

2

Introduction to Imaging

The Normal Examination

Dara Lee, MD and Scott D. Solomon, MD

CONTENTS

TWO-DIMENSIONAL, M-MODE, AND DOPPLER ECHOCARDIOGRAPHY

ECHOCARDIOGRAPHIC VIEWS

THE PARASTERNAL POSITION

APICAL POSITION

SUBCOSTAL POSITION

SUPRASTERNAL POSITION

SUMMARY

SUGGESTED READING

CASE PRESENTATION

A 30-yr-old pregnant woman is referred for an echocardiogram to evaluate a heart murmur. She has no significant medical problems and is in the third trimester of an uncomplicated pregnancy. The systolic murmur was noticed on a routine obstetrical examination; the patient has no complaints of dyspnea, chest discomfort, or palpitations. She walks daily without limiting cardiac or respiratory symptoms. She has no history of rheumatic fever and has never been told of a heart murmur in the past.

Findings

As expected, the study is entirely normal. The most likely cause of the patient's murmur is the increased intravascular volume expansion associated with third trimester pregnancy, which often leads to a benign "flow murmur." Such a murmur may be auscultated in other states of increased flow across a normal valve, such as fever or hyperthyroidism.

TWO-DIMENSIONAL, M-MODE, AND DOPPLER ECHOCARDIOGRAPHY

The basic principles of echocardiography, including the basics of physics and instrumentation are discussed in Chapter 1. This chapter is an introduction to the echocardiographic examination, and a detailed description follows in Chapter 3.

TWO-DIMENSIONAL ECHOCARDIOGRAPHY

Two-dimensional (2D) images form the basis of the echocardiographic study, providing structural and functional information as well as guiding the use of M-mode and Doppler techniques. The tomographic images described next constitute the 2D study. As discussed in Chapter 1, ultrasound waves generated from the ultrasound transducer travel to the heart and are then reflected back to the transducer. Returning ultrasound waves are analyzed for depth location (based on the time elapsed between signal emission and return), and density (denser structures will reflect a greater proportion of the ultrasound beam than less refractile objects). Figures 1 and 2 demonstrate a 2D image from the parasternal long-axis (please *see* companion DVD for corresponding video for Fig. 1).

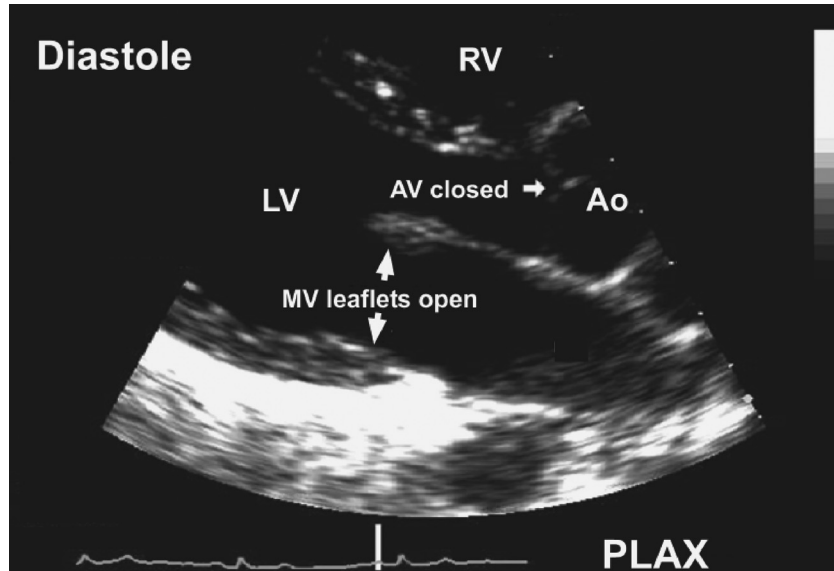


Fig. 1. Parasternal long-axis view (PLAX) demonstrating the following cardiac structures: RV, right ventricle; LV, left ventricle; AV, aortic valve; Ao, aorta; MV, mitral valve. This image is normal, as are all the images in this chapter. (Please *see* companion DVD for corresponding video.)

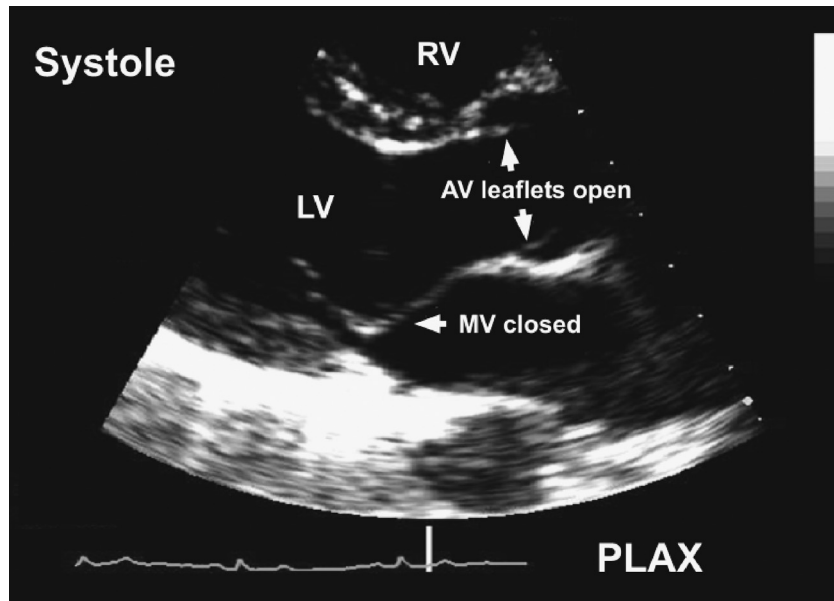


Fig. 2. Parasternal long-axis view at end systole demonstrating the following cardiac structures: RV, right ventricle; LV, left ventricle; AV, aortic valve; MV, mitral valve.

M-MODE ECHOCARDIOGRAPHY

M-mode images (M stands for “motion”) can be thought of as a one dimensional, or “ice-pick” image, recorded over time. Most M-mode images are recorded in the parasternal long-axis view previously described (still frame of M-mode in parasternal long-axis). The ultrasound beam is maneuvered to slice through the structure of interest, producing a high-resolution image of this slice over time. The high resolution of M-mode

images, and the ability to correlate them with a simultaneously recorded electrocardiogram, makes M-mode the image of choice for many measurements. Figures 3 and 4 demonstrate M-mode views through the left ventricle (LV) and through the mitral valve (MV).

