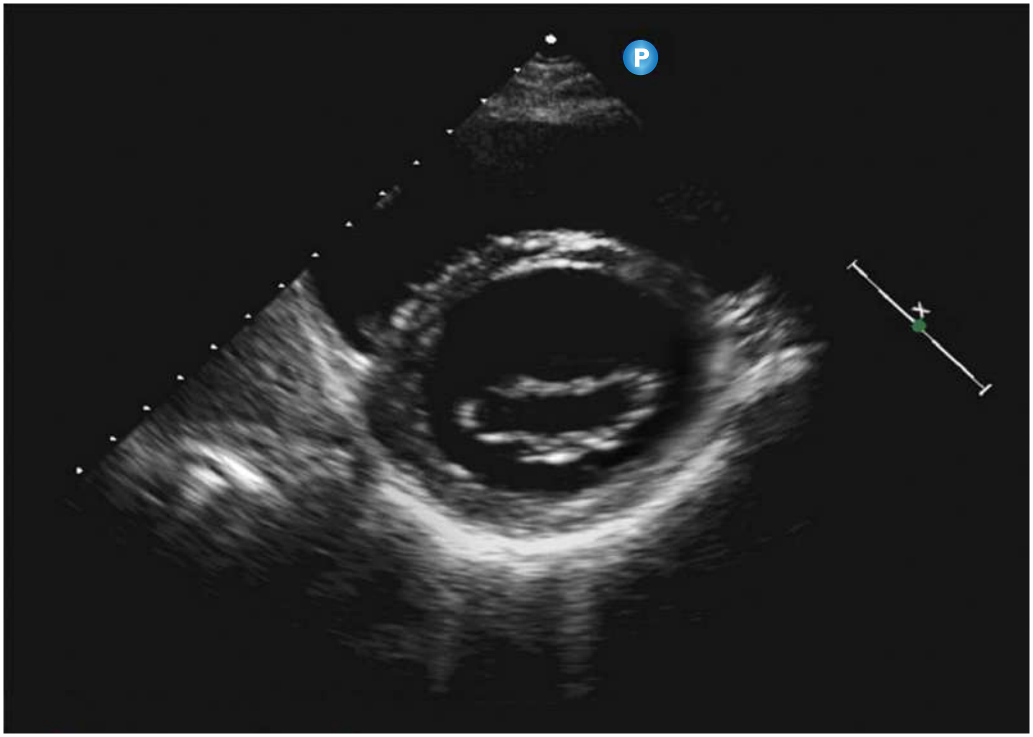
Parasternal short-axis – mitral valve level



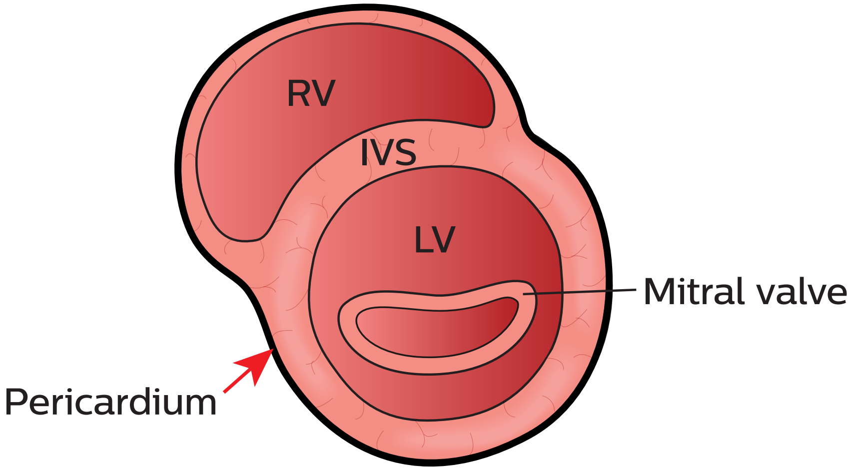


- From the parasternal long-axis view, rotate the transducer 90 degrees clockwise.
- Transducer orientation marker is pointing toward the patient's left shoulder (~2 o'clock).
- Transducer is perpendicular to the chest wall.
- Depth 12–16 cm.

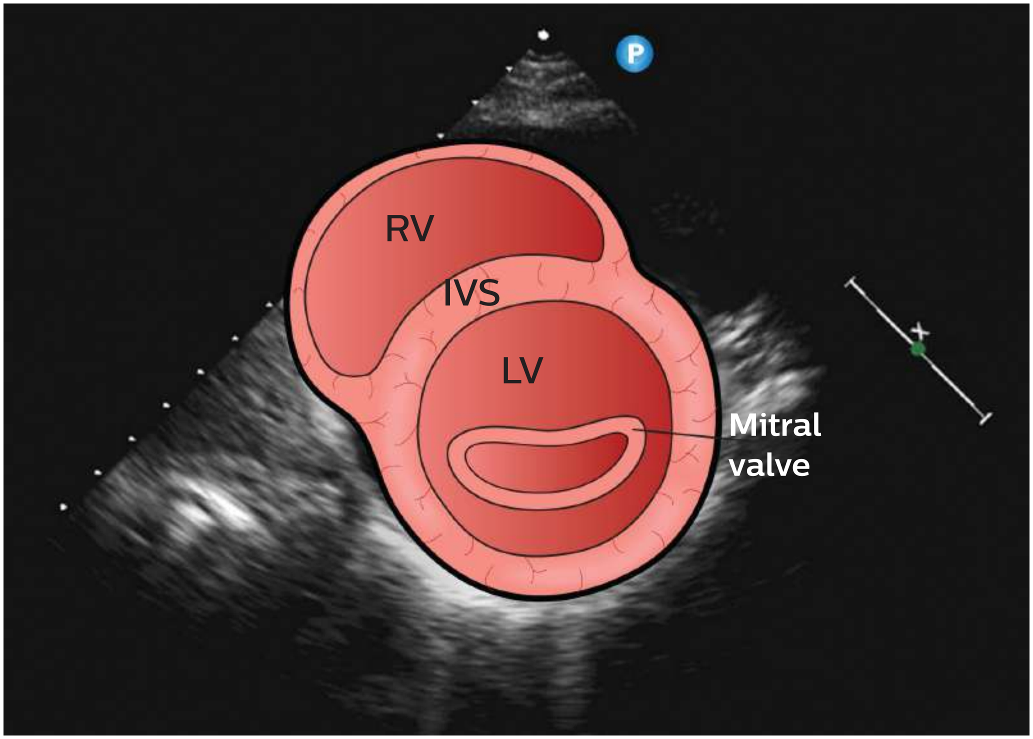
Structure	Assessment
RV (right ventricle)	size and function
IVS (interventricular septum)	systolic and diastolic shape
LV (left ventricle)	size and function
Mitral valve	opening and calcification
Pericardium	pericardial fluid



Parasternal short-axis view – mitral valve level.



Parasternal short-axis – mitral valve level



Parasternal short-axis view with overlay at the mitral valve level. RV = right ventricle; IVS = interventricular septum; LV = left ventricle.

[Video 3]

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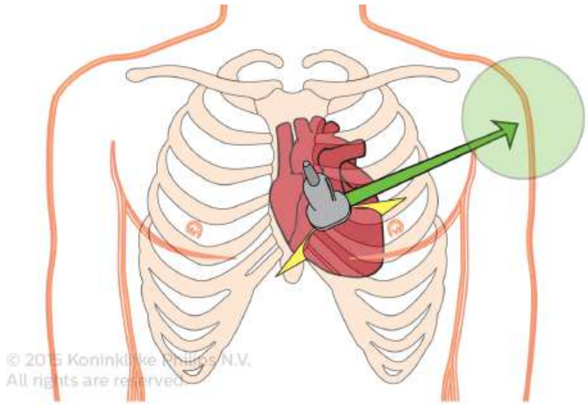
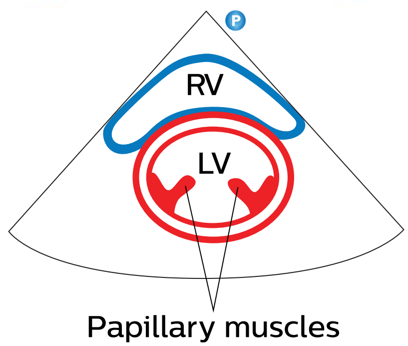
Parasternal short-axis view at the mitral valve level.

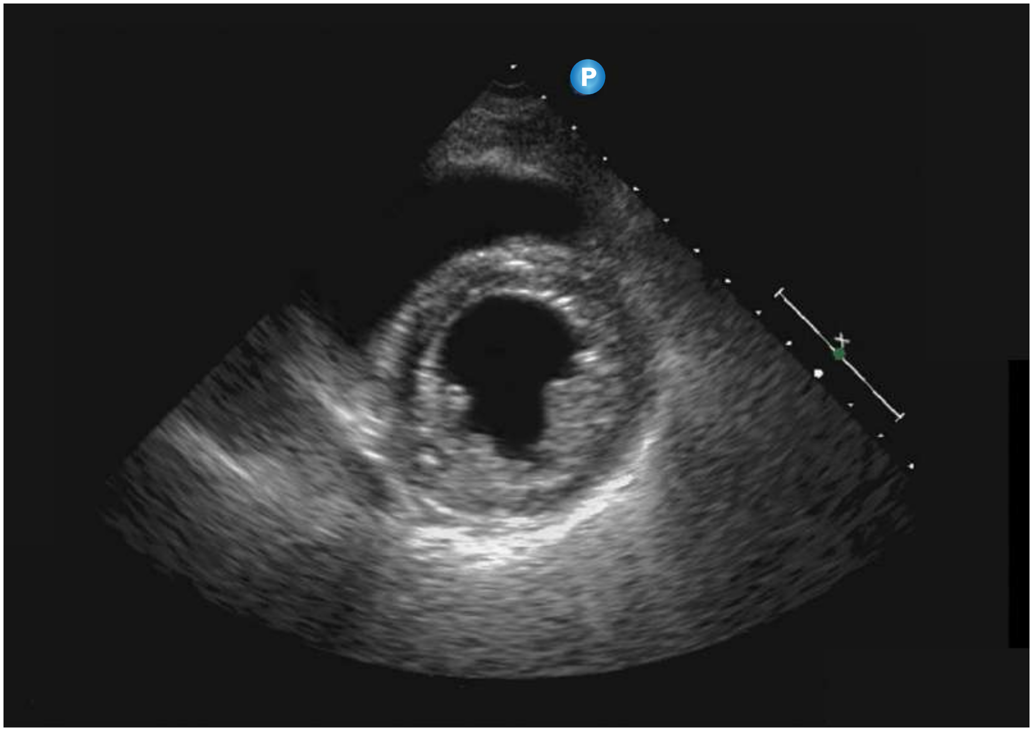
Parasternal short-axis – papillary muscle level



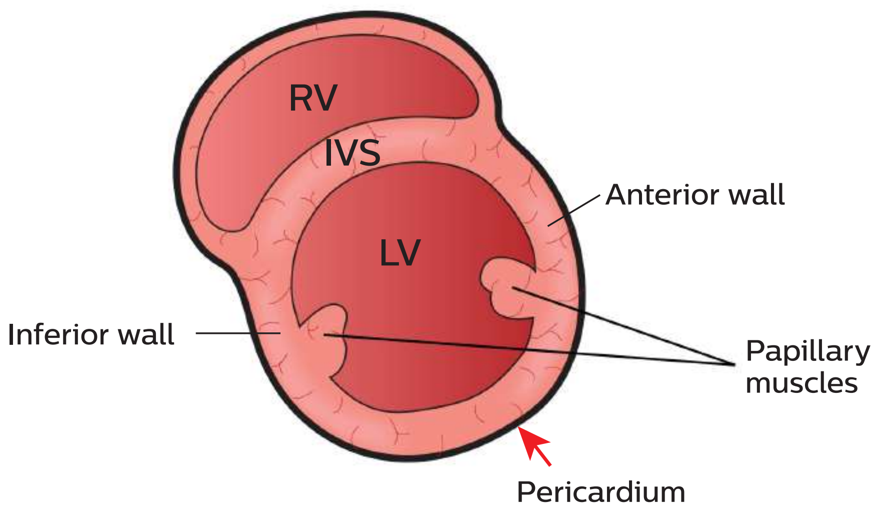


- From the parasternal long-axis view, rotate the transducer 90 degrees clockwise.
- Transducer orientation marker is pointing toward the patient's left shoulder (~2 o'clock).
- Tilt the transducer face slightly downward toward the patient's left flank.
- Depth 12–16 cm.

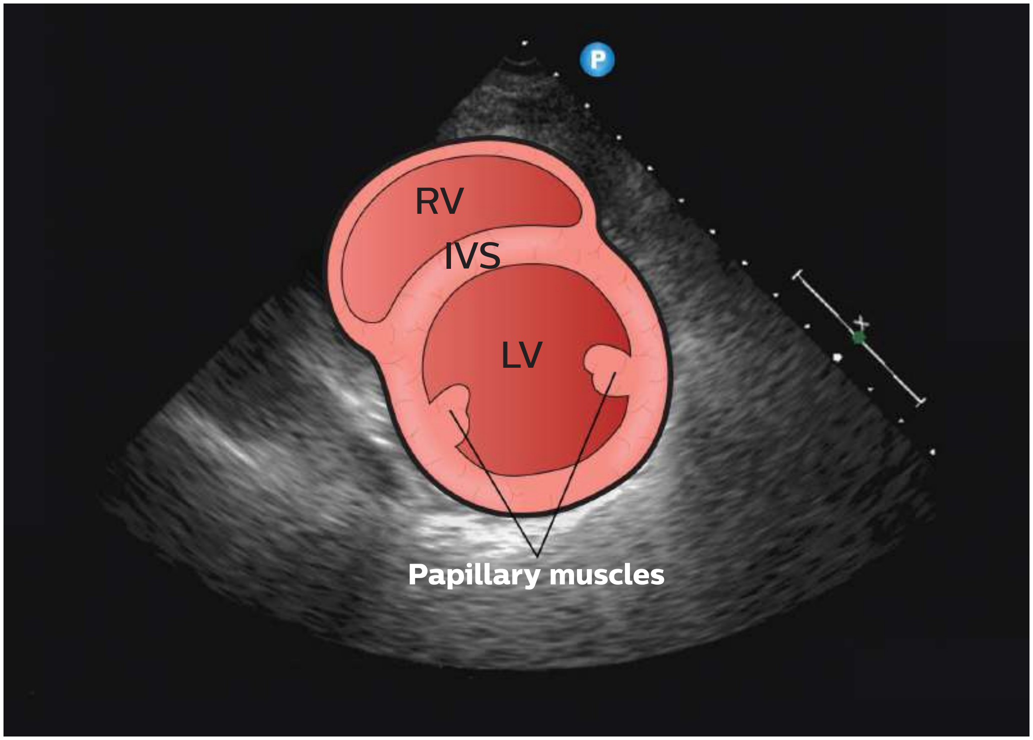
Structure	Assessment
RV (right ventricle)	size and function
IVS (interventricular septum)	systolic and diastolic shape
LV (left ventricle)	size and function
Inferior wall	thickening and motion
Anterior wall	thickening and motion
Pericardium	pericardial fluid



Parasternal short-axis view – papillary muscle level. The LV should be round and in the center of the image.



Parasternal short-axis – papillary muscle level



Parasternal short-axis view with overlay at the papillary muscle level. RV = right ventricle; IVS = interventricular septum; LV = left ventricle.

[Video 4]

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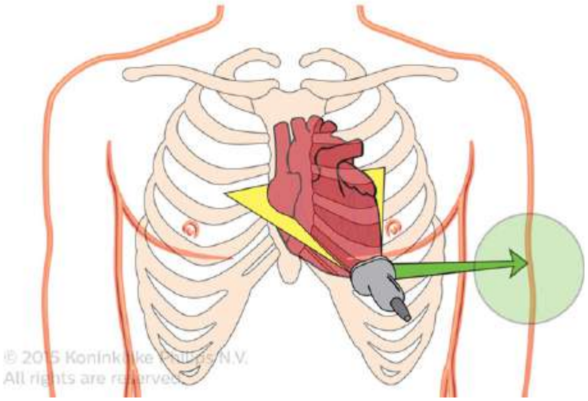
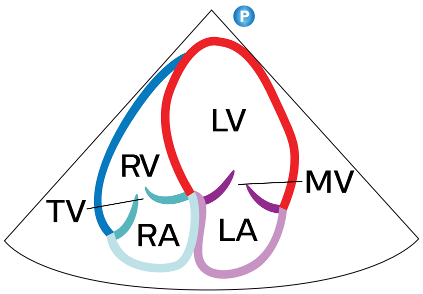
Parasternal short-axis view at the papillary muscle level.

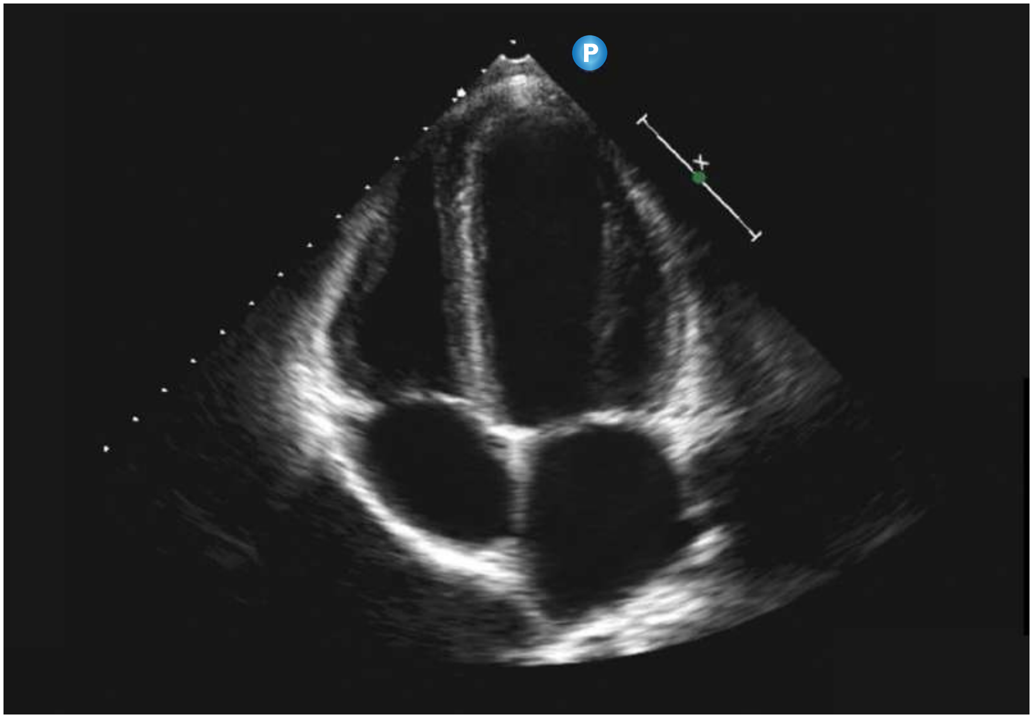
Apical four-chamber (A4C)



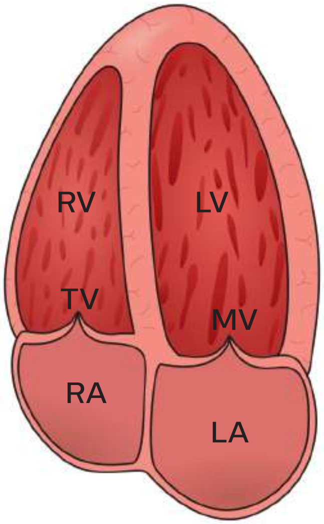


- The transducer is placed on the apical impulse.
- Tilt the face of the transducer up until the ultrasound beam cuts through the long axis of the heart.
- Transducer orientation marker is at ~3 o'clock.
- Depth: 14–18 cm.

