Focused echo – assessment of LV function in the ED

Philips tutorial

Dale Quirke, MD
Wake Emergency Physicians, Wake Medical Hospital, Raleigh, North Carolina

Anthony J. Weekes, MD, RDCS, RDMS
Director, Emergency Ultrasound Fellowship, Carolinas Medical Center
Associate Clinical Professor of Emergency Medicine
University of North Carolina, Chapel Hill

Contents

Focused echo – assessment of LV function in the ED

1 Introduction

Echocardiography at the bedside is rapidly becoming an integral part of patient care in the emergency department (ED), especially in the evaluation and treatment of hypotensive and/or critically ill patients.

The emergency medicine physician is frequently challenged by limited information when determining the etiology of a patient's illness. Furthermore, the patient's body habitus, the patient's inability to cooperate, or external factors such as mechanical ventilation, can limit the physician's ability to perform an adequate physical examination. In addition, the physical examination alone has been shown to be unreliable when differentiating hypovolemic shock from cardiogenic shock.[1, 2] Thus, in critically ill patients, these complicating factors create a barrier to identifying potentially life-threatening conditions.

Prior to the availability of ultrasound in the ED, other more invasive methods such as pulmonary artery (Swan-Ganz) catheters were used to aid in differentiating cardiogenic shock from other causes of shock. However, due to the invasive nature of placing the catheters, their use in the ED has fallen out of favor.

Comprehensive echocardiograms performed by the cardiology department can be ordered in the ED and their diagnostic accuracy is known to be excellent. However, when treating critically ill patients, a comprehensive echo frequently cannot be obtained in a timely fashion.

These factors combined have led emergency medicine physicians to seek competency in point-of-care (POC) echocardiography in order to provide real-time diagnostic and therapeutic measures to patients suspected of having cardiac pathology.

The ACEP 2006 Emergency Ultrasound Imaging Criteria Compendium includes several indications for the use of emergency physician-performed focused echo.[3]

These indications include:

- Evaluation of gross cardiac activity in the setting of cardiopulmonary resuscitation
- Evaluation of global left ventricular systolic function
- Detection of pericardial effusion and/or tamponade
- Gross estimation of intravascular volume status and cardiac preload

Additionally, the American College of Cardiology/American Heart Association (ACC/AHA) task force on practice guidelines for the clinical application of echocardiography cited patients with unexplained hypotension, dyspneic patients with clinical signs of elevated central venous pressure (CVP) when a cardiac etiology is suspected, and patients in whom CVP cannot be obtained with confidence as additional indications for bedside echo.[4, 5]

Several studies have demonstrated that emergency medicine physicians can accurately evaluate global cardiac function using goal-directed cardiac ultrasound. In one study, for example, *Moore et al.* showed that emergency physicians can accurately and with good reliability classify the ejection fraction based on visual estimates when compared to a cardiologist's interpretation of the same exams.[6] Left ventricular ejection fraction in this study was classified into three categories by visual estimation: normal, moderately depressed, and severely depressed. The results of the visual estimates were then compared to numerical measurements and were found to be favorably comparable when assessed for interobserver variability.

In another study by *Randazzo et al.*, the researchers confirmed that visual estimation of left ventricular ejection fraction was more accurate when comparing bedside echo performed by emergency physicians to a formal echo obtained within a four-hour window.[7] Three categories were used to rate LV ejection fraction: normal (>55%), moderate (30–55%), and poor (<30%).

As a result of this research, a consensus statement was developed supporting the use of the visual estimation method and confirmed that this descriptive approach showed good correlation with interpretation by echocardiographers *(American Society of Echocardiography 2010)*.[8]

Common clinical indicators for left ventricular systolic function assessment

Hypotension	Syncope
Dyspnea	Dizziness
Chest pain	Lethargy
Dysrhythmia	Jugular venous distension
Palpitations	Bilateral leg edema
Cardiomegaly	Weakness
Evaluation of inotropic medication capture	Suspected heart failure

This tutorial focuses specifically on the POC echo exam for the assessment of global left ventricular function (LVF) for the primary indications of undifferentiated hypotension or suspected congestive heart failure. This tutorial will review how 2D, M-mode and pulsed wave Doppler can be used to assess LV function in the ED setting. Only the echo views used to assess left ventricular function will be discussed. This tutorial does not cover all standard POC echo views.