DOPPLER ECHOCARDIOGRAPHY

Doppler echocardiography is used to measure blood flow; it can assess flow velocity, direction, and turbulence

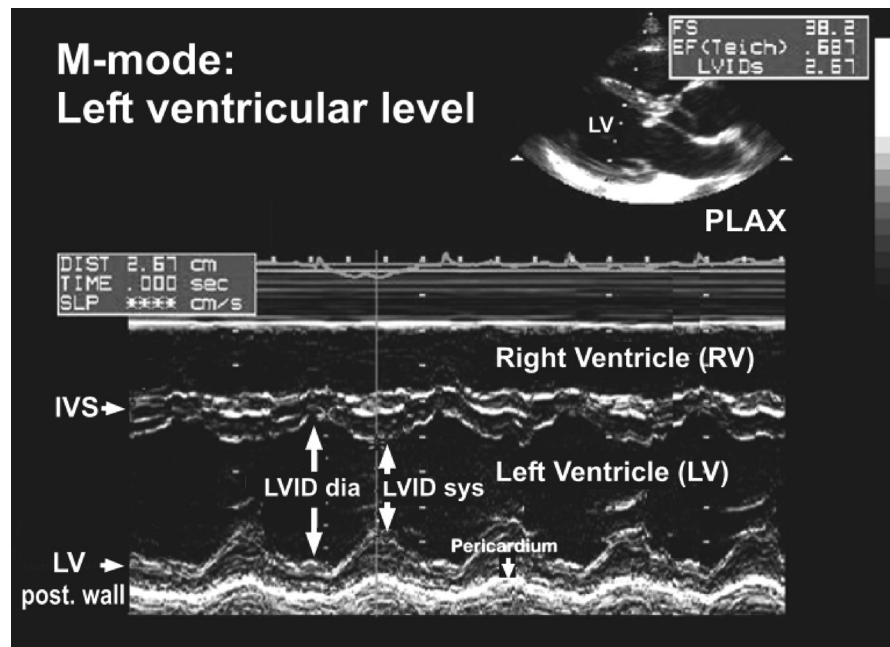


Fig. 3. M-mode through the left ventricle. From this view, measurements of left ventricular wall thickness, and end-diastolic and end-systolic diameter can be made. The electrocardiogram is useful for timing the cardiac cycle.

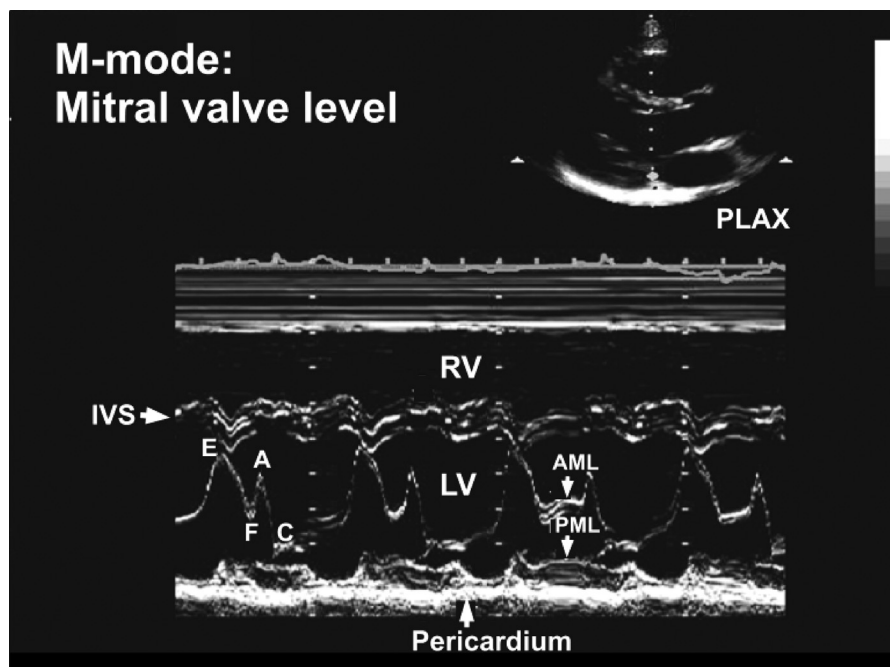


Fig. 4. M-mode through the mitral valve. From this measurement, the morphology of the mitral valve can be visualized. Note the typical M configuration of the mitral valve during early diastolic filling (E), and atrial filling (A). The anterior mitral leaflet (AML) and the posterior mitral leaflet (PML) are noted, as is the pericardium.

(see Chapter 1). Doppler is primarily used to assess blood flow velocity. Spectral Doppler (Fig. 5) shows waveforms that represent blood velocity, with time on the x -axis and velocity on the y -axis. See Chapter 1 for an explanation of the differences between pulsed- and continuous-wave Doppler.

COLOR FLOW DOPPLER ECHOCARDIOGRAPHY

Color flow Doppler depicts blood velocity data superimposed on the 2D image (Fig. 6; please see companion DVD for corresponding video). Nonturbulent flow that is below the Nyquist limit (see Chapter 1) and directed toward the transducer appears in red and nonturbulent

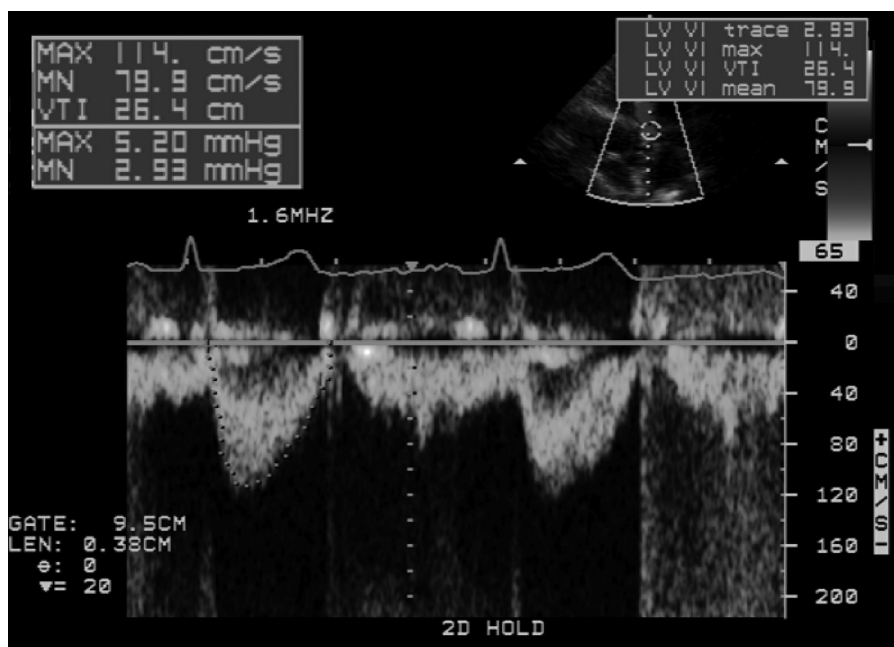


Fig. 5. Pulsed Doppler through the left ventricular outflow tract. The waveform demonstrates the velocity of blood (y-axis), with time on the x-axis. The electrocardiogram allows correlation with the cardiac cycle.