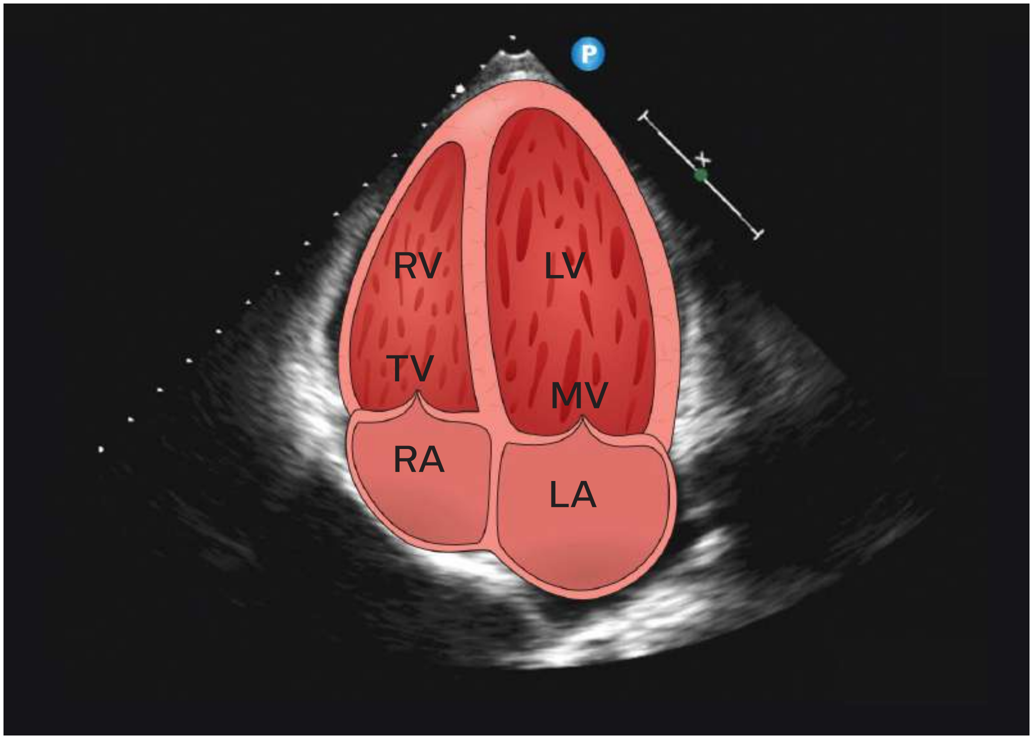
Structure	Assessment
RV (right ventricle)	size and function
LV (left ventricle)	size and function
LA (left atrium)	size
RA (right atrium)	size
MV (mitral valve)	motion and regurgitation
TV (tricuspid valve)	motion and regurgitation



Apical four-chamber view – tilt the transducer up until all four chambers are visualized and the long axis of the heart is vertical.



Apical four-chamber (A4C)



Apical four-chamber view with overlay. RV = right ventricle; LV = left ventricle; TV = tricuspid valve; MV = mitral valve; RA = right atrium; LA = left atrium.

[Video 5]

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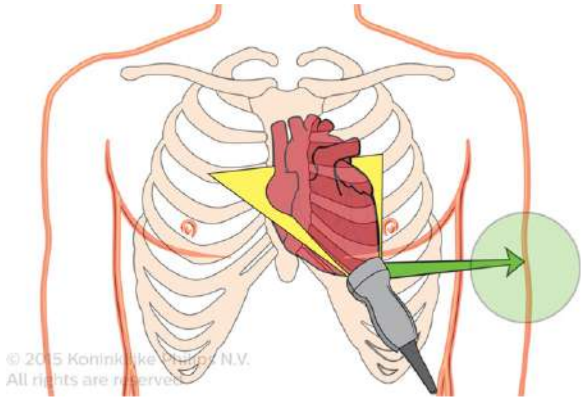
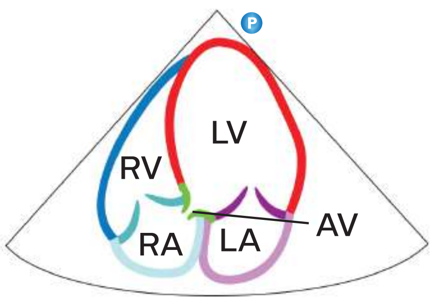
Apical four-chamber view.

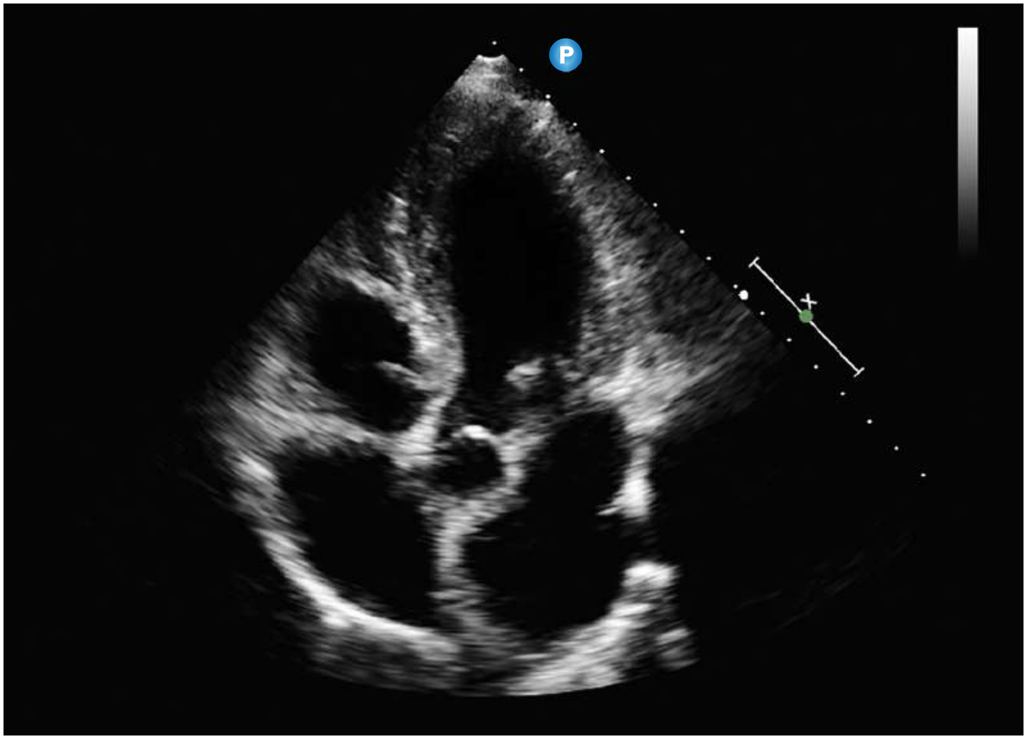
Apical five-chamber (A5C)



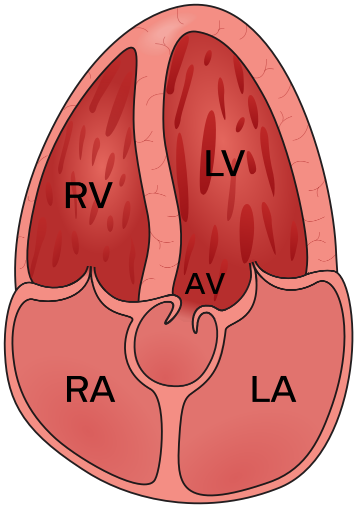
- From the apical four-chamber view, tilt the face of the transducer slightly upward until the aortic valve appears.
- Transducer orientation marker is at ~3 o'clock.
- Depth 14–18 cm.



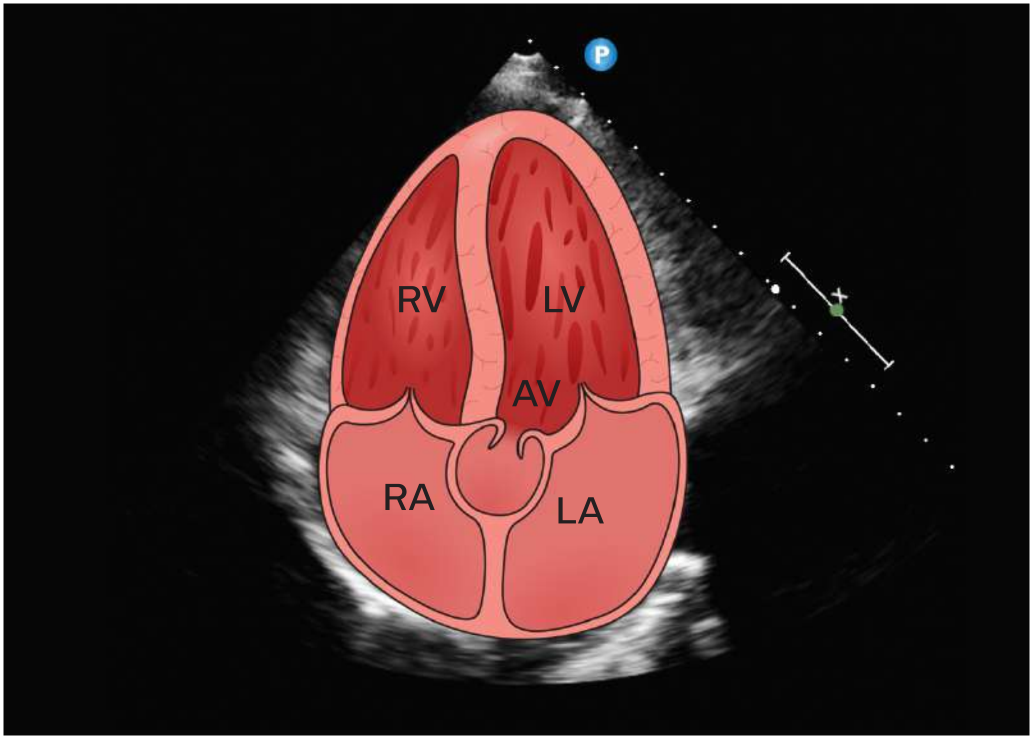
Structure	Assessment
AV (aortic valve)	motion and regurgitation
LV (left ventricle)	foreshortened in this view
RV (right ventricle)	foreshortened in this view
LA (left atrium)	foreshortened in this view
RA (right atrium)	foreshortened in this view



Apical five-chamber view – tilt the transducer upward until the aortic valve appears. The LV and RV will be foreshortened in this view.



Apical five-chamber (A5C)



Apical five-chamber view with overlay. RV = right ventricle; LV = left ventricle; AV = aortic valve; RA = right atrium; LA = left atrium.

[Video 6]

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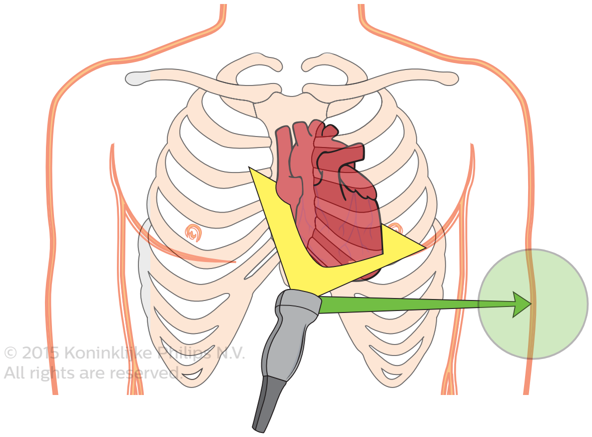
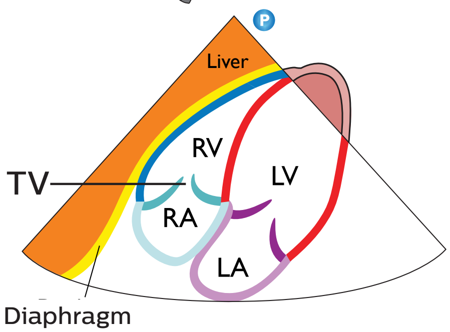
Apical five-chamber view.

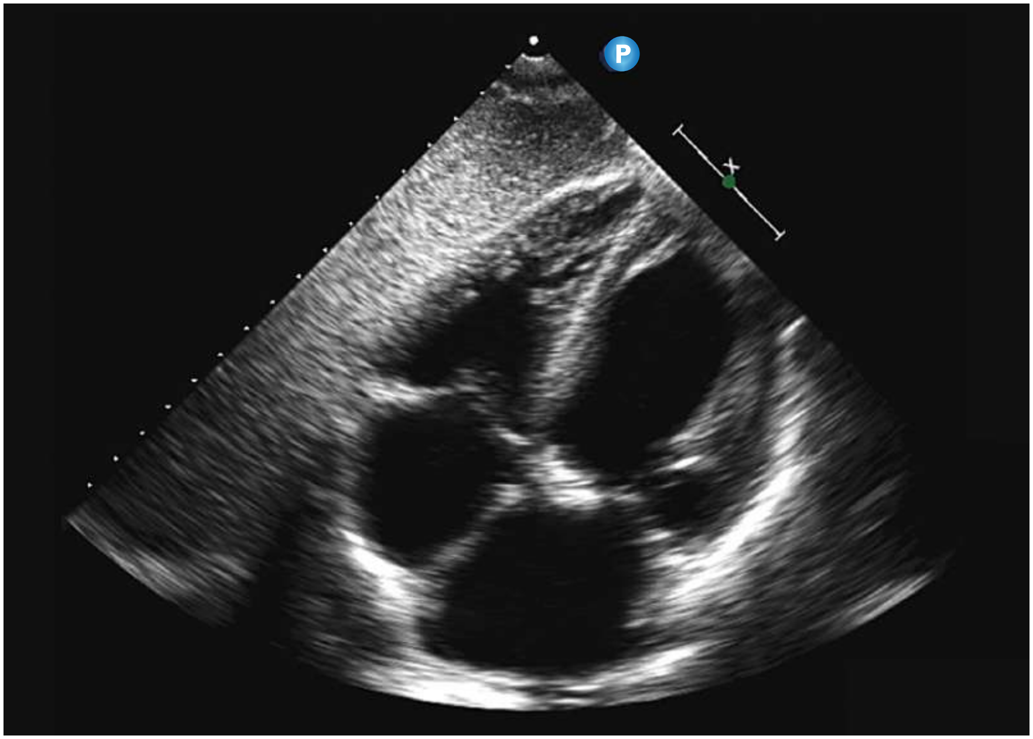
Subcostal four-chamber



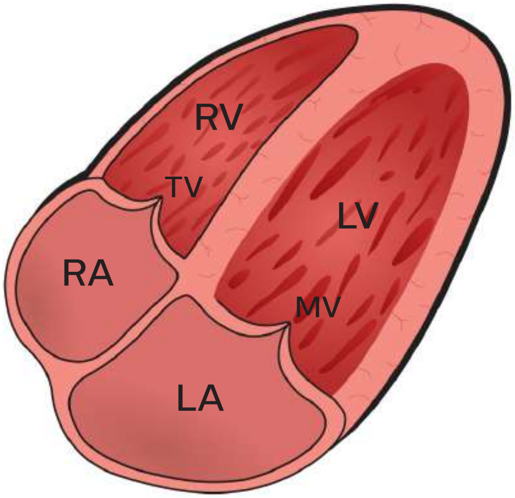


- Patient is supine.
- Transducer is placed 2–3 cm below the xyphoid process.
- Direct the transducer toward the patient's chin/left shoulder.
- Transducer orientation marker is at ~3 o'clock.
- Hold the transducer palm down to facilitate cephalad angulation of the ultrasound beam.
- Depth 16–24 cm.

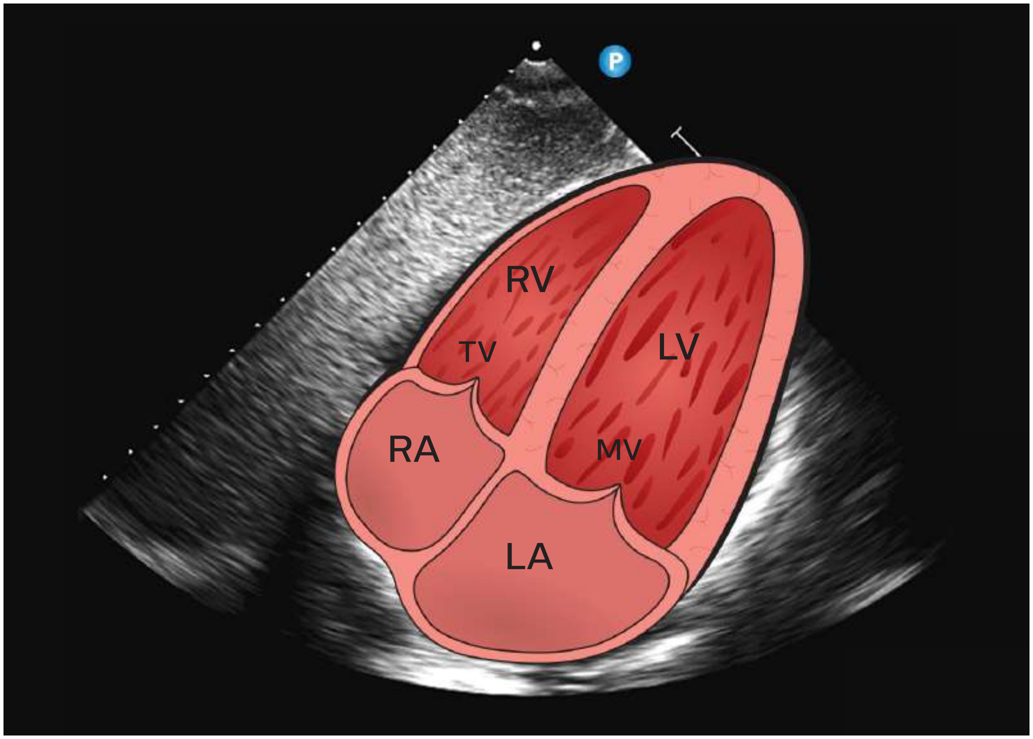
Structure	**Assessment**
LV (left ventricle)	size and function
RV (right ventricle)	size and function
LA (left atrium)	better assessed from A4C view
RA (right atrium)	better assessed from A4C view
MV (mitral valve)	motion and regurgitation
TV (tricuspid valve)	motion and regurgitation
Pericardium	pericardial fluid



Subcostal four-chamber view – directing the ultrasound beam too posterior is a common mistake in the subcostal view.



Subcostal four-chamber



Subcostal four-chamber view with overlay. RV = right ventricle; LV = left ventricle; TV = tricuspid valve; MV = mitral valve; RA = right atrium; LA = left atrium.

[Video 7]

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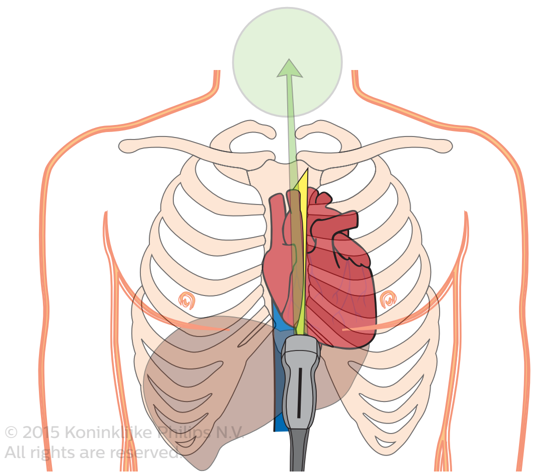
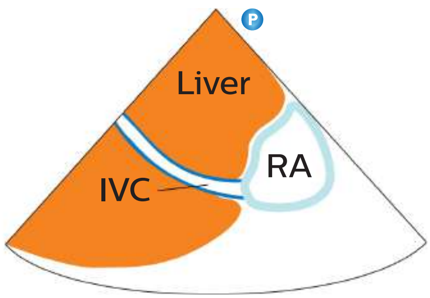
Subcostal four-chamber view.