2 Assessment of LV function using 2D

The 2D views used for the evaluation of left ventricular function include:

- Parasternal long-axis
- Parasternal short-axis
- Apical four-chamber
- Subcostal

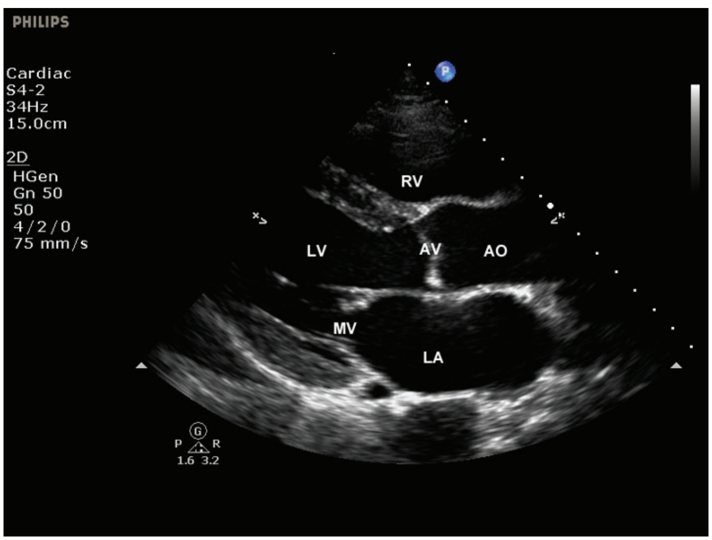
Using 2D imaging, the clinician can rapidly assess LV wall motion and thickening as well as relative chamber size. It is important to note that optimal 2D views are required for accurate assessment of LV function.

2D still-frame images and video clips can be archived on the ultrasound system for review. Video clips are important in the estimation of cardiac function because they allow for review of myocardial thickening and contractility as well as valvular motion.

Parasternal long-axis (PSLA) view

The parasternal long-axis image is obtained by placing the transducer in the second or third intercostal space near the sternum with the transducer orientation marker directed towards the patient's right shoulder. In an optimal view, the interventricular septum and LV posterior wall are parallel and as horizontal as possible.

The parasternal long-axis view is the most important view used in estimating cardiac function at the bedside for emergency physicians because it is typically the easiest view to obtain and it provides important information regarding cardiac contractility, the presence or absence of pericardial effusion, and right ventricular strain. It provides an excellent view of the left ventricle, left atrium, mitral valve and left ventricular outflow tract. The right ventricle is seen anterior to the left ventricle and is noticeably smaller with thinner walls. The right atrium is not seen in this view.

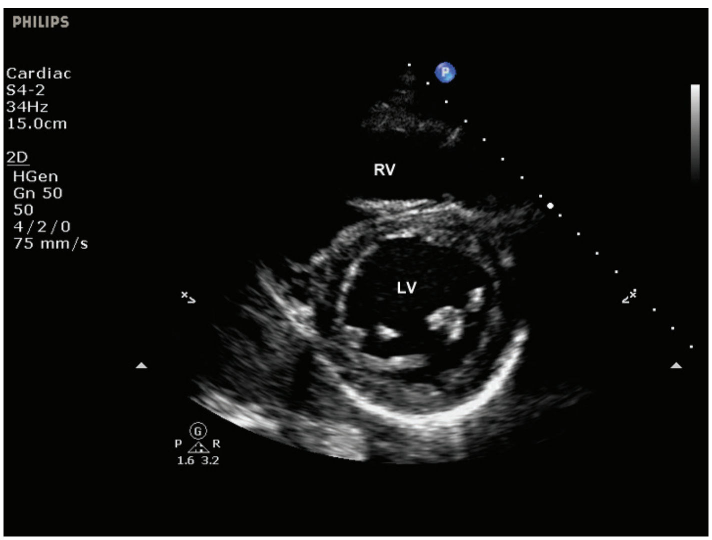


[Figure 1] **Parasternal long-axis. RV = Right Ventricle, LV = Left Ventricle, AV = Aortic Valve, AO = Aorta, LA = Left Atrium, MV = Mitral Valve.**

Parasternal short-axis (PSSA) view

To obtain a standard parasternal short-axis image, begin with the parasternal long-axis view and rotate the transducer 90° clockwise (the orientation marker will be directed towards the patient's left shoulder). In an optimal view, the LV will be round and in the center of the image.