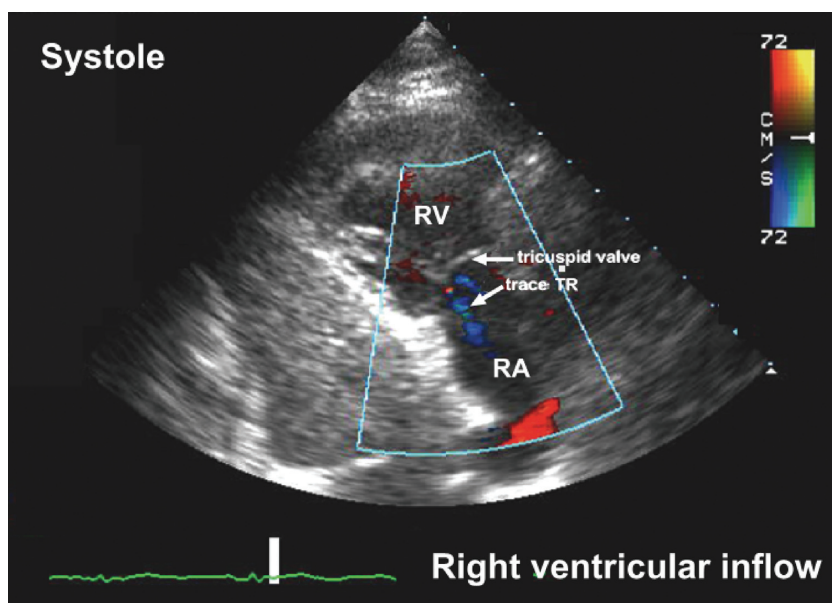


Fig. 6. Example of color flow Doppler demonstrating tricuspid regurgitation (a normal finding in this patient). Color flow Doppler is a form of pulsed-wave Doppler in which blood velocities are color encoded and superimposed on top of the two-dimensional image. The scale on the upper right hand side of the image shows the velocity associated with each color gradation as described in the text. (Please see companion DVD for corresponding video.)

flow below the Nyquist limit directed away from the transducer appears in blue. Perpendicular flow is not well visualized by Doppler images. Turbulent flow, and flow in which the velocities are faster than the Nyquist limit, is seen as a multi-color mosaic signal.

The Views

This patient's study, like most studies, is comprised of a standard set of views recommended by the American Society of Echocardiography. Multiple different viewing angles are needed to fully visualize all the cardiac

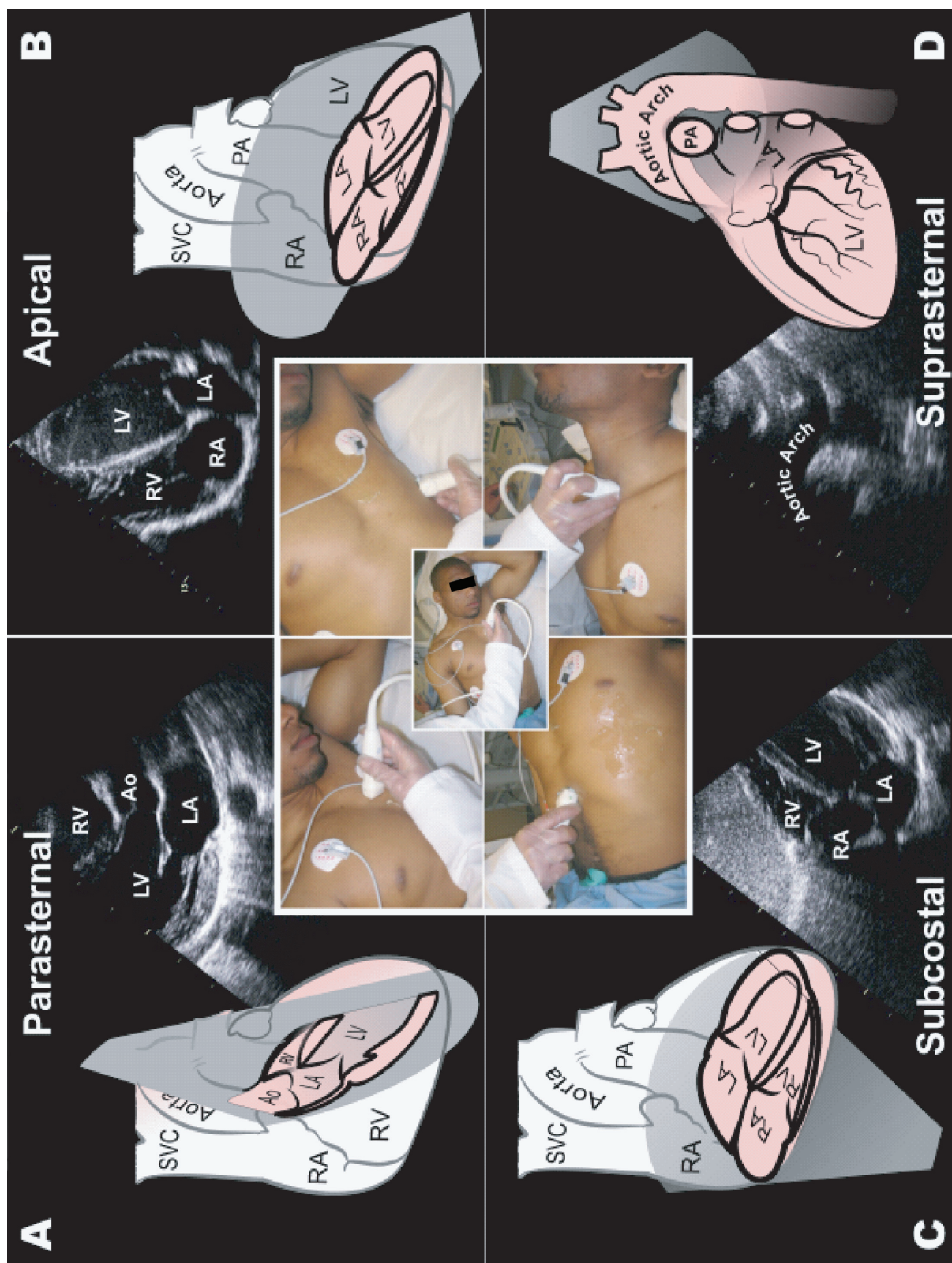


Fig. 7. Illustration showing transducer placement for each of the major echocardiographic views: (A) parasternal location for parasternal long and short-axis; (B) apical location for apical four-, two-chamber and long-axis views; (C) subcostal location for subcostal views; (D) suprasternal location for suprasternal notch view.

Table 1
Echocardiographic Views

<i>View</i>	<i>Patient/transducer position</i>	<i>Structures imaged</i>	<i>Doppler</i>
Left parasternal: long-axis view	Supine/third to fourth interspace	Overview of cardiac structures, chamber dimensions, and ventricular function. Most standard measurements, including LA, aortic root, LV diastolic and systolic dimensions. RV size and function measurements variable in this (and all) views.	Color flow Doppler looking for mitral regurgitation and aortic insufficiency.
Left parasternal: RV inflow	Same but tilt inferomedially, slight clockwise rotation	Long-axis view of RV, RA; good view for TV and regurgitant velocity.	Color flow Doppler looking for tricuspid regurgitation; spectral Doppler (CW) demonstrating tricuspid regurgitant velocity.
Left parasternal: short-axis view	Same but rotate perpendicular, tilt up and down to image from base to apex	Cross-section of LV to assess global and regional LV function from apex to base as transducer is tilted. Papillary muscles, MV in cross-section—good for planimetry of MV in mitral stenosis. At base, AV seen in cross-section; RVOT seen across top of image, PV to right of AV.	Color flow Doppler through the aortic valve for assessment of aortic insufficiency.
Apical: four and five chamber	Left lateral decub/point of maximal impulse. Anterior rotation produces five-chamber view.	All four chambers; ventricular septum, lateral wall of LV. Atrial septum, MV and TV with regurgitant jets and inflow velocity profiles. Inferior pulmonary veins seen as they enter LA. In five chamber view, aortic valve and root also seen, good view to assess for aortic regurgitation or stenosis.	Color flow Doppler looking for mitral regurgitation, aortic insufficiency, and tricuspid regurgitation; spectral Doppler (PW) of mitral inflow, outflow tract, and in suspected aortic stenosis, CW Doppler of aortic valve. CW Doppler for assessment of tricuspid regurgitant velocity.
Apical: two and three chamber	Same but with perpendicular rotation.	LV anterior and inferior walls, LA, MV and regurgitant jet. Three-chamber view brings aortic valve and root into view, and shifts to inferolateral and anteroseptal segments of LV.	Color flow Doppler for mitral regurgitation (two- and three-chamber views), and aortic insufficiency (three-chamber view).
Subcostal	Supine with hips and knees flexed/subxiphoid, at or slightly right of midline	Often best view in patients with hyperinflated lungs; long-axis similar to parasternal window but may provide better visualization of apex, RA and IVC, interatrial septum. Good view to look for PFO/ASD. Short-axis similar to parasternal. Abdominal aorta can be seen in this window.	Color flow Doppler of intra-atrial septum looking for evidence of atrial septal defect.