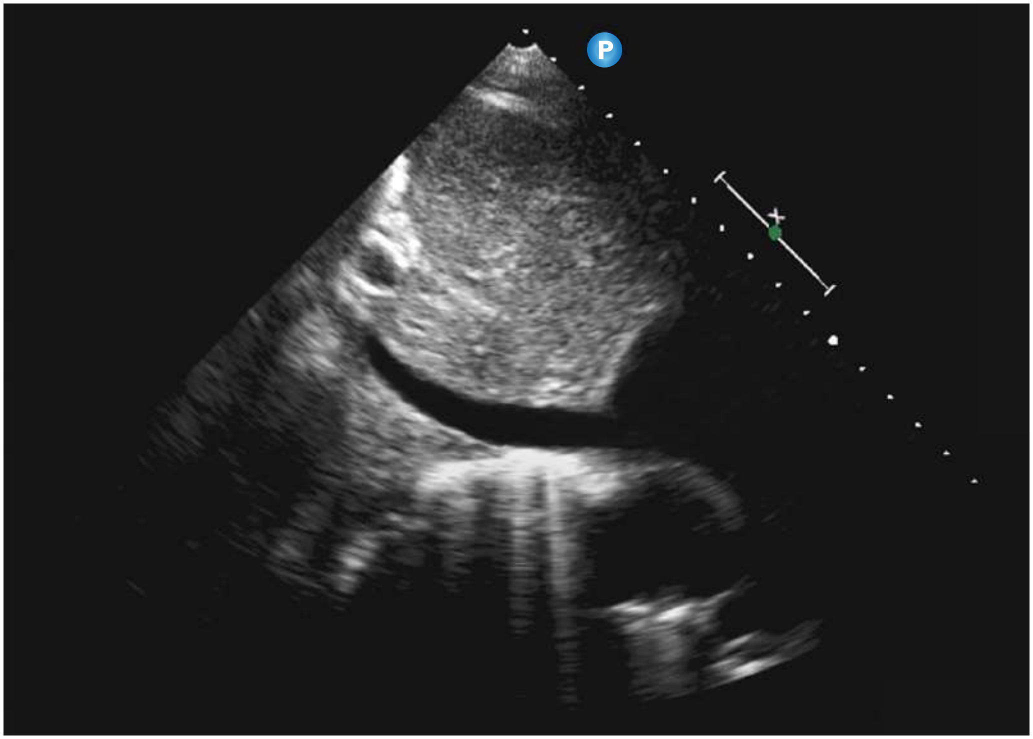
Subcostal inferior vena cava (IVC)



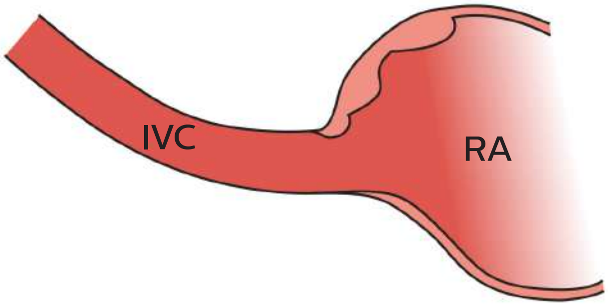


- From subcostal four-chamber view, rotate the transducer 90 degrees counter-clockwise, always keeping the right atrium on the screen.
- Transducer orientation marker at ~12 o'clock.
- Depth 16–24 cm.
- It is important to see the IVC merging into the RA. This will confirm that you are not visualizing the aorta.

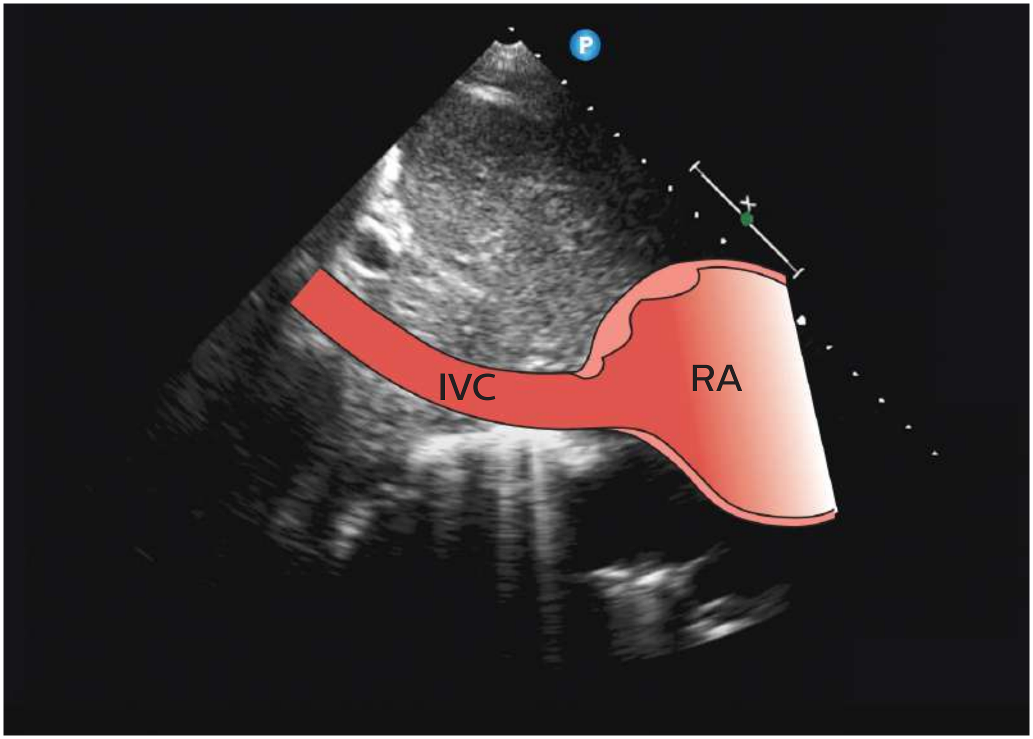
Structure	Assessment
IVC (inferior vena cava)	size and respiratory variations



Subcostal inferior vena cava view – the IVC should be seen merging into the RA.



Subcostal inferior vena cava (IVC)



Subcostal view of the inferior vena cava with overlay.
IVC = inferior vena cava; RA = right atrium.

[Video 8]

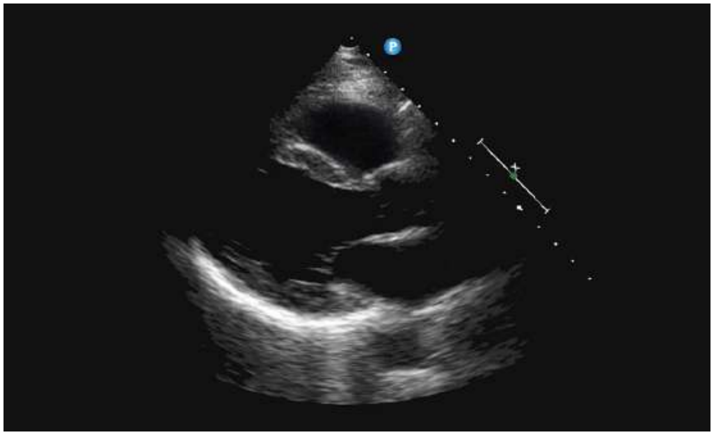
Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

Subcostal inferior vena cava view.

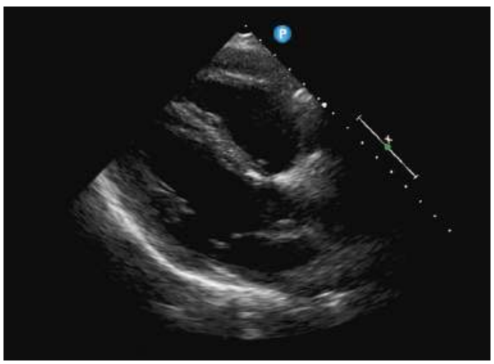
4 Tips for image optimization

Parasternal long-axis: optimizing the image

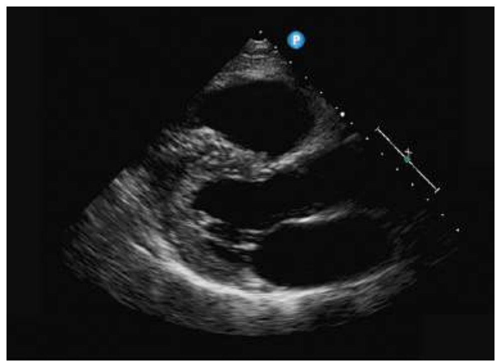
Optimal parasternal long-axis view



Interventricular septum and LV wall are parallel and as horizontal as possible.

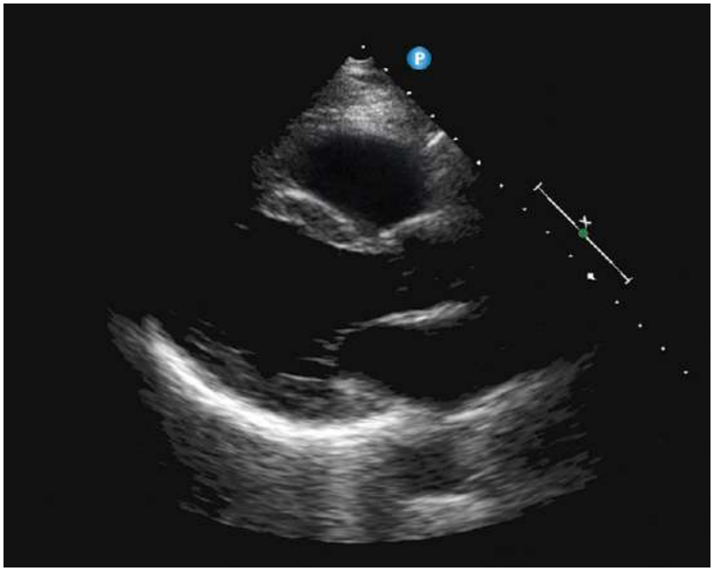


If the IVS and LV wall are vertical, try moving the transducer one intercostal space higher.



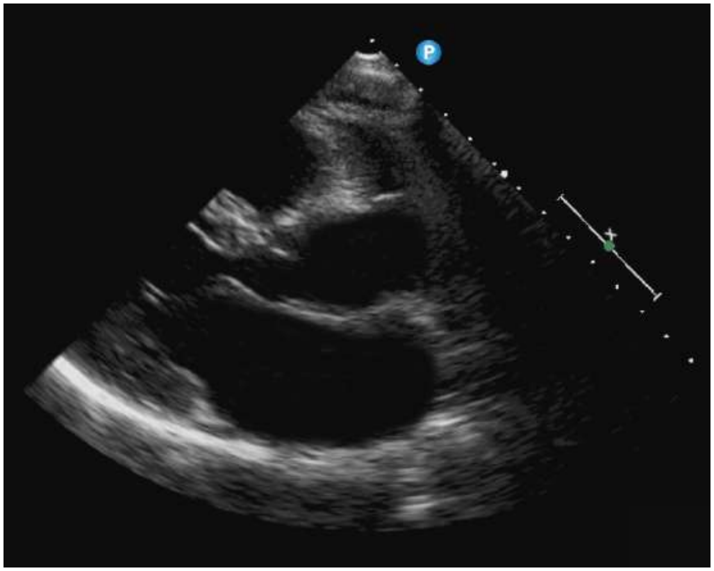
If the LV appears "closed," rotate the transducer to open it.

Caution: The septum and LV wall must be parallel in order to estimate LV function using the parasternal long-axis view. If the septum and LV wall are NOT parallel, LV function will be overestimated.



Optimal parasternal long-axis view

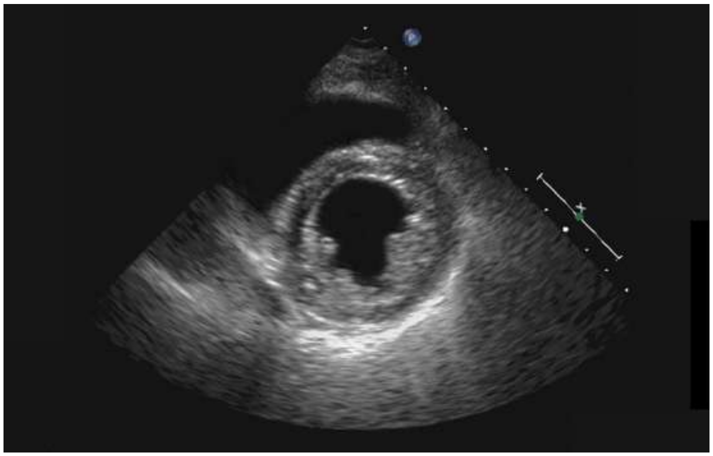
Aortic and mitral valves are in the center of the image.



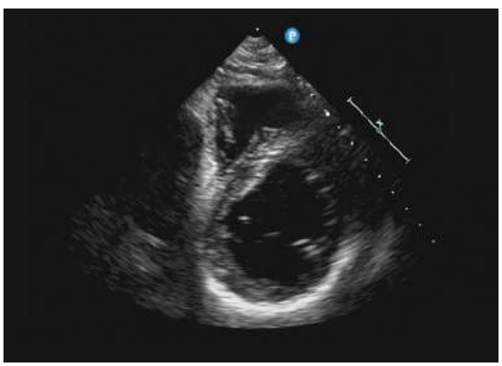
If the valves are off-center, tilt the transducer away from the sternum.

Parasternal short-axis, papillary muscle level: optimizing the image

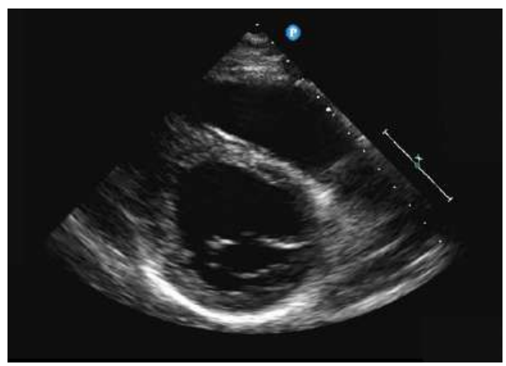
Optimal parasternal short-axis view



The LV should be round and in the center.



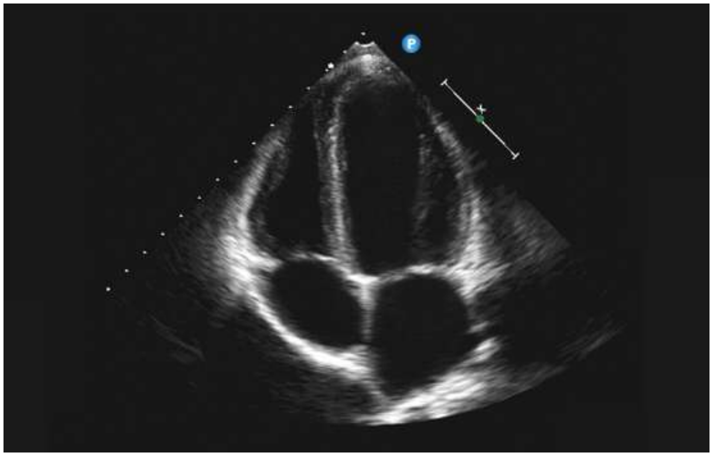
If the LV is pear-shaped, you are too low, try scanning one intercostal space higher.



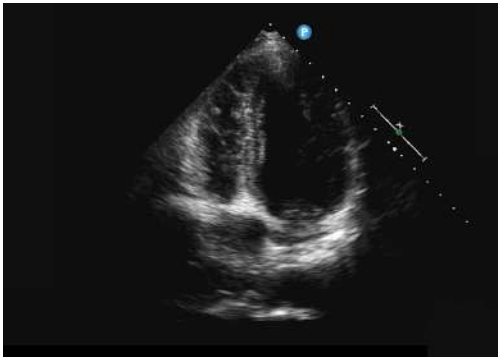
If the LV is asymmetric, rotate the transducer clockwise or counter-clockwise.

Apical four-chamber: optimizing the image

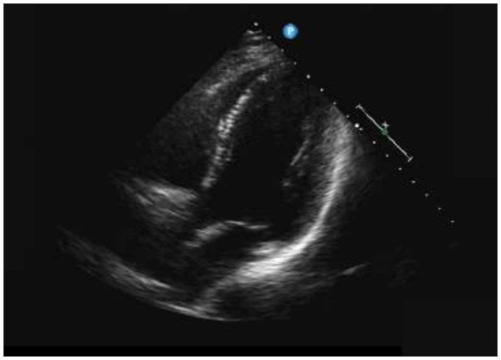
Optimal four-chamber view



All four chambers are visualized and the long-axis of the heart is vertical.



If you don't see the atria, the transducer may be aimed too posterior. Tilt the face of the transducer upwards.



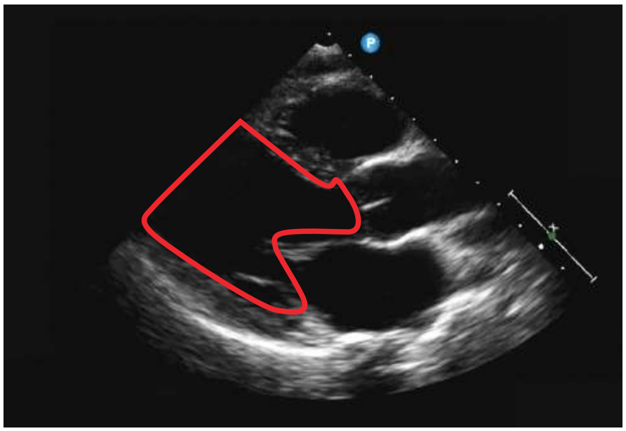
If the heart appears tilted to the right, you are too medial. Move your transducer laterally.

5 Assessment of structures

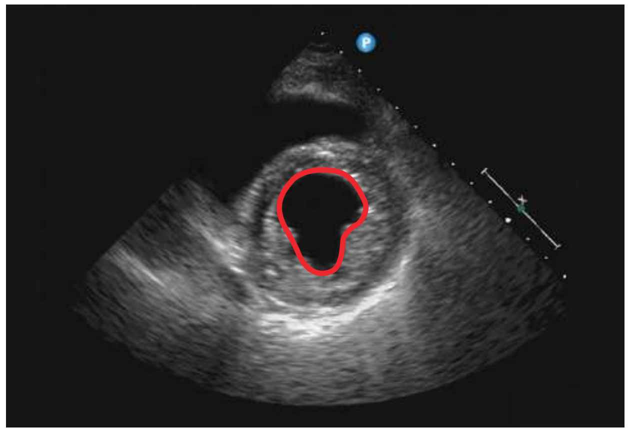
Left ventricle

LV function

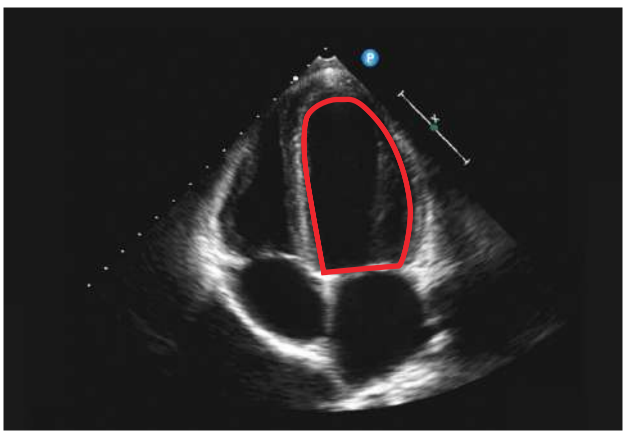
LV function can be assessed from the following views:



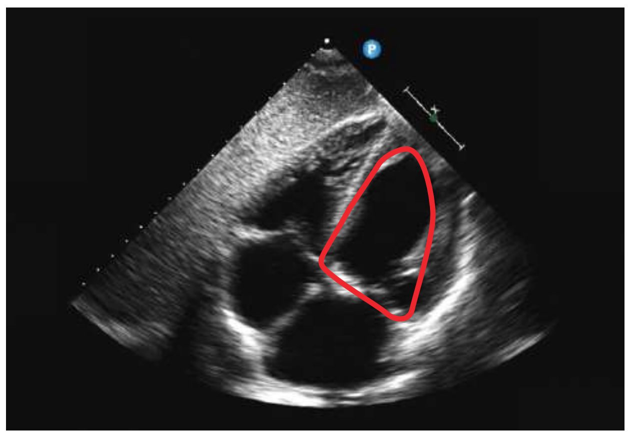
Parasternal long-axis



Parasternal short-axis



Apical four-chamber



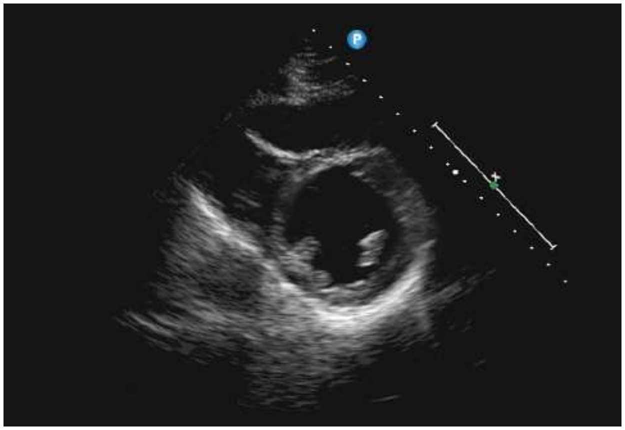
Subcostal four-chamber

LV function

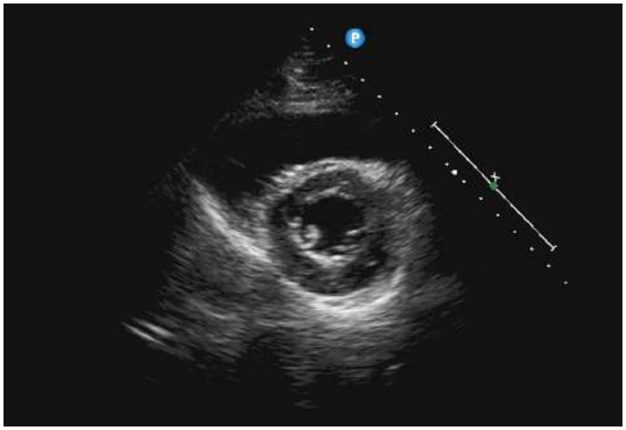
For most clinical purposes, visual estimation of LV function (ejection fraction) provides accurate and reliable information.

LV function can be assessed by visual estimation using:

- Wall thickening and motion
- Comparison between LV size in systole and diastole



Diastole – parasternal short-axis papillary muscle level

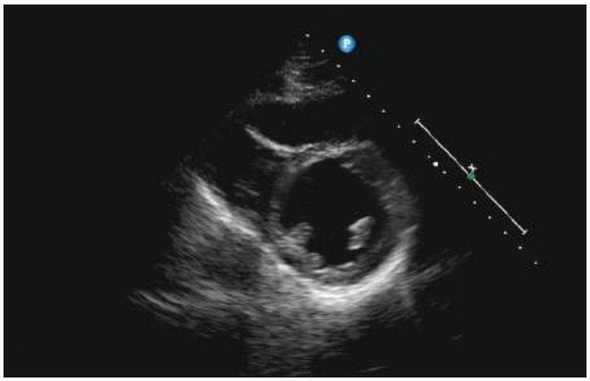


Systole – parasternal short-axis papillary muscle level

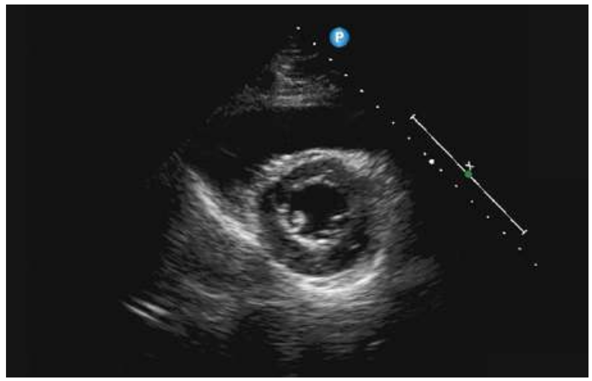
LV function

Normal LV function

The walls thicken and move toward the center of LV symmetrically. Note the difference in the LV size between diastole and systole. All examples are the parasternal short-axis papillary muscle level view.



Diastole

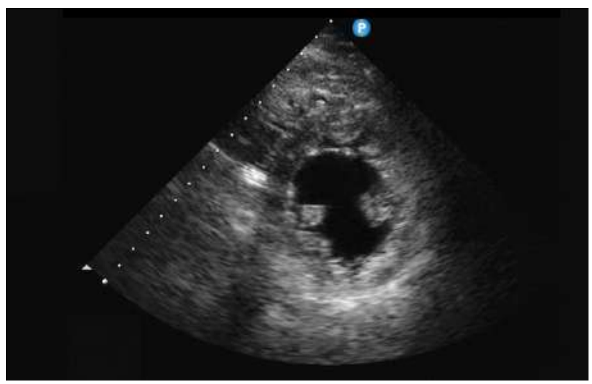


Systole

Mild-moderate LV dysfunction

There is moderate wall thickening and mild-moderate change in LV size between diastole and systole.

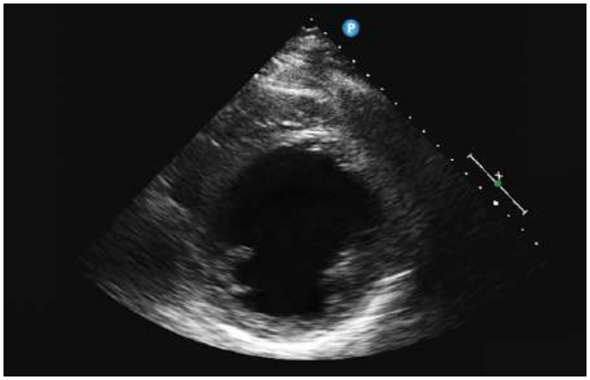
Diastole



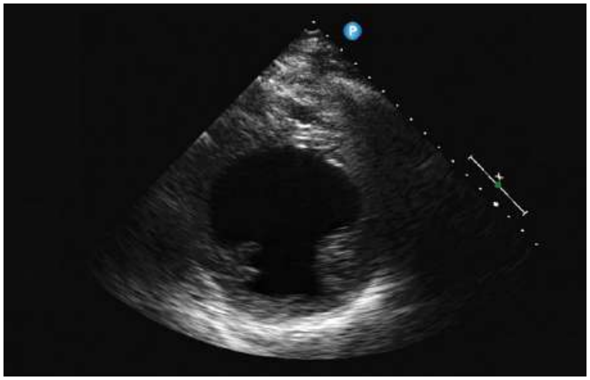
Systole

Severe LV dysfunction

There is only minimal change in wall thickness and chamber size between diastole and systole.



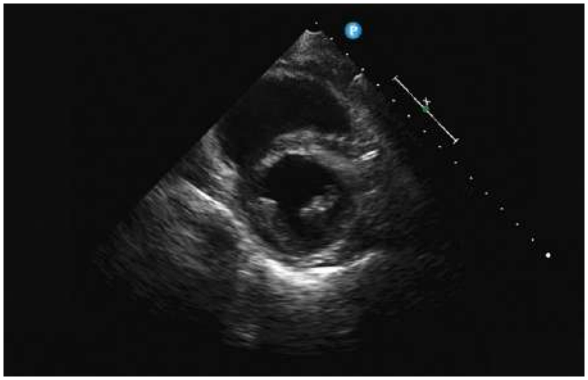
Diastole



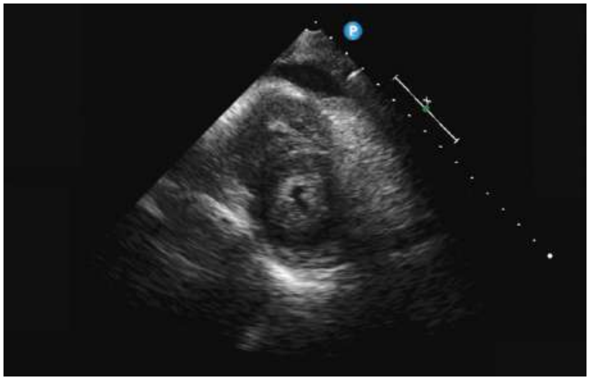
Systole

Hyperdynamic LV function

Wall thickening and motion almost obliterate the chamber in systole.

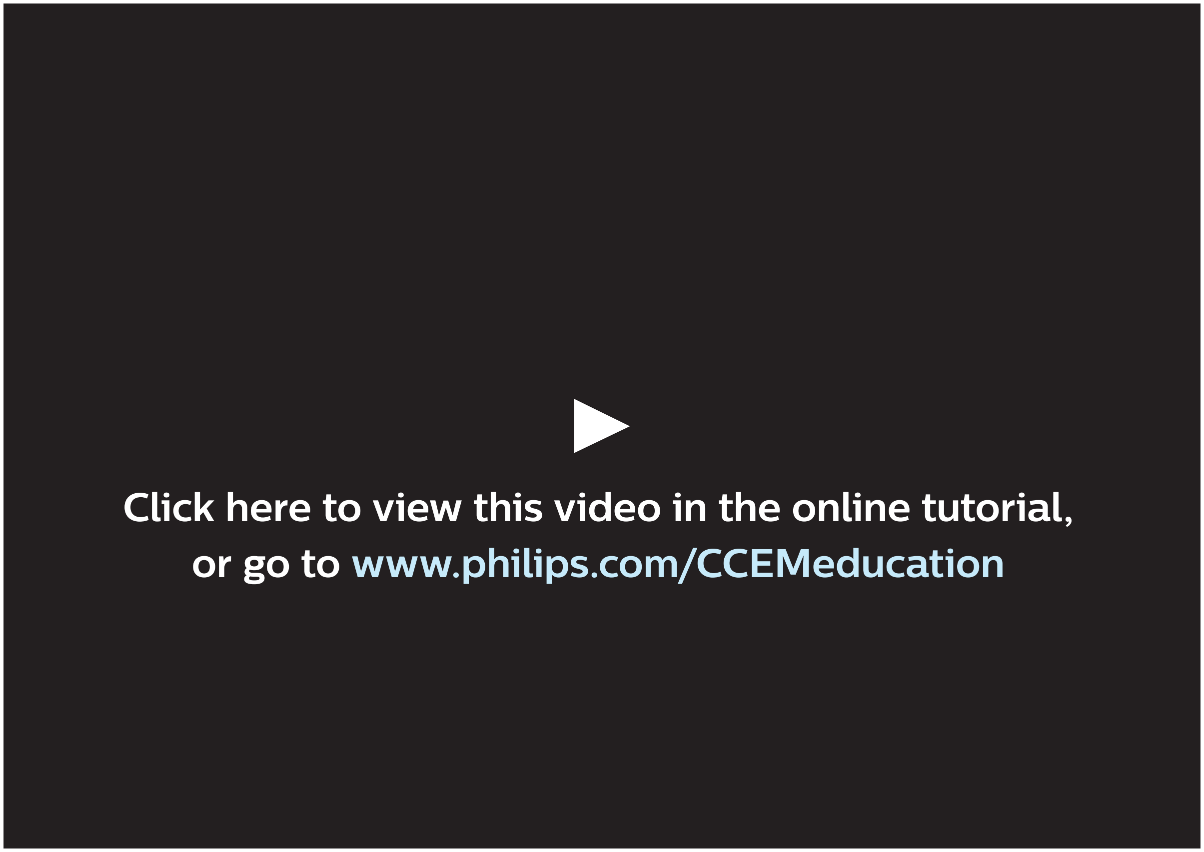


Diastole



Systole

[Video 9]



Video demonstrating normal LV function, severely depressed LV function, and hyperdynamic LV function in a parasternal short-axis view at the papillary muscle level. Note the motion and thickening of the LV walls and the change in chamber size in each example.

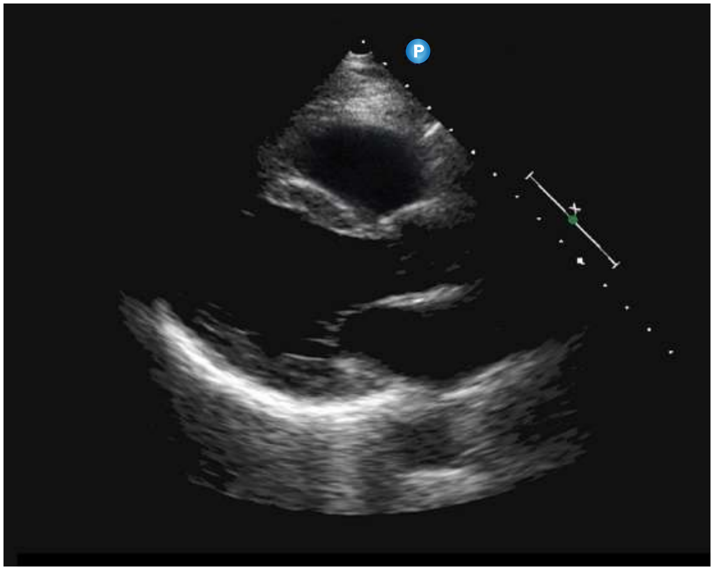
[Video 10]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

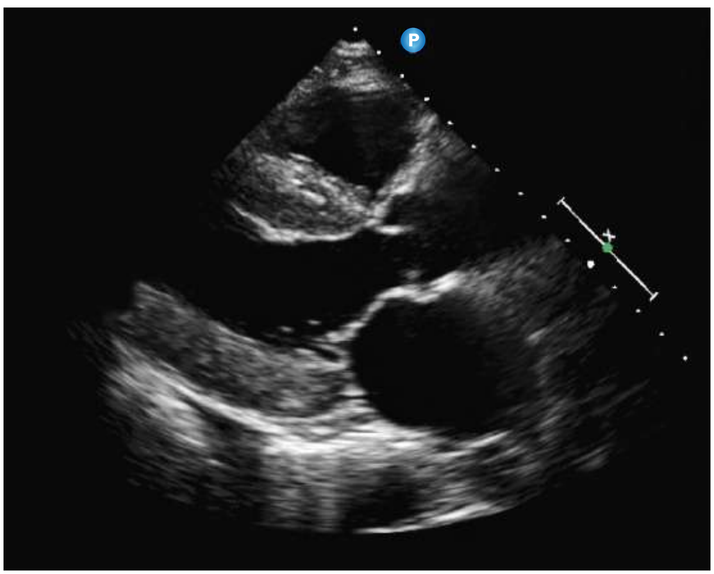
Video demonstrating normal LV function, severely depressed LV function, and hyperdynamic LV function in an apical four-chamber view. Note the motion and thickening of the LV walls and the change in chamber size in each example.

Left ventricular hypertrophy (LVH)

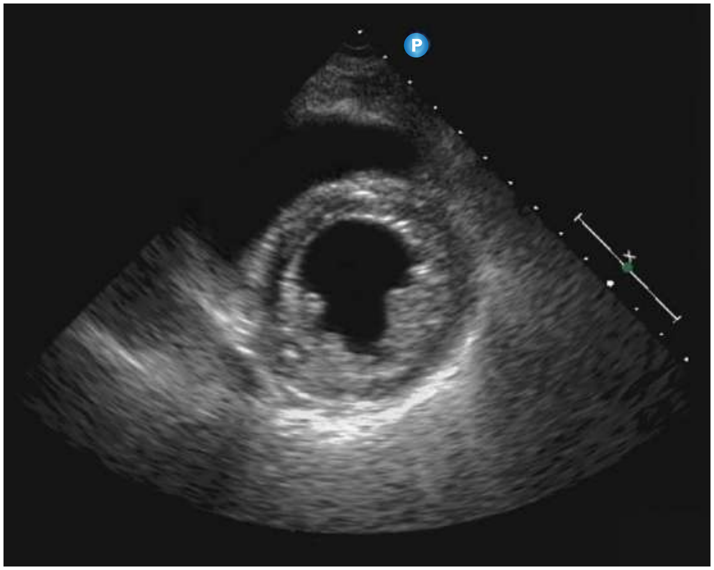
Note the thickened left ventricular walls in each image demonstrating LVH.



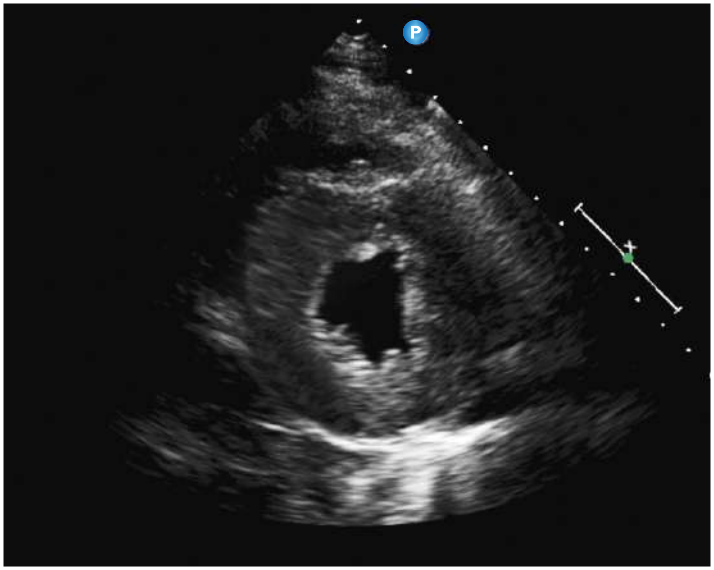
Normal parasternal long-axis



Parasternal long-axis with LVH



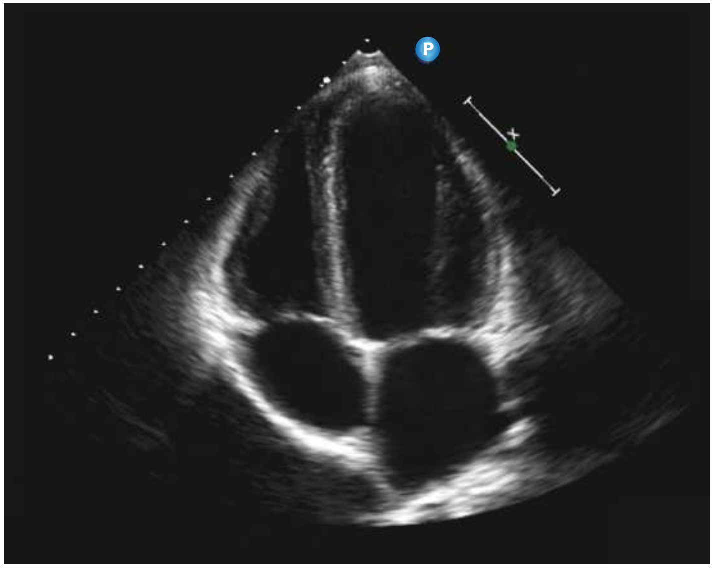
Normal parasternal short-axis papillary muscle level



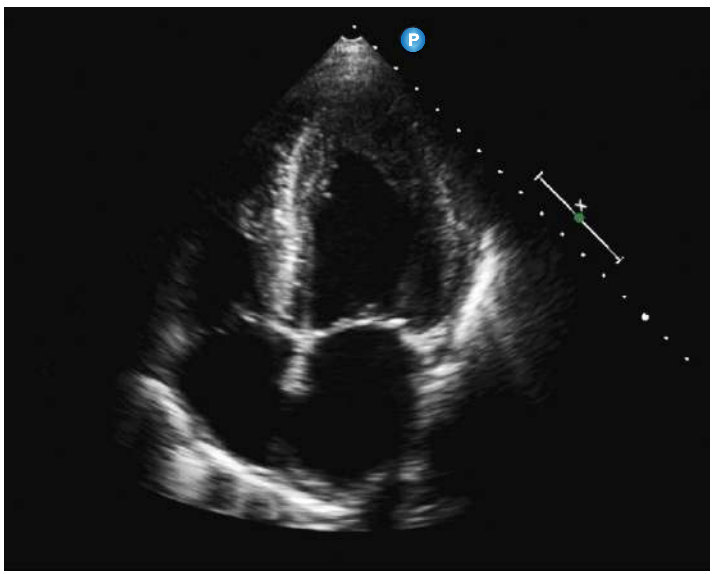
Parasternal short-axis with LVH

Left ventricular hypertrophy (LVH)

Note the thickened left ventricular walls in each image demonstrating LVH.