(Continued)

Table 1 (*Continued*)

<i>View</i>	<i>Patient/transducer position</i>	<i>Structures imaged</i>	<i>Doppler</i>
Suprasternal	Supine with pillow under shoulders, head to left/suprasternal notch.	Ascending aorta, aortic arch, proximal brachiocephalic vessels, descending thoracic aorta, and right and main PAs (sometimes the left PA). Good position to measure transaortic velocity/gradient in aortic stenosis, assess for diastolic flow reversal in aortic regurgitation. Depending on image quality, may detect aortic aneurysm or dissection, postductal coarctation or patent ductus arteriosus; superior vena cava flow velocity profile.	PW or CW Doppler can be used to interrogate possible coarctation of the aorta.

CW, continuous wave; LA, left atrium; LV, left ventricle; MV, mitral valve; PA, pulmonary artery; PW, pulsed wave; RA, right atrium; RVOT, right ventricular outflow tract; TV, tricuspid valve.

structures, because each echo view provides only a 2D image of the 3D heart. There are four major transducer positions: the parasternal, apical, subcostal, and suprasternal notch positions (Fig. 7). From each transducer position, rotating and tilting the probe will produce several different tomographic images.

By convention, the echo images shown here and at most centers are presented in a triangular window, with the top of the triangle generally at the top of the screen (Fig. 1). Some labs, by convention, invert the triangle. The location of the transducer, relative to the image, is always at the top of the triangle; the structures closest to the top are therefore those closest to the transducer (and closest to the patient's skin). An electrocardiogram tracing is recorded simultaneously with the echo images, so that the phase of the cardiac cycle can be correlated to the mechanical activity of the heart; this is usually located at the bottom of the screen.

The proper positioning of the patient and the probe is described for each view. Transducer heads are marked with a notch, groove, or dot known as the "index;" this index is perpendicular to the imaging plane.

Keep in mind that the views and positions described next are those most frequently used in the majority of patients. However, certain anatomical variations or pathological conditions may require nonstandard views; deviating from the usual transducer positions may be necessary to obtain optimal images in these cases.

ECHOCARDIOGRAPHIC VIEWS

Table 1 describes each echocardiographic view, the patient and transducer position, and structures imaged in each view.

The Parasternal Position

For the parasternal views, the patient lies in the left lateral decubitus position with the left arm supporting the head. The transducer is generally placed just left of the sternum, in the second, third, or fourth intercostal space (Fig. 7). From here, both short- and long-axis views of the heart can be obtained.

PARASTERNAL LONG-AXIS VIEW (FIG. 1)

The index is pointed toward the patient's right shoulder, producing a longitudinal section through the LV. Remember that the image is displayed as if the transducer tip were at the top of the triangle; therefore, the structures at the top of the triangle are the most anterior (i.e., closest to the surface of the chest). The right ventricle (RV) lies anterior to the LV, so the chamber at the top of the triangle is the RV. (If there is a pericardial fluid collection or a prominent epicardial fat pad anterior to the RV, this will be seen above the RV in the parasternal long-axis view.) Below the RV is the LV; the anterior interventricular septum is uppermost, and the posterior LV wall is below, with the LV apex to the left. The ascending aorta is on the

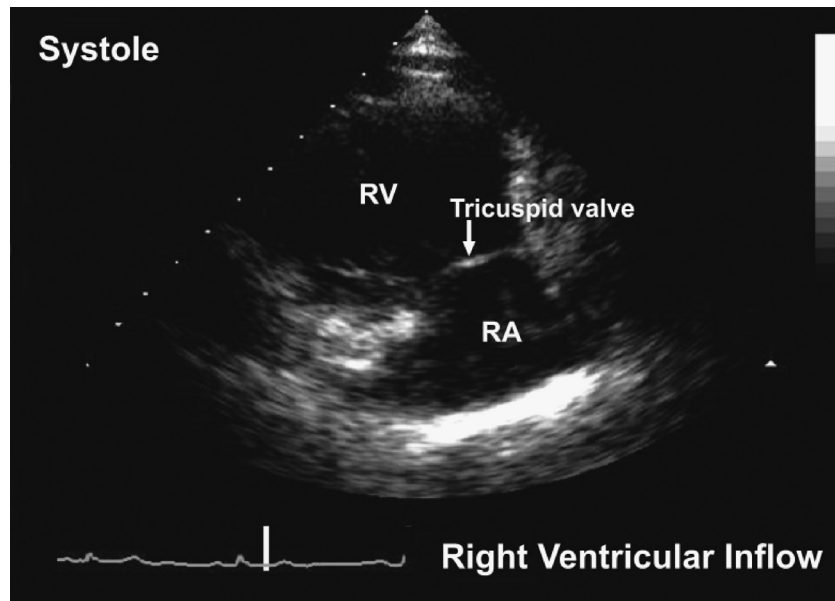


Fig. 8. Right ventricular inflow view. From this view, we can see a longitudinal view of the right ventricle (RV) and right atrium (RA). The RA is to the right and bottom (posterior) and the RV is above (anterior) and left. This view allows visualization of the tricuspid valve, as well as assessment of tricuspid regurgitation and measurement of tricuspid regurgitant velocity. (Please *see* companion DVD for corresponding video.)

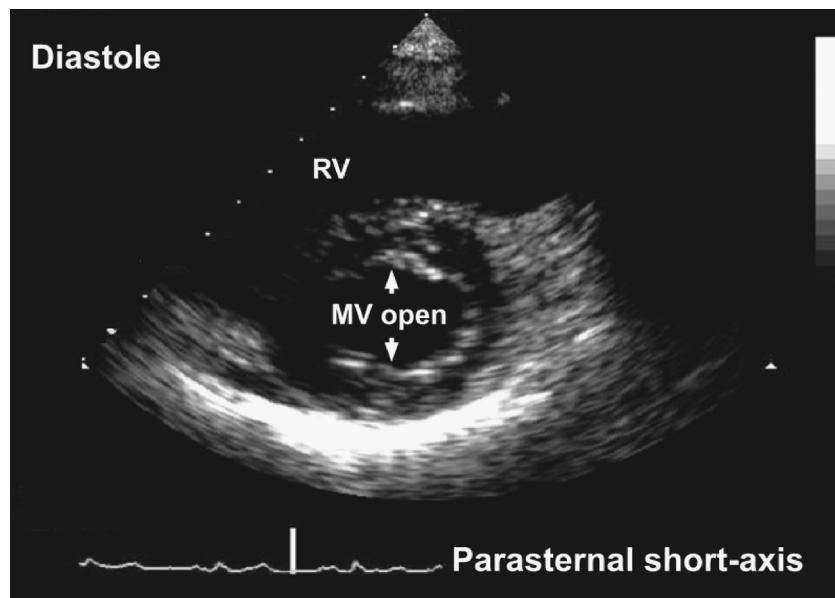


Fig. 9. Parasternal short-axis view, mitral position. This view represents a “breadloaf” slice through the heart at the level of the mitral valve. From this view, you can see the mitral valve in cross-section (“fishmouth” view) with anterior and posterior leaflets (arrows) indicating the wide open early diastolic position. (Please *see* companion DVD for corresponding video.)

right of the screen; moving leftward, the aortic valve (AV) (right coronary AV leaflet superiorly and noncoronary leaflet inferiorly) and LV outflow tract (LVOT) are next. The left atrium (LA) and MV are at the bottom of the screen. The MV chordal apparatus and papillary muscles are also seen in this view.