Normal apical four-chamber



Apical four-chamber with LVH

[Video 11]

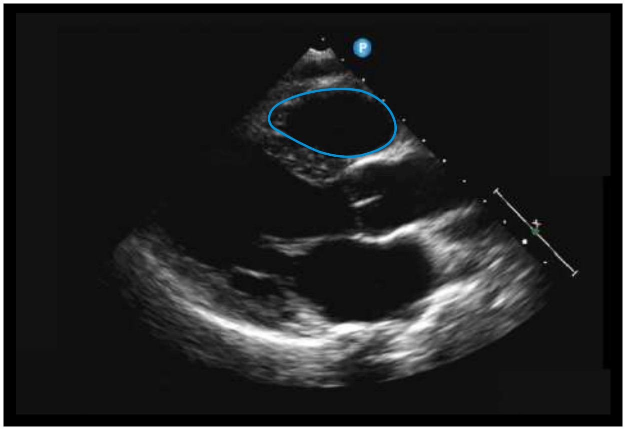
Click here to view this video in the online tutorial, or go to www.philips.com/CCEMeducation

Video demonstrating severe concentric left ventricular hypertrophy in parasternal long-axis, parasternal short-axis and apical four-chamber views. Note the thickened LV walls in each view.

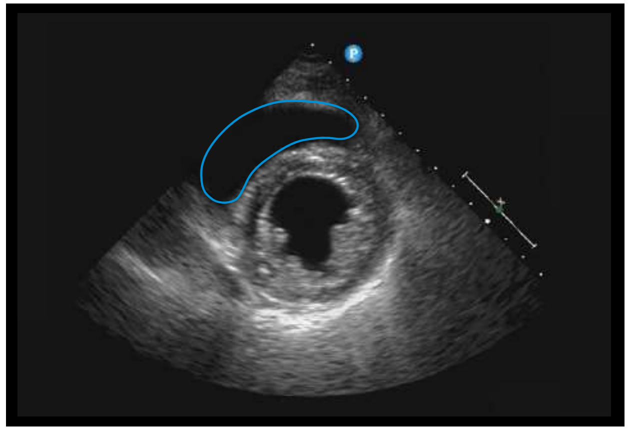
Right ventricle

RV function

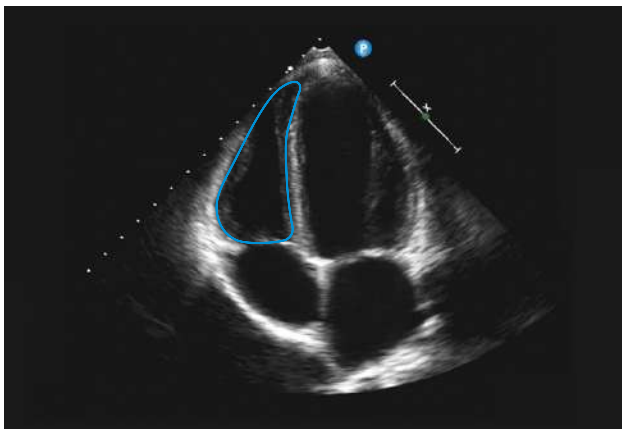
RV can be assessed from:



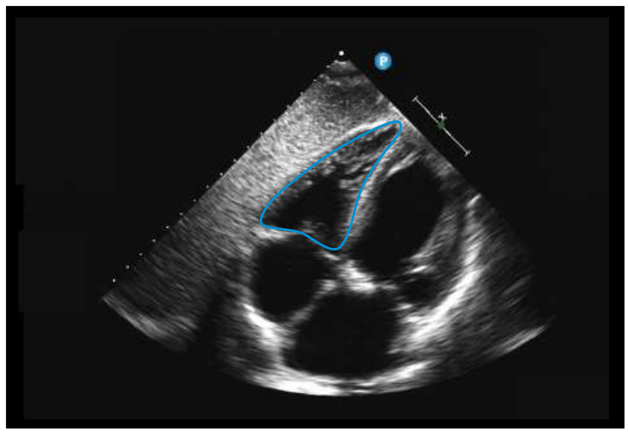
Parasternal long-axis



Parasternal short-axis, papillary muscle level



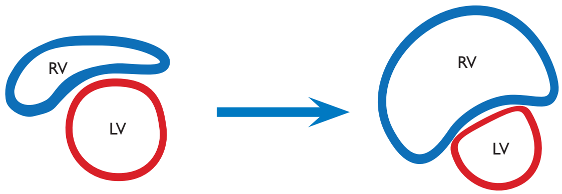
Apical four-chamber

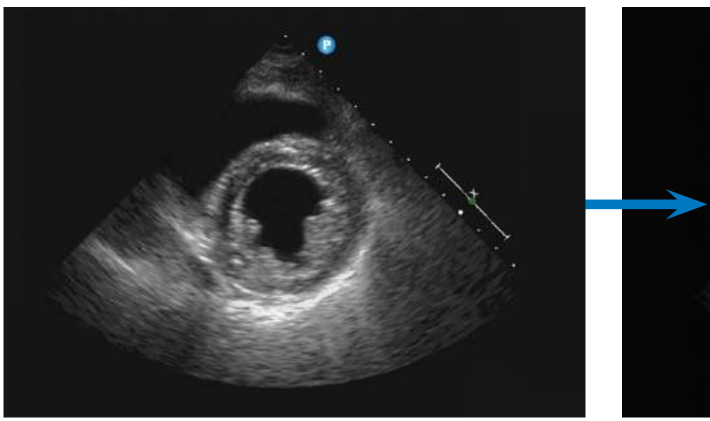


Subcostal four-chamber

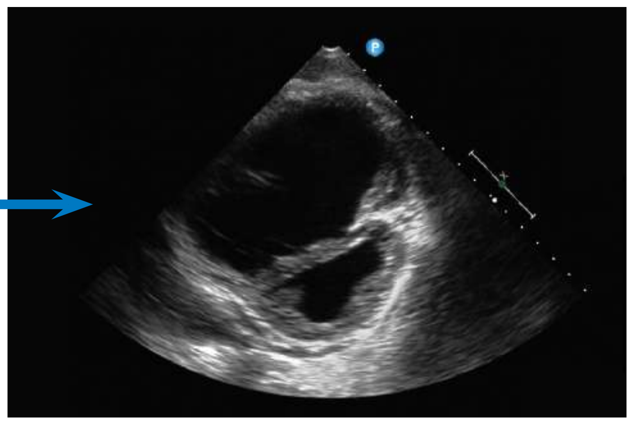
RV assessment

- Normal RV size < 2/3 LV size.
- RV pressure or volume overload will result in interventricular septal flattening in diastole (D-shape of LV) visualized in the parasternal short-axis view at the papillary muscle level.
- RV size is difficult to estimate in a standard fashion due to its complex shape. There are no cut-off values for mild/moderate/severe RV enlargement.





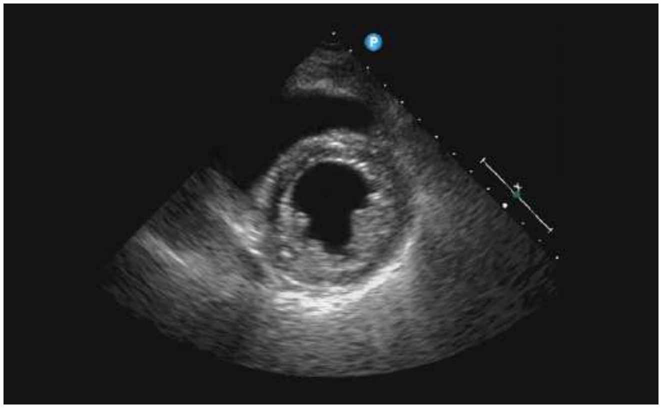
Normal RV (diastole) – parasternal short-axis papillary muscle level.



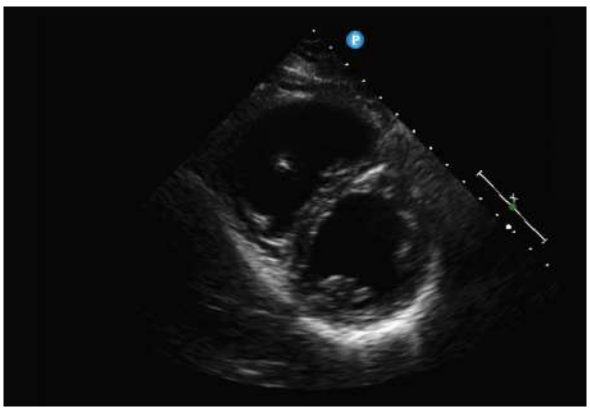
RV overload (diastole) – parasternal short-axis papillary muscle level. Note the flattening of the interventricular septum.

RV assessment

All examples are the parasternal short-axis papillary muscle level view.

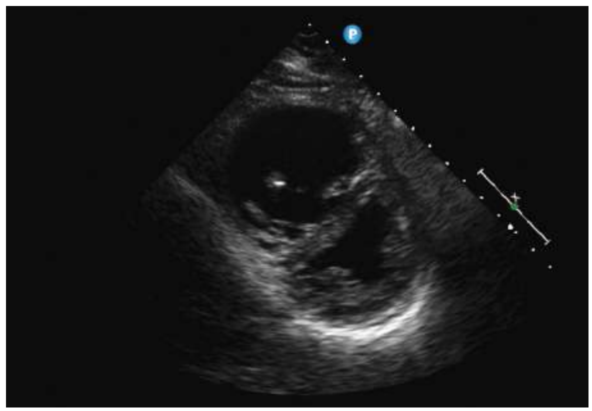


Normal RV (diastole)



Example of RV dilatation

Note the size of the RV is similar to the size of the LV.



Example of severe RV dilatation and dysfunction

Note the size of the RV and the flattening of the interventricular septum.

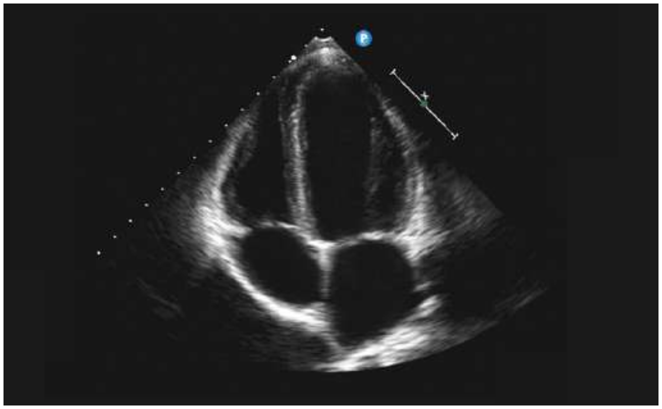
[Video 12]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

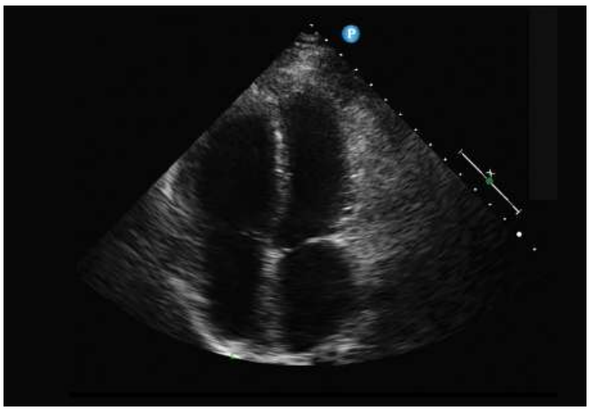
Video demonstrating severe RV dysfunction and dilatation in parasternal short-axis view. Note the size of the RV exceeding the size of the LV and the flattening of the interventricular septum.

RV assessment

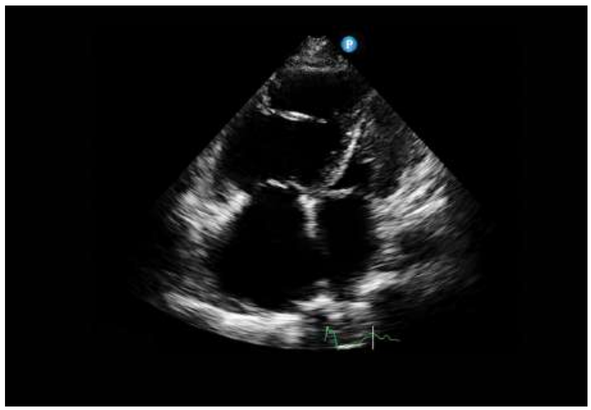
All examples are the apical four-chamber view.



Normal RV



Example of RV dilatation
Note the abnormal bulging of the RV and septum into the LV.



Example of severe RV dilatation and dysfunction
Note the size of the RV compared to the LV.

[Video 13]

▶

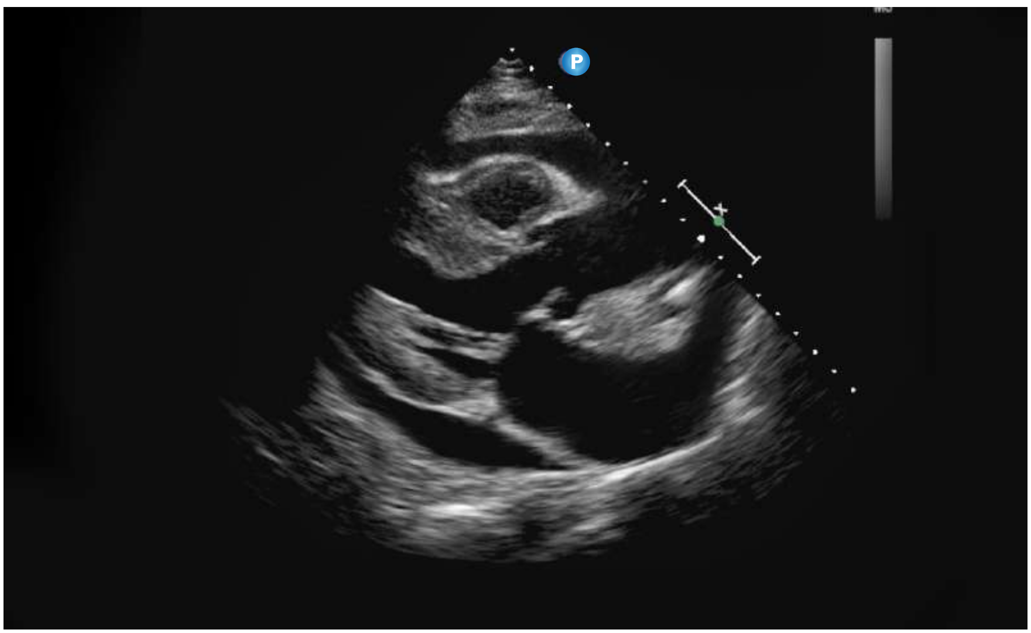
Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

Video demonstrating RV dilatation and dysfunction in an apical four-chamber view. Note the size of the RV and the abnormal septal motion in each example.

Pericardium

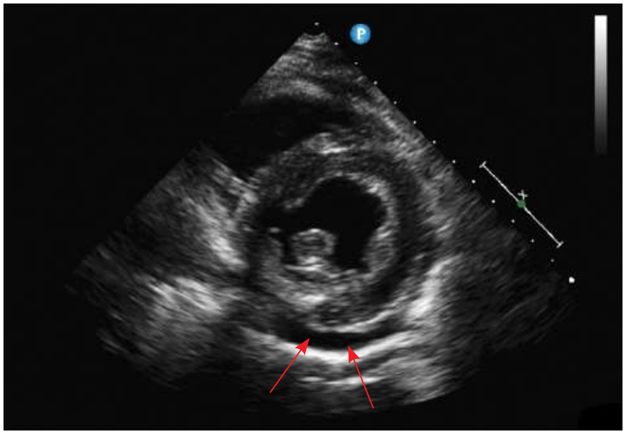
Pericardial effusion

- Pericardial fluid will appear as a dark, echo-free space within the pericardium.
- All views should be used to assess the presence of pericardial fluid.
- Pericardial effusions can be circumferential or localized.
- The size of a pericardial effusion can be estimated semi-quantitively (small, moderate, large) but this is imprecise.
- Precise quantification is not as important as the hemodynamic consequences (see “Main criteria for tamponade” on page 42).

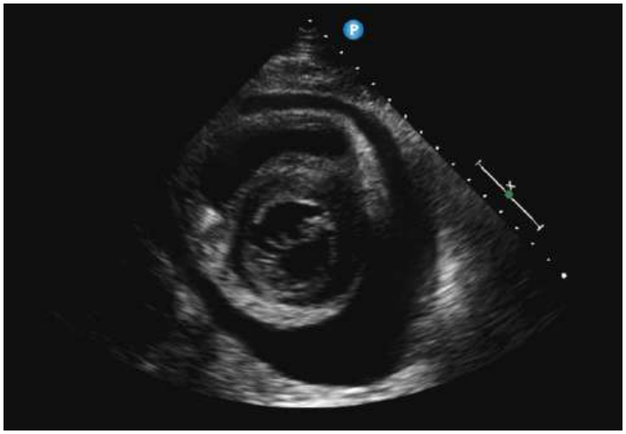


Moderate pericardial effusion – parasternal long-axis

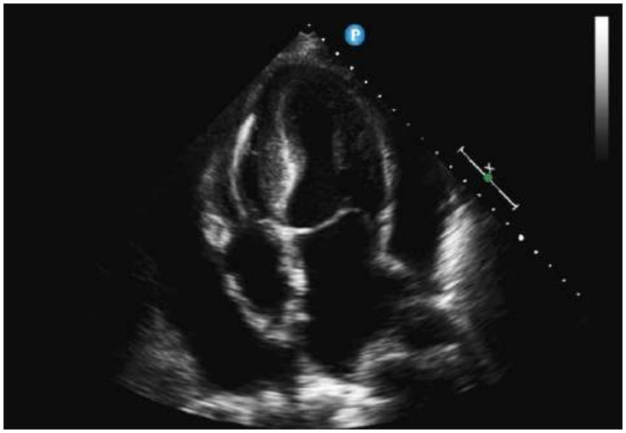
Pericardial effusion



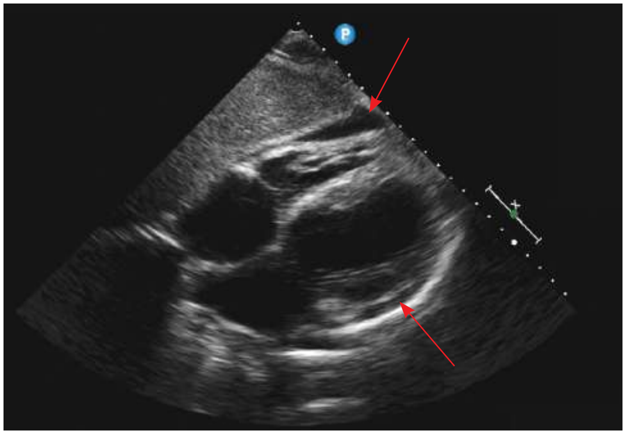
Small pericardial effusion – parasternal short-axis



Moderate to large pericardial effusion – parasternal short-axis



Moderate to large pericardial effusion – apical four-chamber



Subcostal four-chamber view with a small pericardial effusion (predominately anteriorly)

[Video 14]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

Video demonstrating pericardial effusion in parasternal long-axis, parasternal short-axis, apical and subcostal views. Transparent color is briefly overlaid on each example to highlight the effusion.

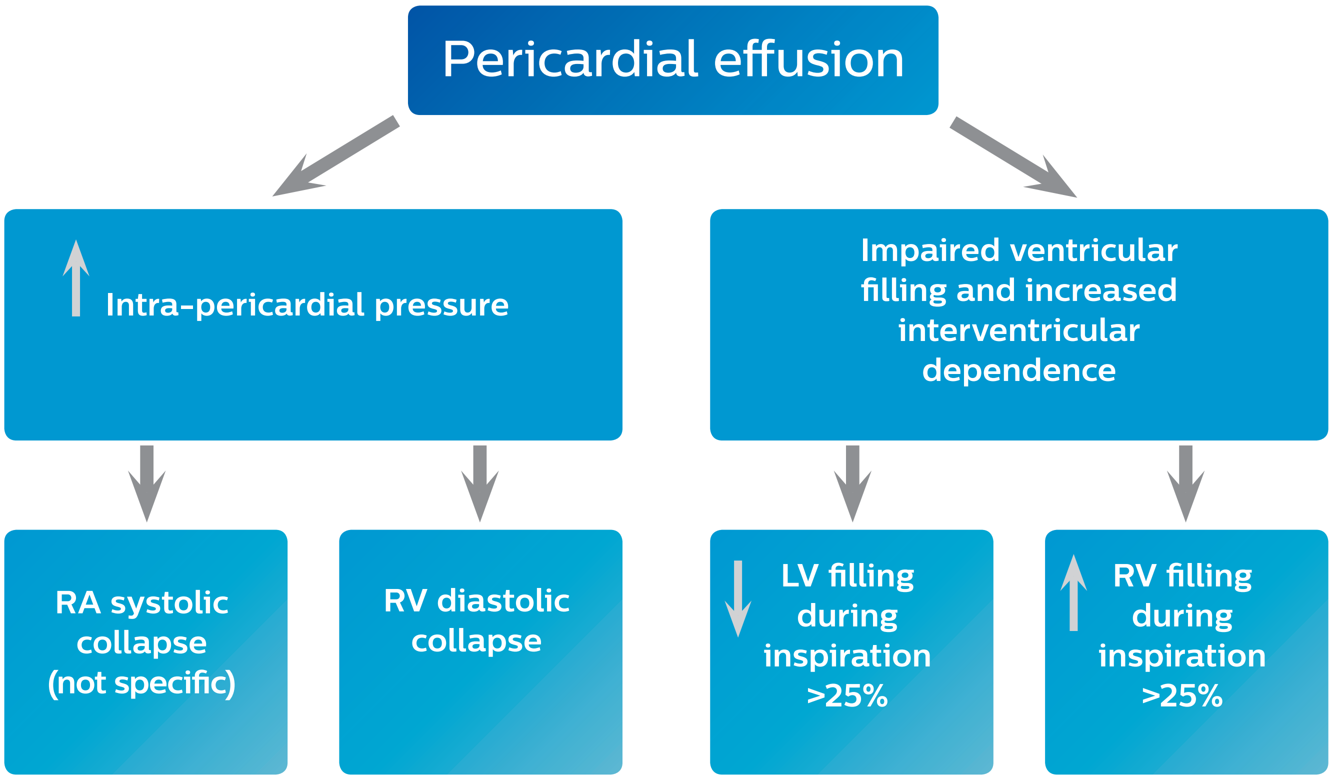
[Video 15]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

Video demonstrating tamponade in parasternal long-axis, parasternal short-axis, apical and subcostal views.

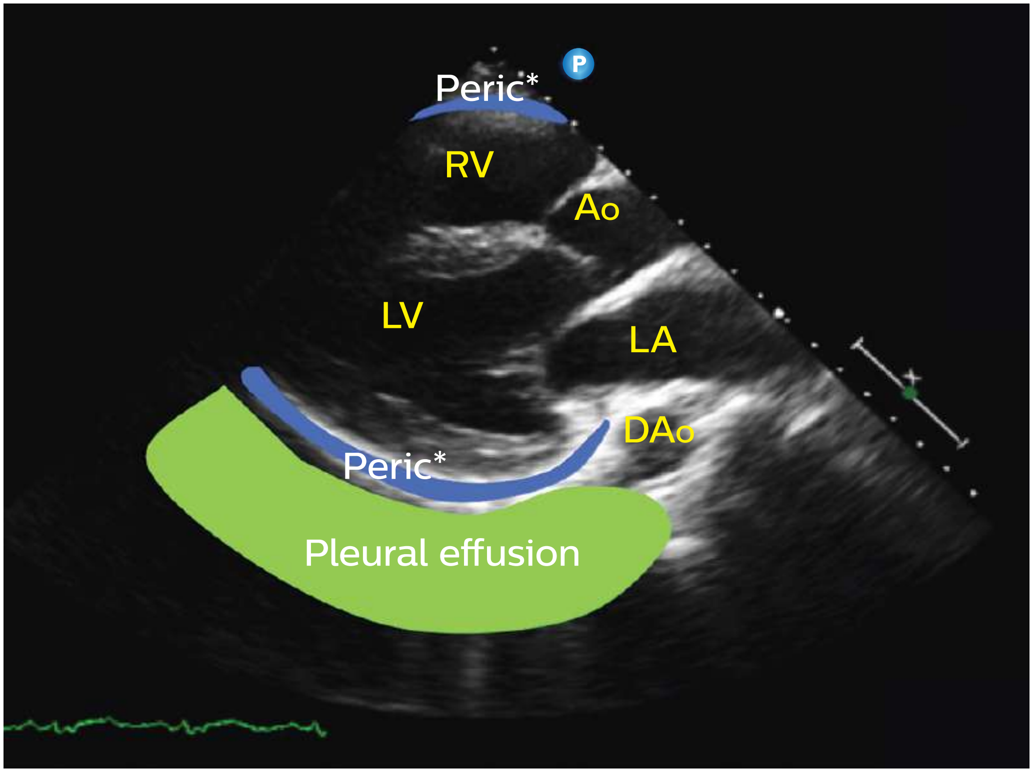
Pericardium

Main criteria for tamponade



Pericardial versus pleural effusion

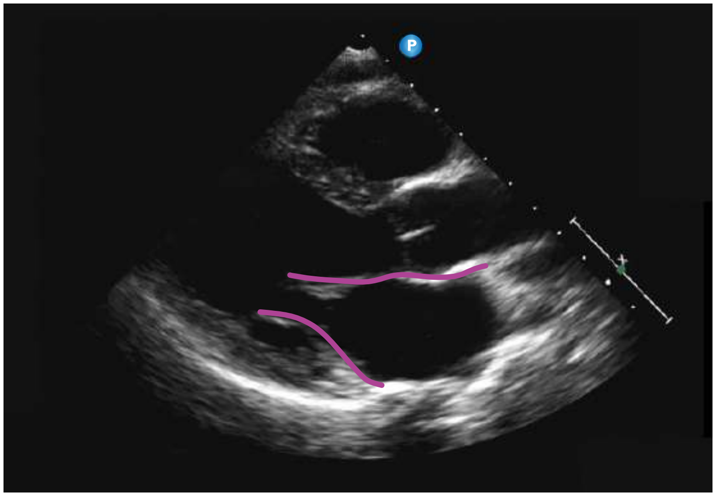
- Best assessed from parasternal long-axis view (depth 20-28 cm)
- Pericardial effusion (blue): anterior to the descending aorta
- Pleural effusion (green): posterior to the descending aorta



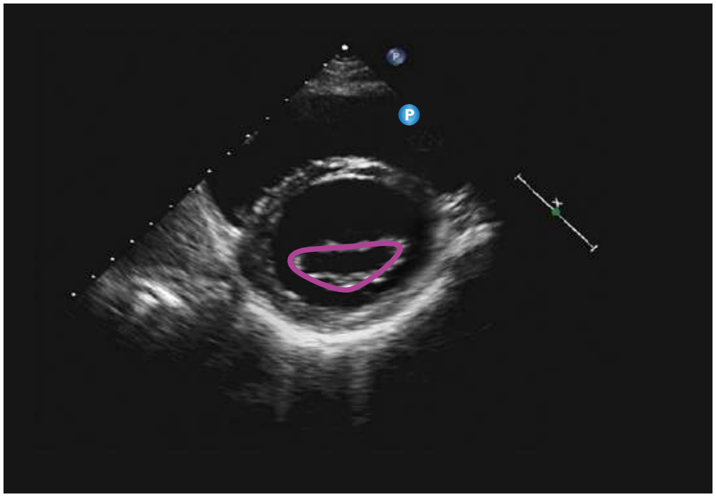
Peric* = pericardial fluid
DAo = descending aorta

Mitral valve

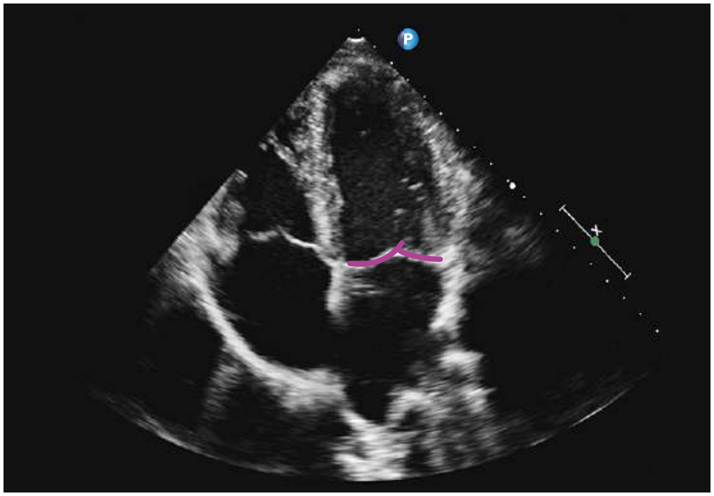
Mitral valve can be assessed from:



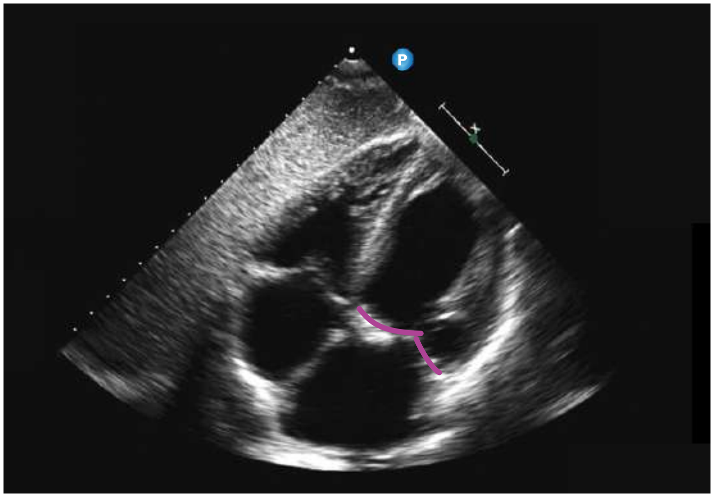
Parasternal long-axis



Parasternal short-axis, mitral valve level



Apical four-chamber



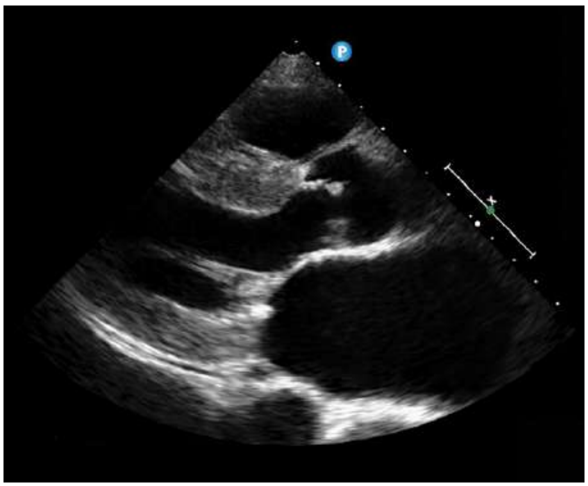
Subcostal four-chamber

Mitral valve

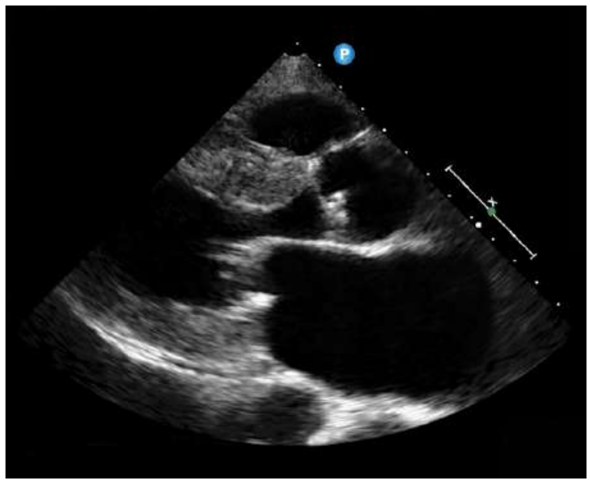
Detection of mitral valve stenosis

Best assessed from parasternal long-axis view.
Look for:

- Thickening and calcification (bright white echoes)
- Restricted valve movement and restricted valve opening
- Doming of the anterior mitral valve leaflet in diastole



Systole – note the thickened and calcific mitral valve.



Diastole – note the doming of the anterior leaflet of the stenotic mitral valve seen in diastole.

[Video 16]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

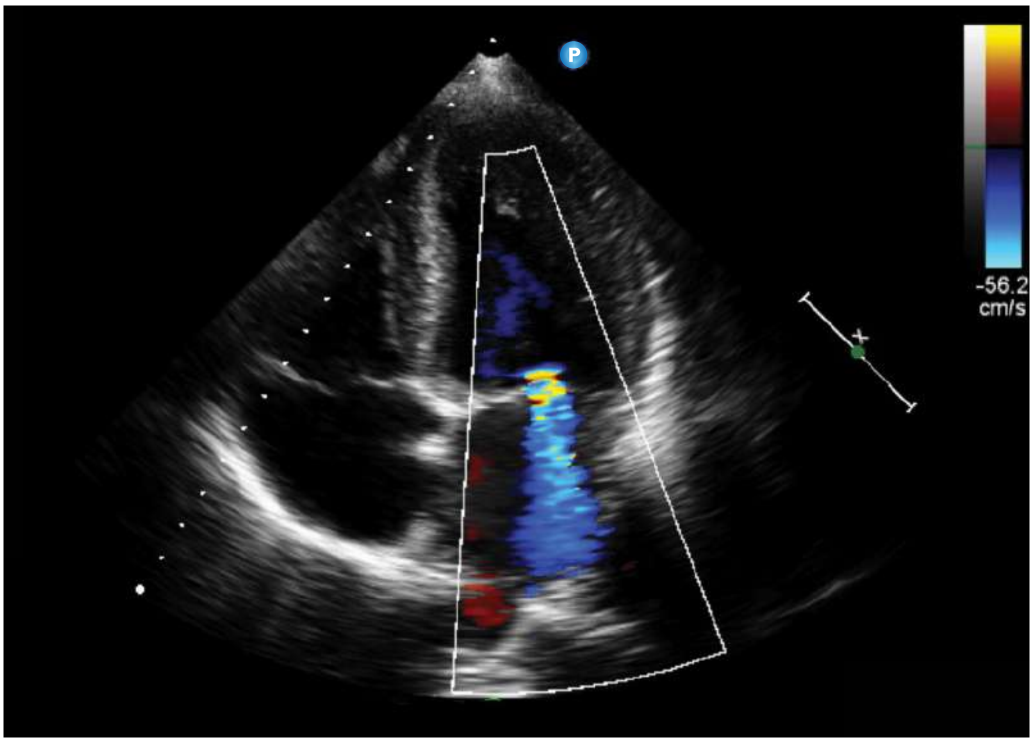
Video demonstrating mitral stenosis in parasternal long-axis and apical views. Note the thickening and calcifications (bright white echoes) of the mitral valve leaflets, the restricted valve movement and doming of the anterior mitral valve leaflet in diastole.

Mitral valve

Detection of mitral regurgitation

Best assessed from apical four-chamber view.

- Systolic flow directed from left ventricle to left atrium
- Color: mainly blue jet in the left atrium



Apical four-chamber view – mitral regurgitation visualized in the left atrium using color flow Doppler.

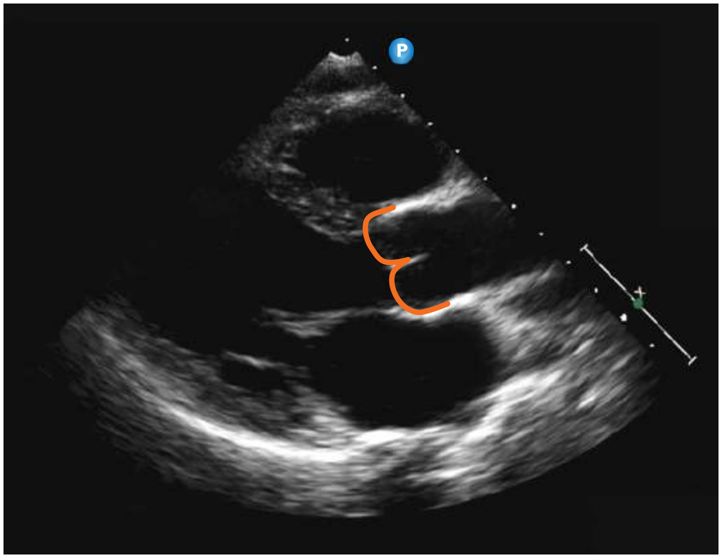
[Video 17]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

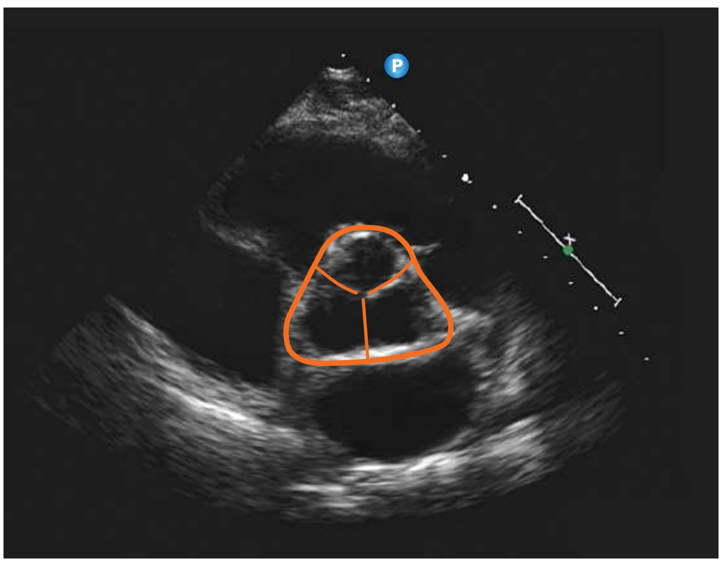
Video demonstrating mitral regurgitation in apical four-chamber views using color flow Doppler. The mitral regurgitation is the blue and yellow jet seen in the left atrium in systole.