The parasternal long-axis view is an excellent overview image of the heart. It is generally the best window for measuring the aortic root and LA, LV chamber dimensions, and LV wall thickness. The mitral and aortic valves are well seen, and anterior structures, such as the RV and pericardial effusions,

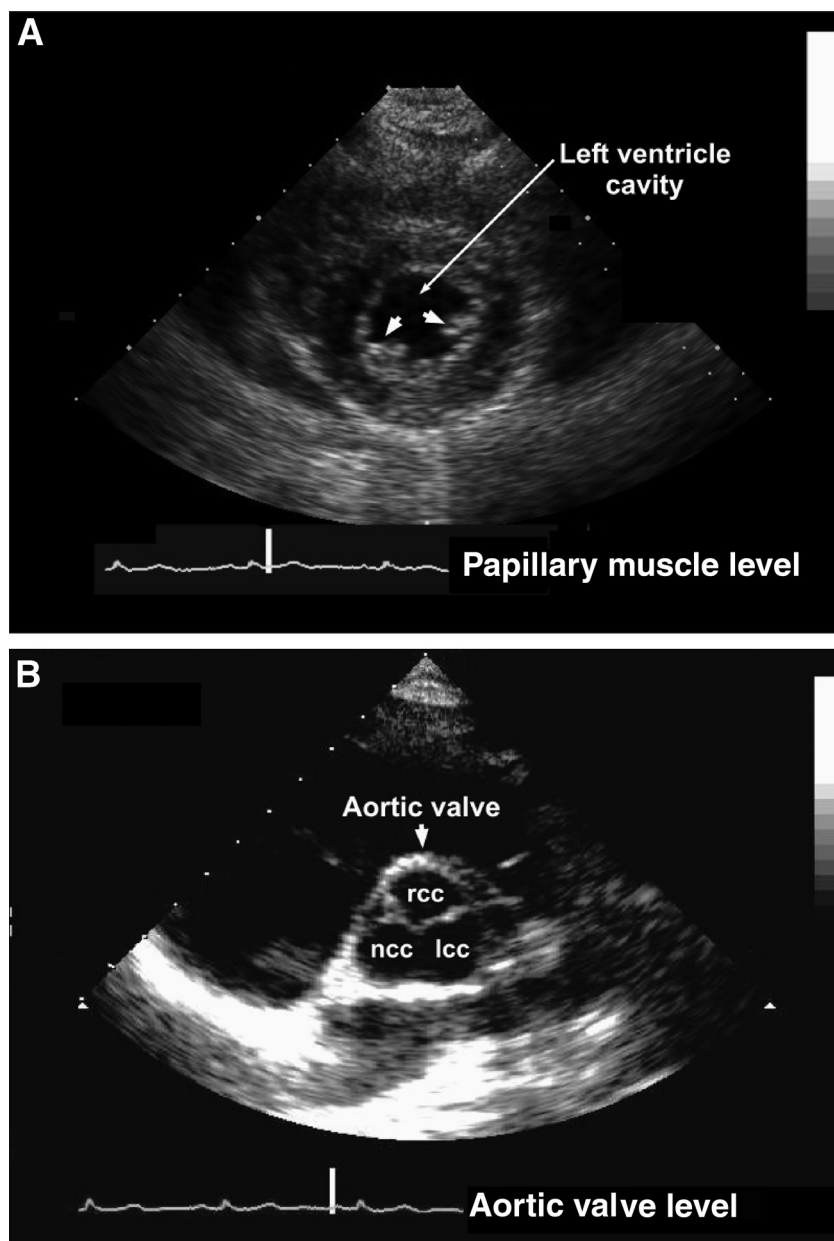


Fig. 10. (A) Parasternal short-axis view, papillary muscle level. This view is similar to the short-axis mitral position but more apical in the ventricle. The papillary muscles (PM) are visualized. This is an excellent view for assessing regional wall motion in the left ventricle. (B) Short axis through the aortic valve, visualized in the center of the screen, is comprised of three cusps, the right coronary cusp (RCC), the non-coronary cusp (NCC) and the left coronary cusp (LCC). Anterior to the aortic valve is the right ventricular outflow tract, with the tricuspid valve seen at 10 o'clock, and the pulmonic valve seen at approx 2 o'clock to 3 o'clock. The left atrium is immediately posterior to the aortic valve in this view. (Please see companion DVD for corresponding video.)

can be visualized as well. This view is generally used for measurement of the LVOT diameter (*see* Chapter 11). In addition, color flow Doppler in this view can reveal evidence of mitral regurgitation or aortic insufficiency. There is generally no need for using spectral Doppler in this view.

RV INFLOW VIEW

With inferomedial tilt of the transducer (still in the same parasternal position), a longitudinal view of the RV and right atrium (RA) can be obtained (Fig. 8; please *see* companion DVD for corresponding video). In this window, the RA is to the right and bottom (posterior) and the

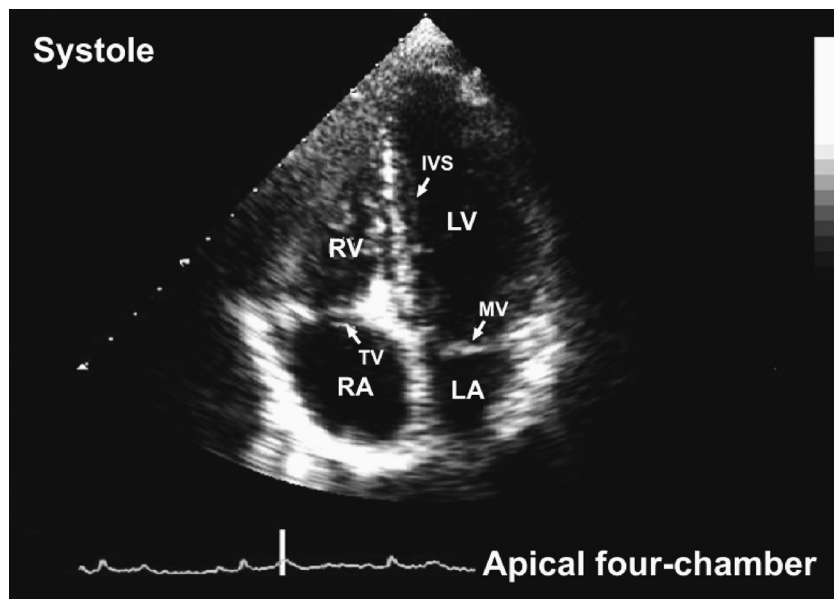


Fig. 11. Apical four-chamber view. From this view, the following structures are easily visualized: left ventricle (LV), right ventricle (RV), left atrium (LA), right atrium (RA), mitral valve (MV), and tricuspid valve (TV). Pulmonary veins (PV) can be visualized at the bottom of the left atrium. Note the prominent moderator band (MB), a normal structure, in the apical third of the right ventricle. (Please see companion DVD for corresponding video.)