Aortic valve

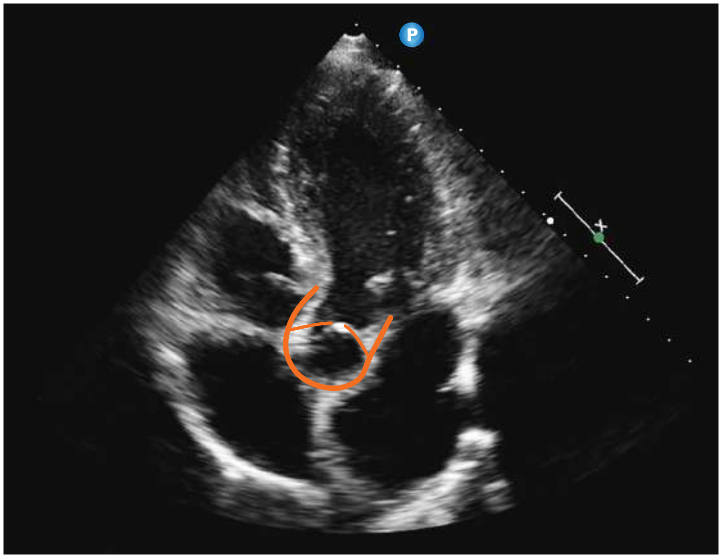
Aortic valve can be assessed from:



Parasternal long-axis



Parasternal short-axis



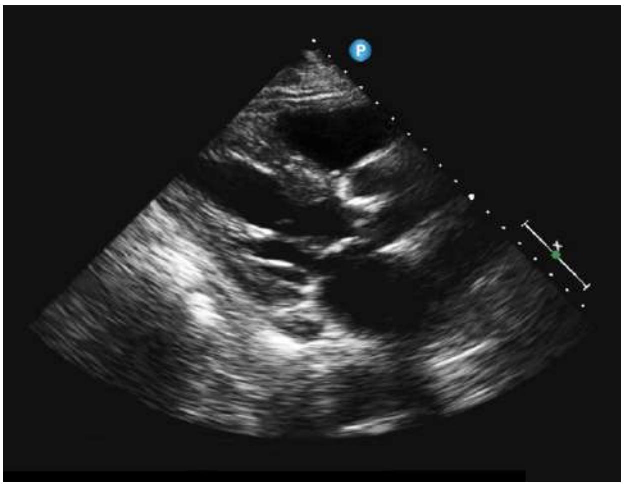
Apical five-chamber

Aortic valve

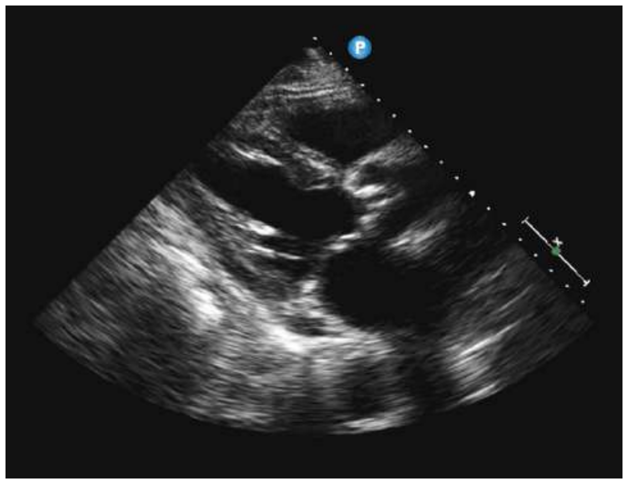
Detection of aortic valve stenosis

Best assessed from parasternal long-axis view. Look for:

- Thickening and calcification (bright white echoes)
- Restricted or reduced valve movement
- Restricted or reduced valve opening in systole



Aortic stenosis – diastole



Aortic stenosis – systole. Note the thickened valve and reduced valve opening.

[Video 18]

Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

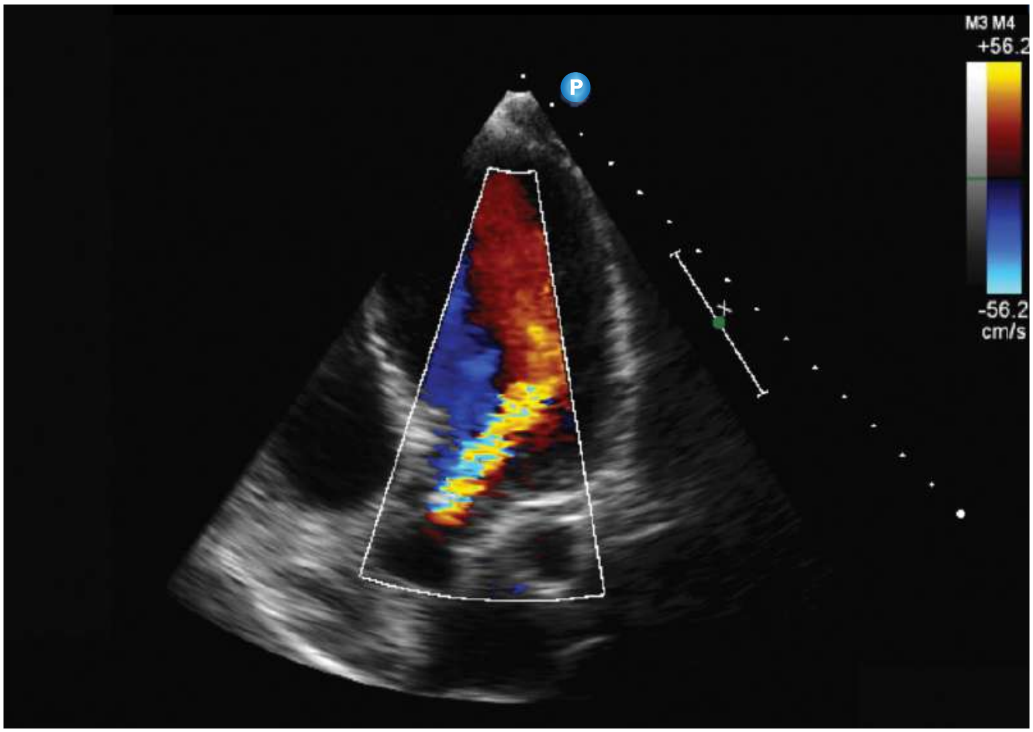
Video demonstrating aortic stenosis in a parasternal long-axis view. Note the thickened and calcified aortic valve leaflets and their restricted movement and reduced opening.

Aortic valve

Detection of aortic regurgitation

Best assessed from apical five-chamber view.

- Diastolic flow directed from aorta to left ventricle
- Color: mainly red-yellow jet in the left ventricle



Apical five-chamber view – aortic regurgitation visualized in left ventricle using color flow Doppler.

[Video 19]

Click here to view this video in the online tutorial,
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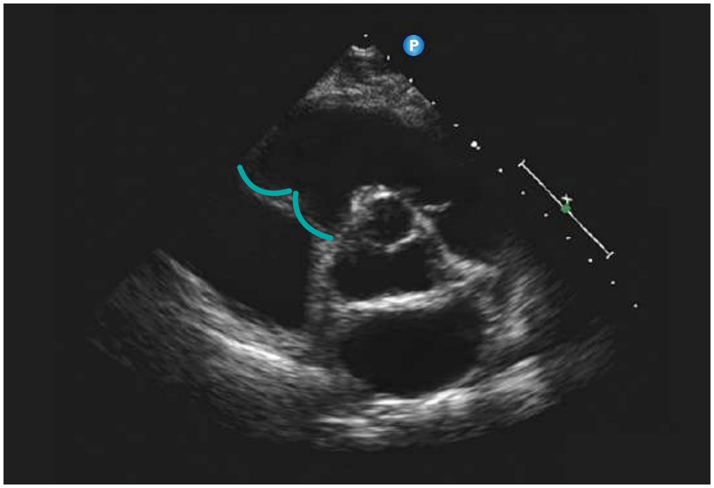
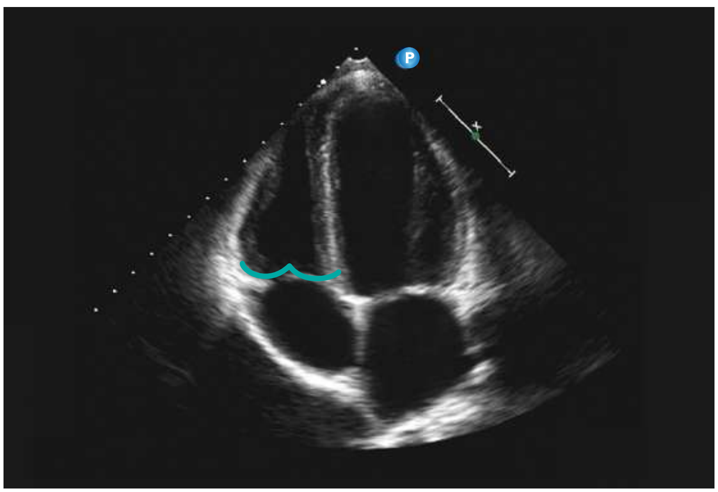
Video demonstrating aortic regurgitation in an apical four-chamber view using color flow Doppler. The aortic regurgitation is the red and yellow jet seen in the left ventricle in diastole.

Tricuspid valve

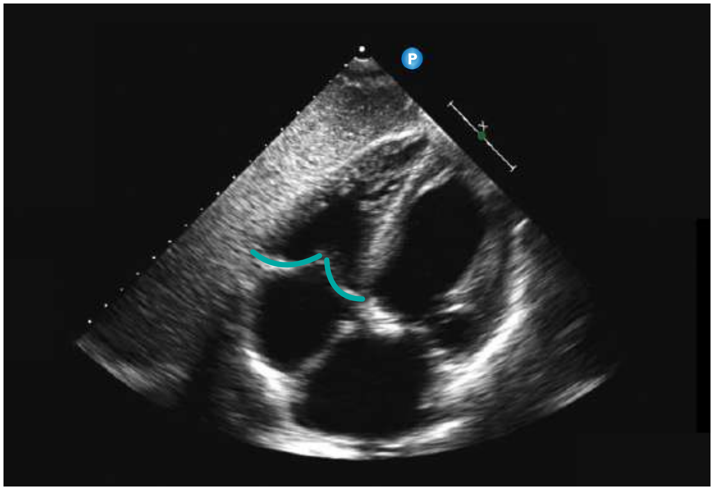
Tricuspid valve can be assessed from:



Parasternal short-axis



Apical four-chamber

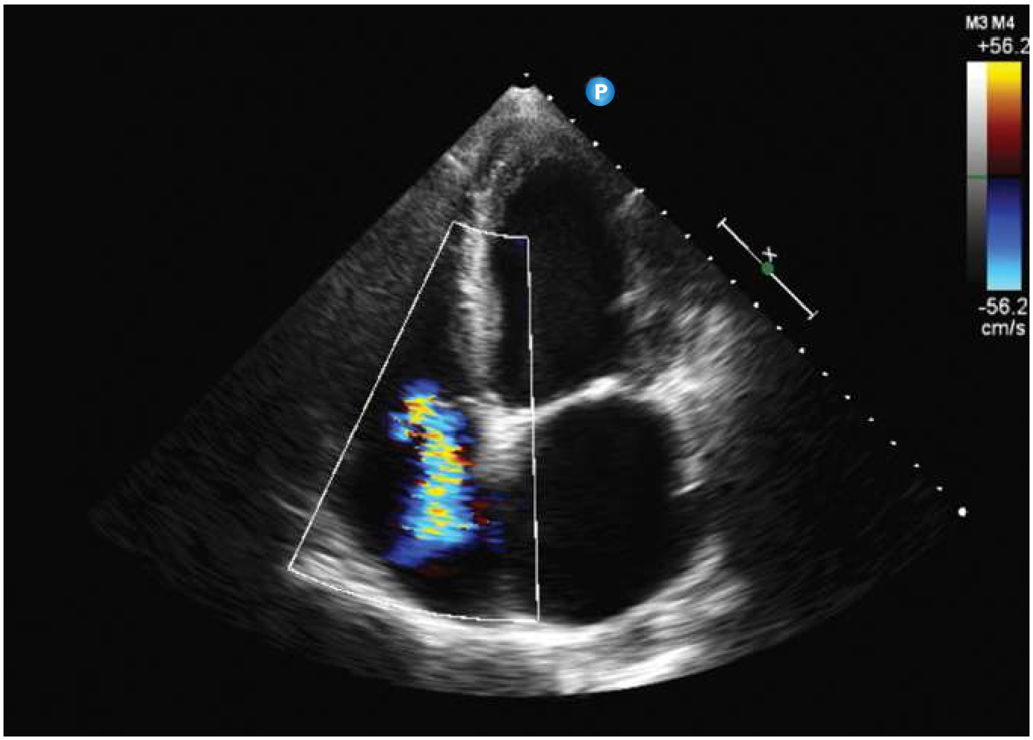


Subcostal four-chamber

Tricuspid valve

Detection of tricuspid regurgitation in apical four-chamber view

- Systolic flow directed from right ventricle to right atrium
- Color: mainly blue jet in the right atrium



Apical four-chamber view – tricuspid regurgitation is visualized in the right atrium using color flow Doppler.

[Video 20]

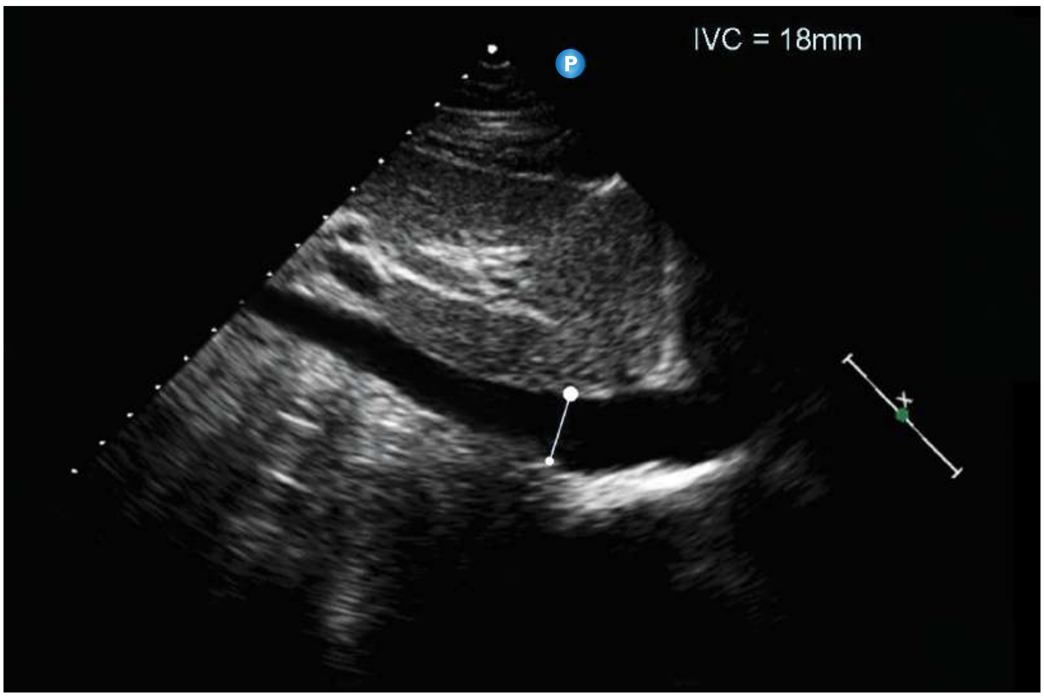
Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

Video demonstrating tricuspid regurgitation in apical four-chamber view using color flow Doppler. The tricuspid regurgitation is the blue and yellow jet seen in the right atrium in systole.

Inferior vena cava (IVC)

IVC and volume status

- The diameter of the IVC should be measured 2 to 3 cm before it merges with the right atrium.
- The reference diameter of the IVC is its largest diameter.



Subcostal view of the IVC

[Video 21]

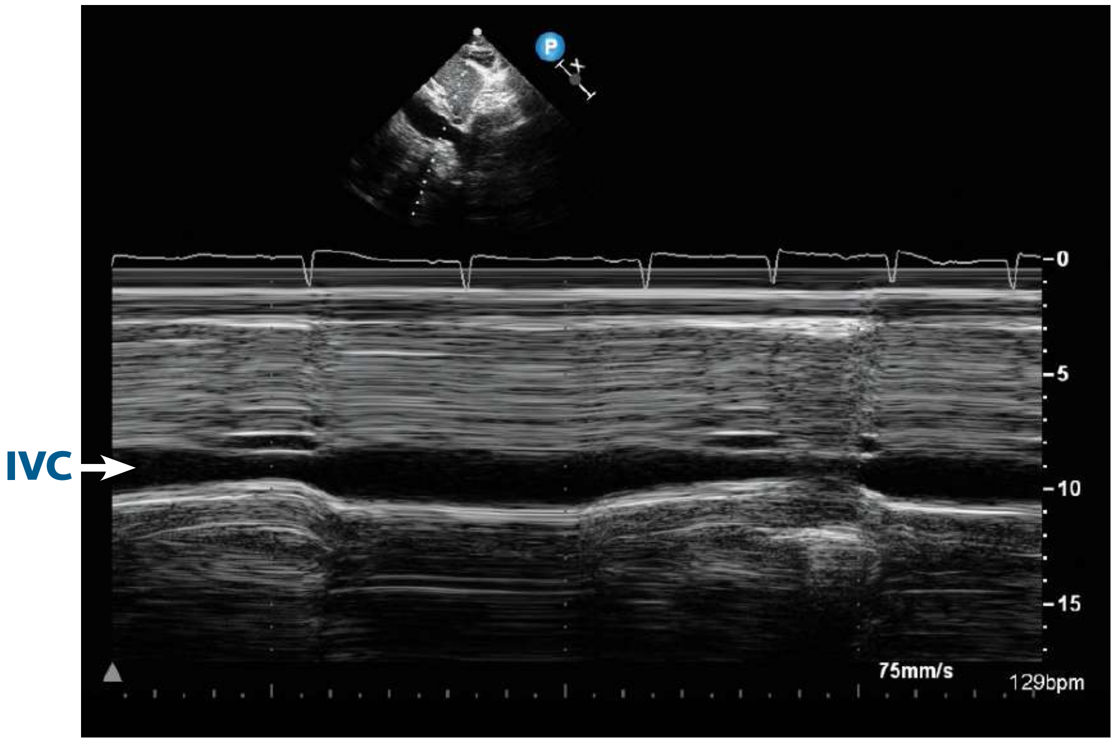
Click here to view this video in the online tutorial,
or go to www.philips.com/CCEMeducation

Video demonstrating normal inferior vena cava (IVC), collapsing IVC and dilated IVC in the subcostal view.

Inferior vena cava (IVC)

IVC respiratory variations

IVC respiratory variation can be assessed using 2D or M-mode. Follow the IVC throughout the respiratory cycle and compare the largest and smallest diameters (being careful to keep the IVC in the imaging plane).



M-mode imaging of the IVC showing IVC collapse > 50% during respiration.

Inferior vena cava and volume status

In mechanically ventilated patients, IVC respiratory variation is a good predictor of pre-load responsiveness.

- Respiratory variation of the IVC diameter is greater in patients who will respond to fluid expansion.
- After fluid infusion, respiratory variation of the IVC diameter decreases significantly in these patients.
- Small IVC diameter (<1.2 cm) has a 100% specificity (with a low sensitivity) for a RA pressure of less than 10 mm Hg.

Feissel M, Michard F, Faller JP, Teboul JL. The respiratory variation in inferior vena cava diameter as a guide to fluid therapy. Intensive Care Med. 2004 Sep;30(9):1834-7.

In spontaneously breathing patients, the size and respiratory collapse of the IVC reflects the RA pressure.

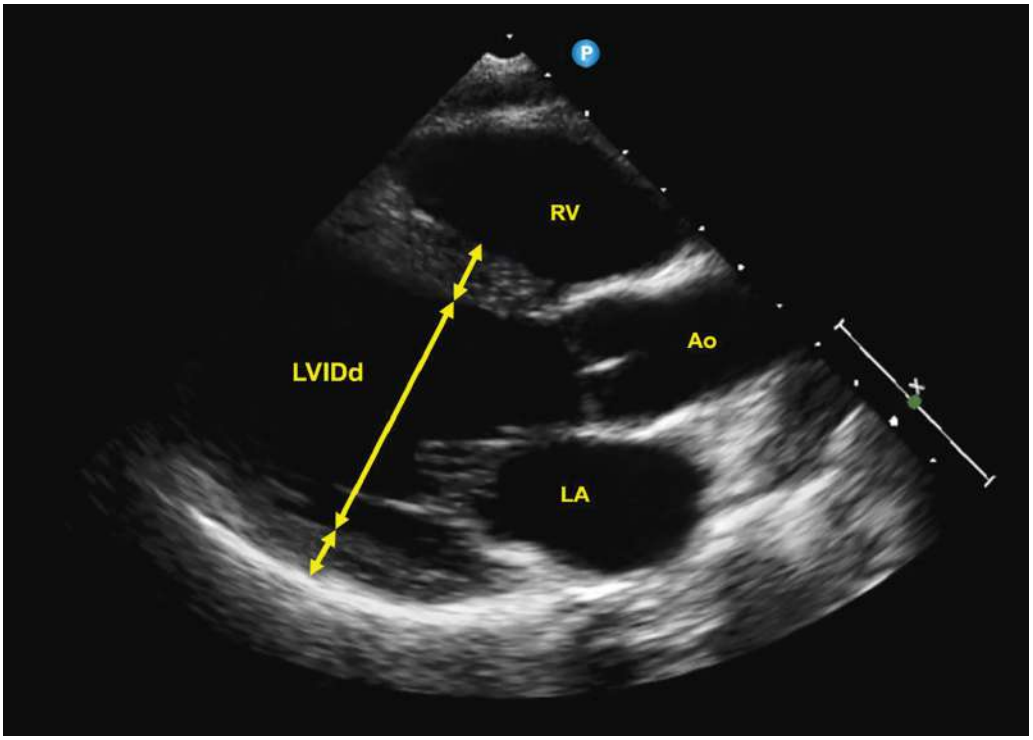
IVC size (mm)	Collapsibility index	RA pressure
<17	>50%	5
>17	>50%	10
>17	<50%	15
>17	No collapse	20

Moreno FL, Hagan AD, Holmen JR, Pryor TA, Strickland RD, Castle CH. Evaluation of size and dynamics of the inferior vena cava as an index of right-sided cardiac function. Am J Cardiol. (1984);53:579-585.

6 Measurements and calculations

This section will introduce some common echo measurements and calculations.

LV size and wall thickness



Parasternal long-axis view

Reference values for LV size and wall thickness

	Normal range	Mild	Moderate	Severe
LVIDd (mm)				
Female	39–53	54–57	58–61	>62
Male	42–59	60–63	64–68	>69
IVSd and LVd (mm)				
	6–10	11–13	14–16	>16

LVIDd = Left ventricular internal dimension diastole
IVSd = Interventricular septum diastole
LVd = LV wall diastole

- Parasternal long-axis view is the optimal view to assess LV size and wall thickness.
- An optimal parasternal long-axis view is required for accurate measurements.
- To increase accuracy, LV size and hypertrophy should be assessed in relation to sex and body surface area.

Lang RM, Bierig M, Devereux RB. Recommendations for chamber quantification. J Am Soc Echocardiogr. 2005 Dec;18(12):1440-63.

Formula for the calculation of ejection fraction (EF)

$$EF = \frac{\text{LVED volume} - \text{LVES volume}}{\text{LVED volume}}$$

LVED = Left ventricular end diastolic

LVES = Left ventricular end systolic

Reference values for EF%

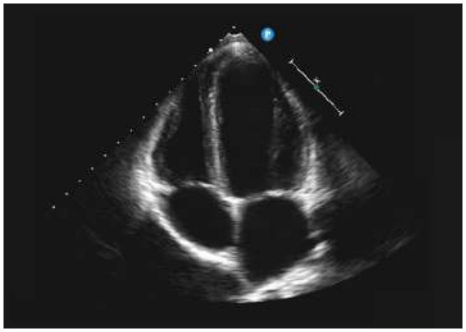
Hyperdynamic	>65%
Normal	**55–65%**
Mild impairment	45–55%
Moderate impairment	30–45%
Severe impairment	<30%

Calculation of ejection fraction using the Simpson's method

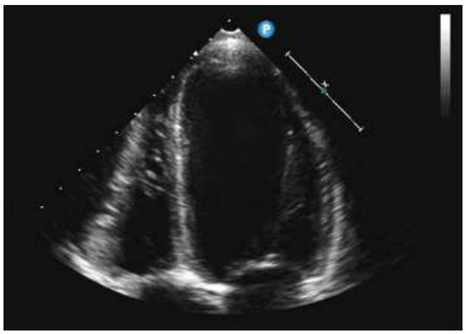
- Measure LVED volume and LVES volume in the apical four-chamber view. (Be careful not to foreshorten the LV.)
- Use the same cardiac cycle for both systolic and diastolic volume.
- Good visualization of endocardial borders is required.
- Use the EF calculation on your ultrasound system.

Lang RM, Bierig M, Devereux RB. Recommendations for chamber quantification. J Am Soc Echocardiogr. 2005 Dec;18(12):1440-63.

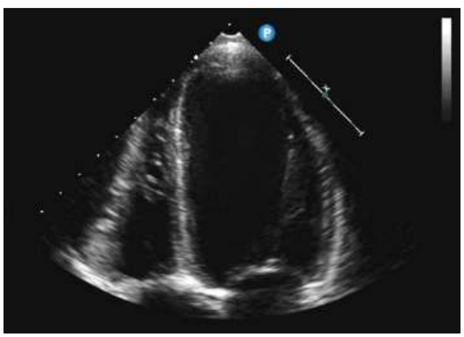
Steps for using the Simpson's method



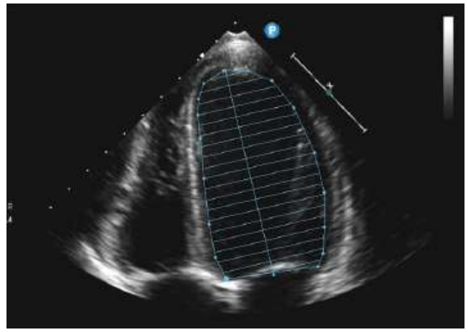
Step 1 Obtain apical four-chamber view.



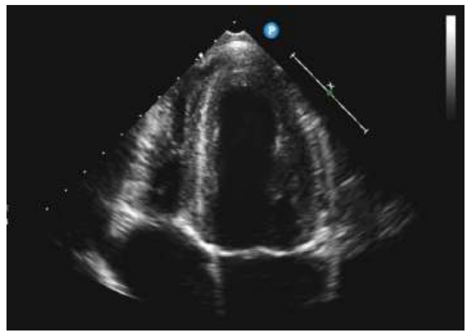
Step 2 Reduce image depth to maximize the LV size in the sector, then freeze the image.



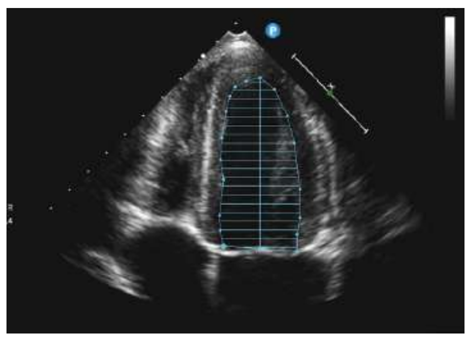
Step 3 Locate end-diastole (frame after mitral valve closure).



Step 4 Trace LV endocardial border to obtain left ventricular end diastolic (LVED) volume.



Step 5 Locate end-systole (frame before mitral valve opening).



Step 6 Trace LV endocardial border to obtain left ventricular end systolic (LVES) volume.

Formula for the calculation of stroke volume (SV)

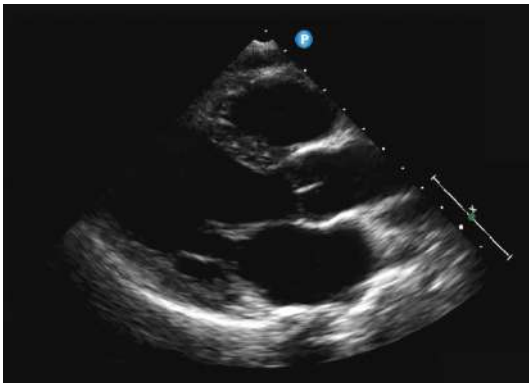
Stroke Volume =
LVOT area x LVOT VTI

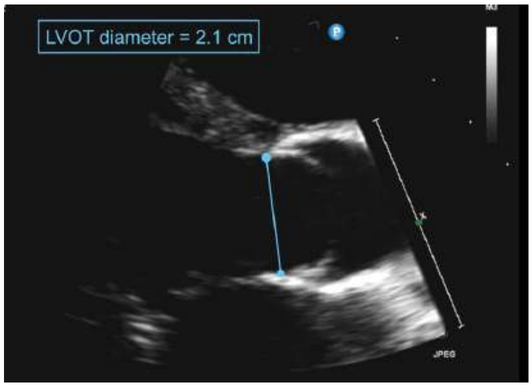
LVOT = Left ventricular outflow tract

VTI = Velocity time integral

Calculation of SV

- Measure LVOT diameter. LVOT area will be calculated using LVOT diameter.
- Measure velocity time integral (VTI) in the LVOT.
- Calculations will be done by the ultrasound system using the measurements described below.

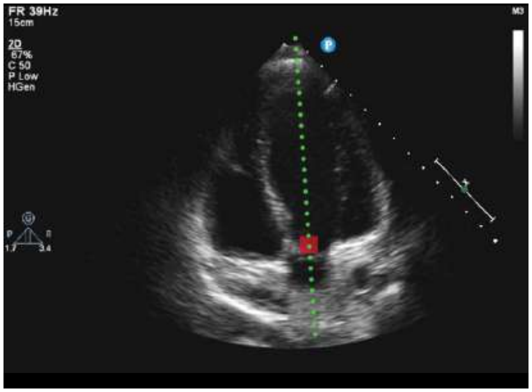




Step 1

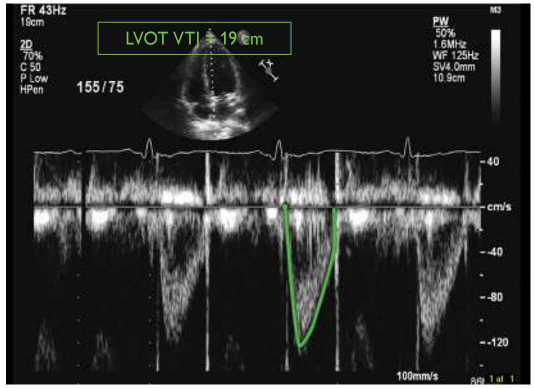
Obtain parasternal long-axis view. Zoom LVOT and aortic valve. Freeze and scroll to mid-systole (aortic valve fully open). Measure LVOT diameter at the base of the aortic valve leaflets.

Zoghbi WA, Quinones MA. Determination of cardiac output by Doppler echocardiography: a critical appraisal. Herz. 1986;11:258-68.



Step 2

In apical five-chamber view, place pulsed wave Doppler sample volume in the LVOT just above the aortic valve.



Step 3

Using 100 mm/s sweep speed, freeze the display. Trace the VTI.

Important things to remember

- Any error in the LVOT diameter measurement will be squared when calculating SV.
- For follow-up studies on the same patient, always use the same LVOT diameter.
- When acquiring the VTI, insure that the ultrasound beam is aligned with the direction of the flow. Any angle will create an underestimation of SV.

Indices calculated from stroke volume

Systolic index (ml/m^2) = SV / body surface area

Cardiac output (l/min) = SV * heart rate

Cardiac index ($l/min/m^2$) = cardiac output/body surface area

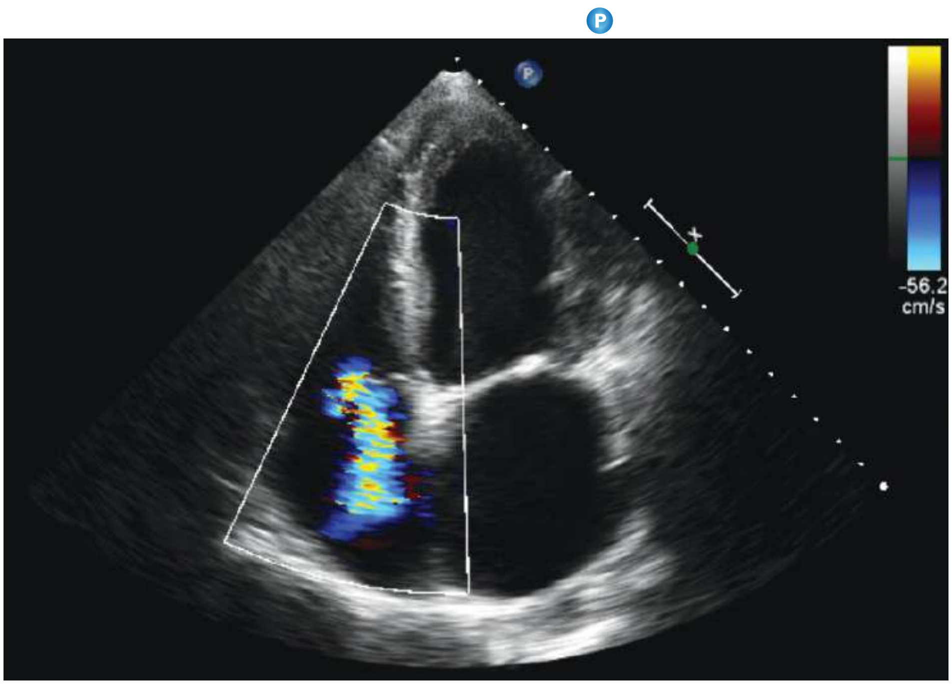
Formula for the calculation of right ventricular systolic pressure (RVSP)

$$RVSP = P_{RV-RA} + P_{RA}$$

P = Pressure

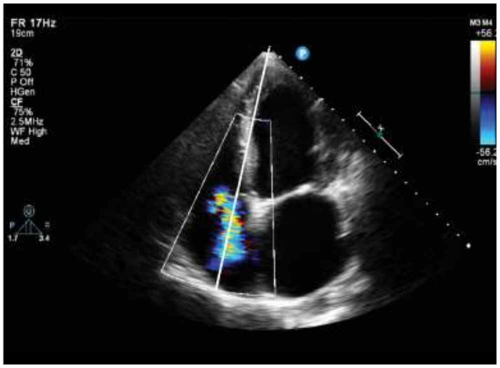
RV = Right ventricle

RA = Right atrium

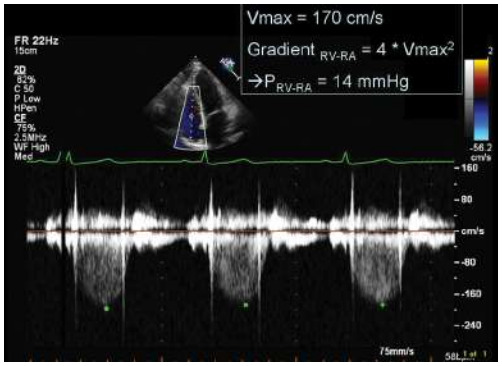


- **P**$_{RV-RA}$ calculated from maximum velocity of the tricuspid regurgitation obtained with continuous Doppler. (Bernoulli equation: $P = 4V^2$)
- **P**$_{RA}$ estimated using IVC size and respiratory variations.

Calculation of RVSP



Step 1 Identify tricuspid regurgitation (TR) in the apical four-chamber view using color flow Doppler. Place the continuous wave Doppler beam in the center of the TR jet.



Step 2 Measure the maximum velocity of the TR jet on the spectral Doppler display. The ultrasound system will calculate the peak systolic gradient between the RA and RV using the modified Bernoulli equation.

Step 3 Estimate RA pressure based on IVC size and respiratory variations or CVP (central venous pressure). To calculate RVSP, add the estimated RA pressure to the peak systolic gradient.

7 Echo during CPR

A protocol for the use of ultrasound during CPR (cardiopulmonary resuscitation) should be defined and in place. The protocol includes the timing of ultrasound during CPR, the goal, and the person identified to perform the ultrasound. CPR will have to be briefly stopped during ultrasound.

Recommendations

- Designated person prepares ultrasound during CPR
- Interrupt CPR at the end of one cycle
- Perform a timed three-second subcostal four-chamber view and record images
- Resume CPR immediately
- Interpret ultrasound images and communicate results to the CPR team

Breitkreutz R, Walcher F, Seeger FH. Focused echocardiographic evaluation in resuscitation management: concept of an advance life support-conformed algorithm. Crit Care Med. 2007 May;35(5 Suppl):S150-61.

8 Abbreviations

Ao – ascending aorta
AV – aortic valve
CVP – central venous pressure
DAo – descending aorta
EF – ejection fraction
IVC – inferior vena cava
IVS – interventricular septum
LA – left atrium
LV – left ventricle
LVED – left ventricular end diastolic
LVES – left ventricular end systolic
LVOT – left ventricular outflow tract
MV – mitral valve
P – pressure
RA – right atrium
RV – right ventricle
RVOT – right ventricular outflow tract
RVSP – right ventricular systolic pressure
SV – stroke volume
TR – tricuspid regurgitation
V – velocity
VTI – velocity time integral

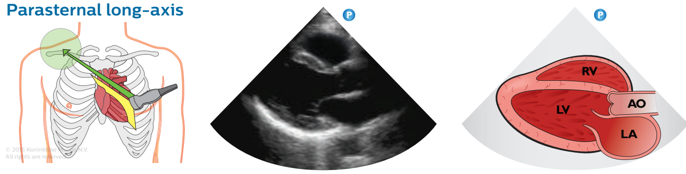
9 POC echo pocket card

This companion pocket card with POC views can be downloaded from the CCEM education web site at **www.philips.com/CCEMeducation**

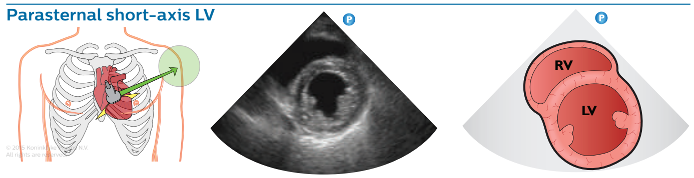
Introduction to transthoracic echo – POC views

Philips Healthcare

Parasternal long-axis



Parasternal short-axis LV



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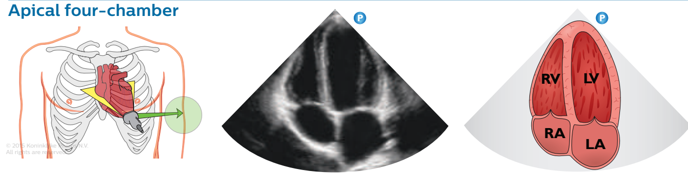
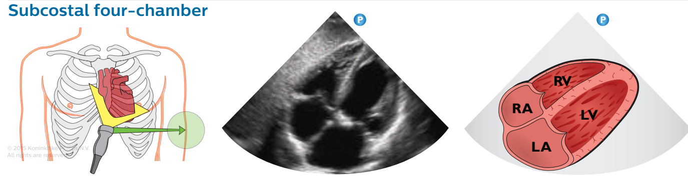
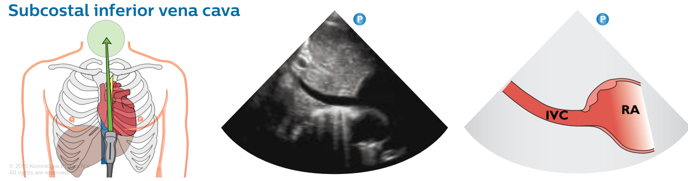
Apical four-chamber



Subcostal four-chamber



Subcostal inferior vena cava



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Additional resources

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critical care and emergency medicine ultrasound visit:
www.philips.com/CCEMeducation

For additional resources related to ultrasound-guided
regional anesthesia and pain medicine procedures visit:
www.philips.com/RAPMeducation

For **feedback** or **comments** regarding this tutorial or the iPad App, please contact us at **ultrasoundeducation@philips.com**

For more information about **Philips Sparq ultrasound system** go to: **www.philips.com/sparq**

This paper reflects the opinion of the author, not Philips Healthcare. Before performing any clinical procedure, clinicians should obtain the requisite education and training, which may include fellowships, preceptorships, literature reviews, and similar programs. This paper is not intended to be a substitute for these training and education programs, but is rather an illustration of how advanced medical technology is used by clinicians.

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