RV is above (anterior) and left. This view allows visualization of the tricuspid valve, as well as assessment of tricuspid regurgitation by colorflow and measurement of tricuspid regurgitant velocity utilizing spectral continuous-wave Doppler.

PARASTERNAL SHORT-AXIS VIEWS

Still in position at the left parasternal third or fourth intercostal space, the transducer is rotated 90° clockwise to obtain the short-axis views (Figs. 9 and 10; please see companion DVD for corresponding video). The index is now facing the patient's left shoulder. From this position, the LV is imaged in cross-section. Slices (as from a loaf of bread) can be obtained at three levels: the base, the midventricle, and the apex. The basal third of the heart is seen by angling the transducer superiorly and rightward; this view includes the MV leaflets and extends to the tips of the papillary muscles. Directing the transducer so that it is perpendicular to the chest wall visualizes the middle third of the LV; this view comprises the length of the papillary muscles, from their chordal attachments to their insertion in the LV. In this position, the RV is seen at the top (because it is anterior) and to the left of the screen. The LV should appear round in this view; if it appears oval, then the LV is being imaged obliquely. This is generally an excellent view for assessing global and regional LV contractility. The

apical third of the LV can be seen with further inferior tilting of the probe.

When the transducer is moved even further up the torso or angulated slightly caudally, a cross-section through the aortic valve is obtained (Fig. 10B; please see companion DVD for corresponding video). Color flow Doppler in the short axis through the aortic valve can be useful for assessing aortic insufficiency.

Apical Position

With the patient still in the left lateral decubitus position, the probe is moved to the cardiac apex, just lateral and caudal to the point of maximal impulse. From this position, the transducer direction is varied to obtain the four-, five-, and two-chamber views of the heart: as a general rule, the apical position is superior to the parasternal for looking at mitral or aortic regurgitation, because the regurgitant jets tend to be more parallel to the color Doppler imaging beam.

APICAL FOUR-CHAMBER VIEW

From the apex, the transducer is angled superiorly toward the patient's right shoulder with the index pointing down (toward the patient's left flank) to obtain the four-chamber view; the imaging plane is perpendicular to the interventricular septum (Fig. 11; please see companion DVD for corresponding video). On the screen, the heart is

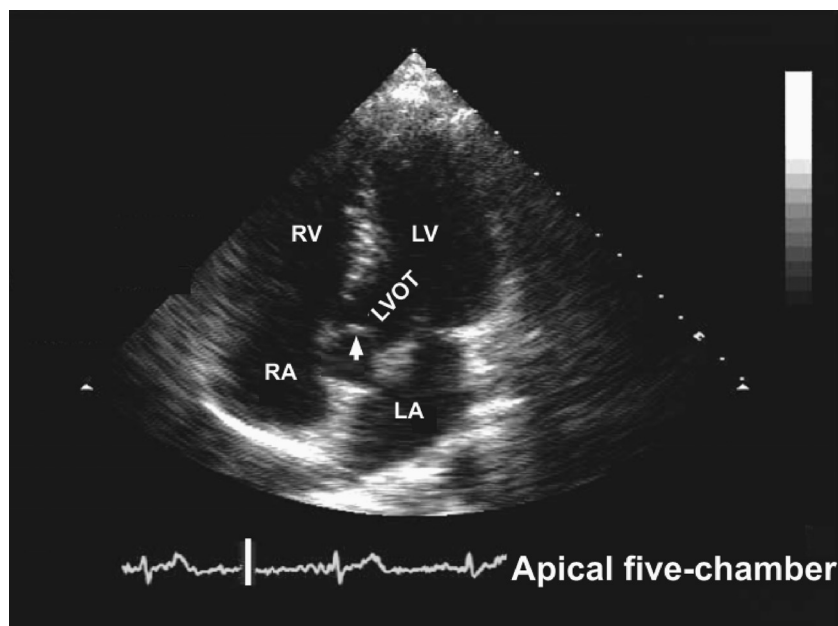


Fig. 12. Apical five-chamber view. Obtained by tilting the scan head 10–20° from the apical four-chamber view, this view allows for visualization of the aortic valve (arrow) and left ventricular outflow tract (LVOT). It is also the best view for obtaining Doppler flow through the aortic valve. (Please *see* companion DVD for corresponding video.)

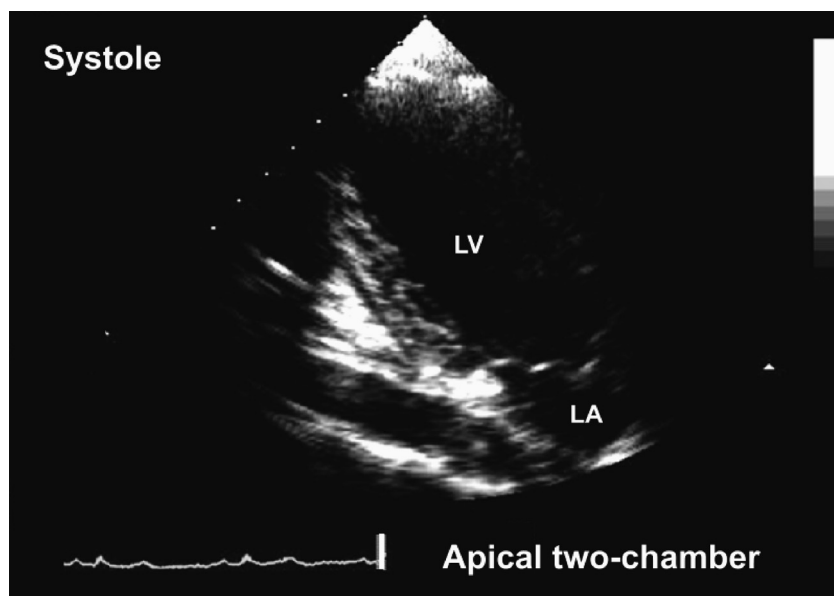


Fig. 13. Apical two-chamber view. Obtained by rotating the transducer 90° counterclockwise from the apical four-chamber view. This view shows the left ventricle (LV) and left atrium (LA), but the right-sided structures are no longer visible. This view is useful for visualizing regional wall motion of the anterior and inferior walls and is also the best angle from which to view the plane of mitral valve coaptation, useful in the diagnosis of mitral valve prolapse. (Please *see* companion DVD for corresponding video.)

displayed upside down, from the perspective of the apically placed transducer. The apex is the structure closest to the transducer and, therefore, it is at the top of the screen; the atria are at the bottom. The LV and LA are on the right and the RV and RA on the left, divided by

the interventricular septum and interatrial septum. Notice that the inner surface of the RV is more heavily trabeculated than that of the LV, and that the RV apex does not reach the LV apex. In many patients, a prominent moderator band can be visualized in the RV; this is a normal

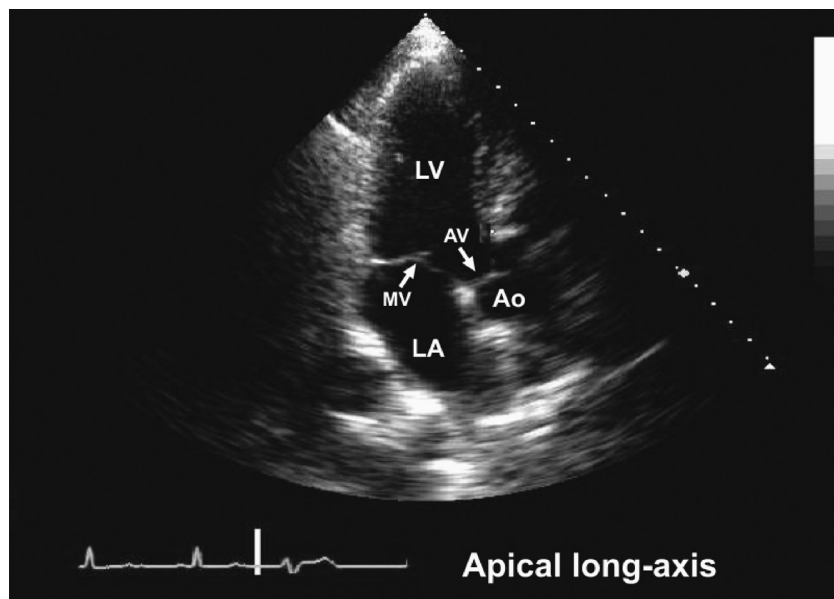


Fig. 14. Apical long-axis view. Obtained by further rotating the transducer another 45° counterclockwise from the apical two-chamber view. This view is almost identical to the parasternal long-axis, although the image is rotated 90° clockwise and the apex is well visualized. This view provides good images of the left ventricular posterior wall, interventricular septum, mitral valve, and aortic valve. (Please see companion DVD for corresponding video.)

finding. Also notice that the attachment of the septal leaflet of the tricuspid valve is approx 5–8 mm closer to the cardiac apex than the mitral attachment. These findings can be helpful in distinguishing the cardiac chambers. The apical four-chamber view is good for assessing ventricular function, particularly the motion of the interventricular septum and the lateral wall of the LV. The anterior RV wall and the AV valves are visualized in this view as well.

Color flow Doppler is used in this view to look for and assess possible mitral regurgitation, aortic insufficiency, and tricuspid regurgitation. The color flow sector should be positioned over the appropriate valve for proper visualization. In addition, color flow of the LVOT can alert the viewer of possible turbulence in this region that might be caused by subaortic stenosis owing to hypertrophic cardiomyopathy or a subaortic membrane.

Spectral Doppler is used to assess mitral inflow. The Doppler cursor is placed at the tips of the leaflets and the mitral inflow signal is assessed. Tricuspid regurgitant velocity can be assessed by continuous-wave Doppler through the tricuspid valve. The tricuspid regurgitant velocity is dependent on the gradient between the RV and the RA. Using the Bernoulli equation (*see* Chapter 1), the pulmonary systolic pressure can be estimated (in the absence of pulmonic stenosis) by adding the estimated

gradient between the RV and the RA to an estimate of RA pressure (*see* Chapter 1).

APICAL FIVE-CHAMBER VIEW

Without changing the position or rotation of the transducer, tilting of the scan head 10–20° anteriorly reveals the five-chamber view, with the imaging plane now traversing the AV and LVOT (the “fifth chamber;” Fig. 12; please see companion DVD for corresponding video). This is often the best view for assessing the structure and function of the aortic valve. Doppler color flow mapping and Doppler pulsed-wave images obtained in this view are useful in determining the presence and severity of aortic regurgitant or stenotic lesions.

APICAL TWO-CHAMBER VIEW (FIG. 13; PLEASE SEE COMPANION DVD FOR CORRESPONDING VIDEO)

The anterior and inferior walls of the LV are not visualized in the four- and five-chamber views because the imaging plane does not traverse them; these can be seen by rotating the imaging plane 90° counterclockwise (so the index now points to the patient’s left shoulder), producing the apical two-chamber view (the two chambers are the LA and LV). Regional wall motion of the anterior and inferior walls is seen in this view; it is also the best angle from

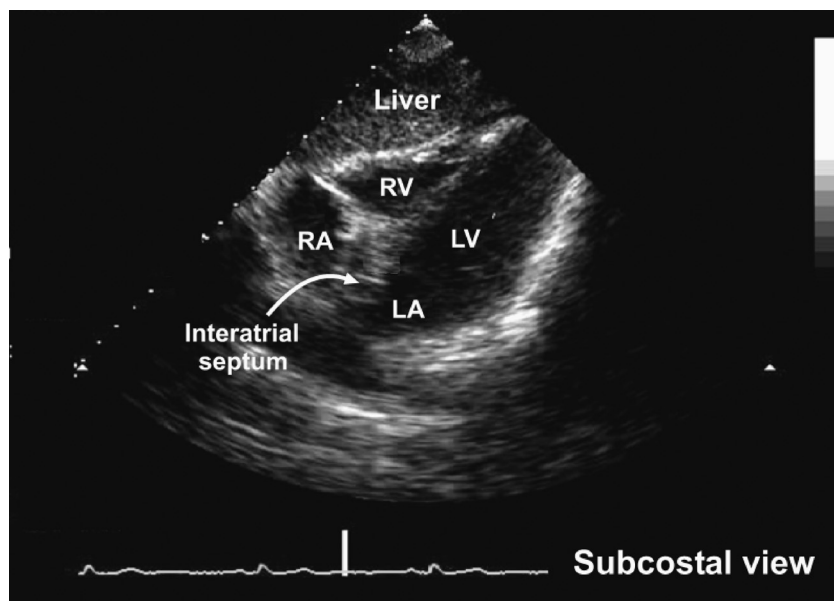


Fig. 15. Subcostal view, showing interatrial septum. The subcostal view demonstrates the right heart structures well. In addition, this view is useful for examination of the interatrial septum, and is used to help rule out atrial septal defects. This is also a useful view for assessing the hepatic veins and inferior vena cava (IVC). (Please *see* companion DVD for corresponding video.)

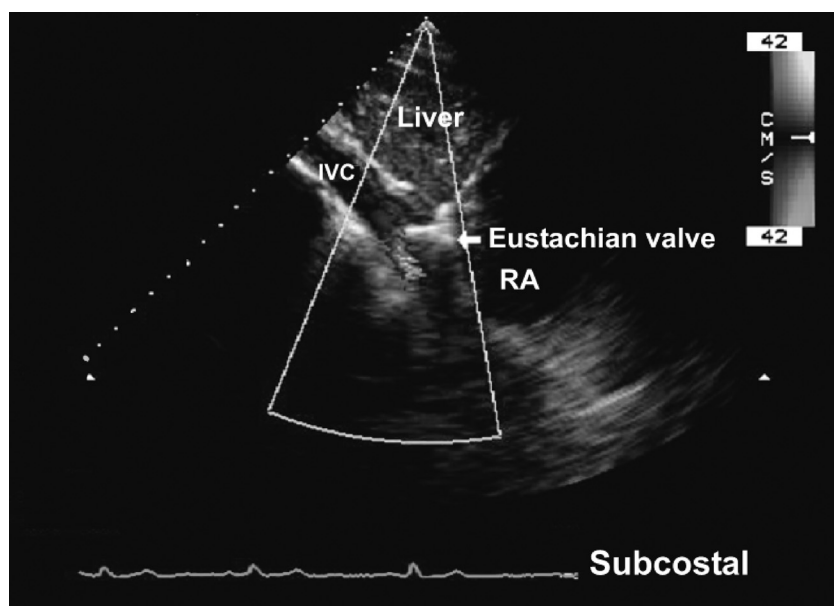


Fig. 16. Subcostal view showing hepatic veins and inferior vena cava (IVC). Elevated right atrium pressure may lead to IVC dilation and loss of the expected inspiratory collapse. (Please *see* companion DVD for corresponding video.)

which to view the plane of MV coaptation, useful in the diagnosis of MV prolapse. Color flow Doppler should be used in this view as well to visualize potential mitral regurgitation in the orthogonal plane to the four-chamber view.

APICAL LONG-AXIS VIEW

Further counterclockwise rotation of the transducer head produces the apical long-axis or three-chamber view (Fig. 14; please *see* companion DVD for corresponding video). This imaging plane is very similar to

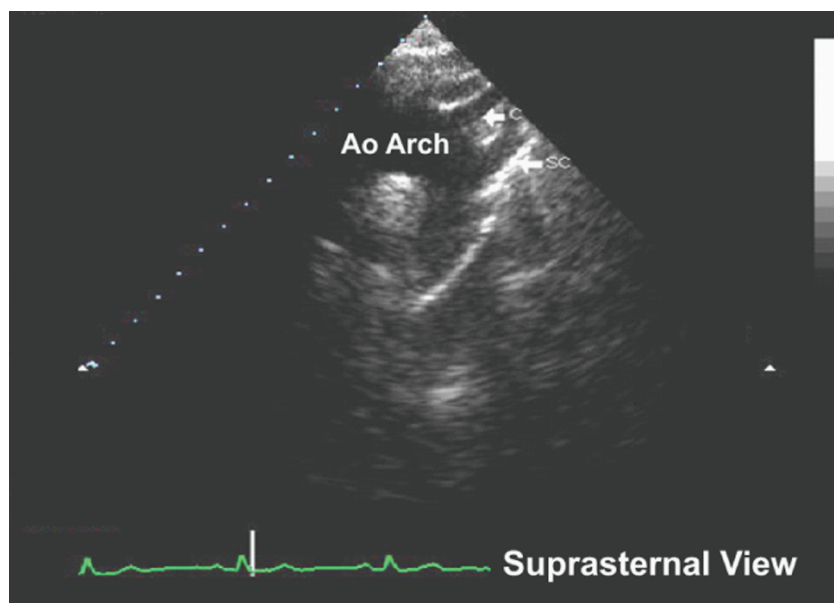


Fig. 17. Suprasternal view. The suprasternal transducer position allows visualization of the aortic arch and its major branches. The innominate artery arises from the ascending aorta (seen on the left of the screen); the left carotid and subclavian arteries arise from the left arch as it becomes the descending thoracic aorta. The right pulmonary artery (RPA) may be seen in cross-section beneath the aortic arch. (Please *see* companion DVD for corresponding video.)

the parasternal long-axis, and provides a good image of the LV posterior wall, interventricular septum, MV, and aortic valve. Color flow Doppler in this view can be useful to view potential aortic insufficiency.

Subcostal Position

For the subcostal views, the transducer is placed in the subxiphoid region, just to the right of center (Figs. 15 and 16; please *see* companion DVD for corresponding video). In this position, the ultrasound beam travels through the abdominal wall, part of the liver, and the diaphragm on its way to the heart. In some patients, such as those with emphysema, this may be the best imaging position (hyperinflated lungs obscure the parasternal windows, and flattened diaphragms optimize subcostal windows). However, in obese patients, subcostal windows may be difficult to obtain. For the subcostal views, the patient is placed in the supine position with knees flexed to relax the abdominal muscles. Deep inspiration with breath hold facilitates optimal imaging in this view.

From this position, a four-chamber view can be obtained by angulation of the transducer head toward the left shoulder, with the index facing the patient's left flank. In this image, the apex of the heart points up and to the right; the RA and RV are above the left heart chambers, adjacent to the liver. The right heart structures are well visualized in this view. The interatrial septum can be

examined with color Doppler imaging for septal defects or patent foramen ovale. Rotating the transducer so the index points to the patient's head emphasizes the right heart structures as well as the hepatic veins and inferior vena cava (IVC). This is the optimal view for assessing the IVC, which can provide an indirect assessment of RA pressure; elevated RA pressure may lead to IVC dilation and loss of the expected inspiratory collapse. Clockwise rotation of the transducer produces a subcostal short-axis view of the LV and RV.

Color flow Doppler should be used to interrogate the interatrial septum for possible atrial septal defects, particularly secundum defects, which are best visualized in this view.

Suprasternal Position

The suprasternal transducer position allows visualization of the aortic arch and its major branches (Fig. 17; please *see* companion DVD for corresponding video). The transducer is placed in the suprasternal notch with the index toward the patient's head and the tip angled caudally; slight anterior or posterior tilting of the transducer maneuvers the imaging plane along the major axis of the aorta. The innominate artery arises from the ascending aorta (seen on the left of the screen); the left carotid and subclavian arteries arise from the left arch as it becomes the descending thoracic aorta. The right

pulmonary artery may be seen in cross-section beneath the aortic arch. Ninety degree rotation of the transducer head reveals the aortic arch in cross-section and the right pulmonary artery in longitudinal axis. This view can be useful in the diagnosis of some aortic diseases and congenital anomalies, including severe aortic insufficiency and aortic coarctation.

SUMMARY

A solid understanding of the normal echocardiogram is a necessary prerequisite to the identification of disease states. Watch this normal study several times, paying close attention to the valve structures and Doppler patterns in each window, the normal thickening of the myocardium, and the relative sizes of the various cardiac chambers. It may be useful to refer back to this study when abnormalities in subsequent chapters are encountered. The next chapter

(Chapter 3) describes technical details of the standard echocardiographic examination in greater detail, and is designed to complement the overview presented in this chapter.

SUGGESTED READING

- Jawad IA. Ultrasound in cardiology. In: Jawad IA, ed. *A Practical Guide to Echocardiography and Cardiac Doppler Ultrasound*, 2nd ed. Boston: Little, Brown, and Co, 1996:13–85.
- Oh JK, Seward JB, Tajik AJ. Transthoracic echocardiography. In: Oh JK, Seward JB, Tajik AJ, eds. *The Echo Manual*, 2nd ed. Philadelphia: Lippincott-Raven, 1999:7–22.
- Sehgal CM. Principles of Doppler imaging and ultrasound. In: St. John Sutton MG, Oldershaw PJ, Kotler MN, eds. *Textbook of Echocardiography and Doppler in Adults and Children*, 2nd ed. Cambridge: Blackwell Science, 1996:3–30.
- St. John Sutton MG, Oldershaw PJ, Plappert TJ. Normal transthoracic Doppler echocardiographic examination. In: St. John Sutton MG, Oldershaw PJ, Kotler MN, eds. *Textbook of Echocardiography and Doppler in Adults and Children*, 2nd ed. Cambridge: Blackwell Science, 1996:31–66.



<http://www.springer.com/978-1-58829-332-9>

Optimization in Drug Discovery

Yan, Z.; Caldwell, G.W. (Eds.)

2004, XVI, 420 p., Hardcover

ISBN: 978-1-58829-332-9

A product of Humana Press