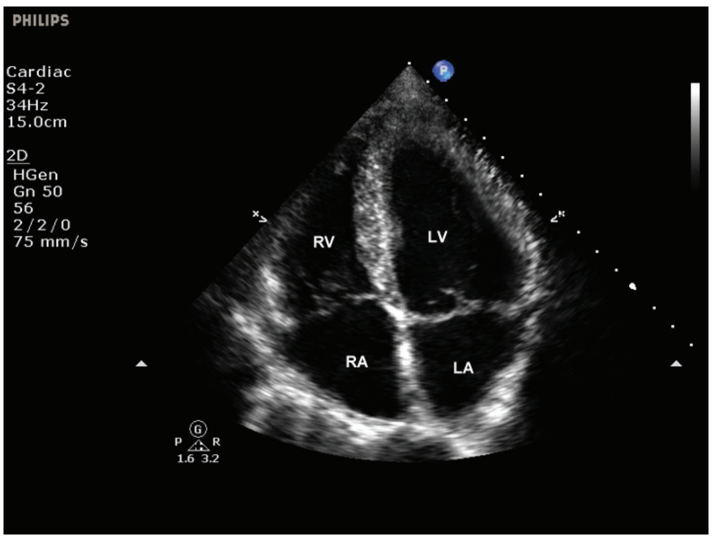
The parasternal short-axis view at the papillary muscle level is another common view used to assess global cardiac function in the ED. To visualize the papillary muscles, tilt the transducer so the ultrasound beam is gently angled toward the apex. Careful consideration must be used to ensure that the papillary muscles are not mistaken for left ventricular hypertrophy.



[Figure 2] Parasternal short-axis view at the papillary muscle level. RV = Right Ventricle, LV = Left Ventricle.

Apical four-chamber view

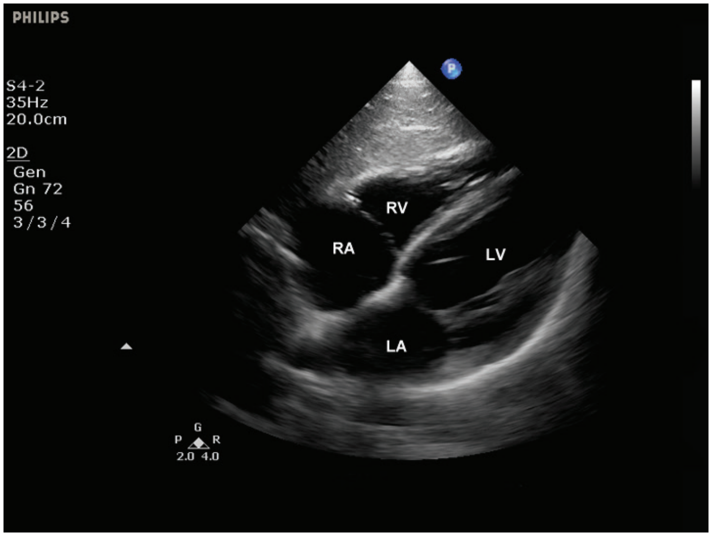
The apical four-chamber image is obtained by placing the transducer just lateral and inferior to the left nipple. Place the transducer on the apical impulse if possible. The orientation marker on the transducer should be to the patient's left. Angle the ultrasound beam up toward the base of the heart until the ultrasound beam cuts through the long axis of the heart (all four chambers will be visualized). The interventricular septum will be in the midline of the image in an optimal view. The mitral and tricuspid valves are well visualized in this view.



[Figure 3] **Apical four-chamber view. All four chambers are seen, as well as the mitral and tricuspid valves. Note the increased left ventricular size compared to the right ventricular size, as expected in a patient with normal cardiac function. RV = Right Ventricle, LV = Left Ventricle, LA = Left Atrium, RA = Right Atrium.**

Subcostal view

The transducer is placed in the subxiphoid region with the orientation marker pointed towards the patient's left. All four chambers as well as the pericardium are visualized. This is the most common view used when performing CPR to avoid interruptions in cardiac compression or ongoing thoracic procedures.



[Figure 4] Subcostal standard view. All four chambers are seen in the subcostal view. Note that the right ventricle abuts the liver. RA = Right Atrium, RV = Right Ventricle, LA = Left Atrium, LV = Left Ventricle.

3 Interpretation

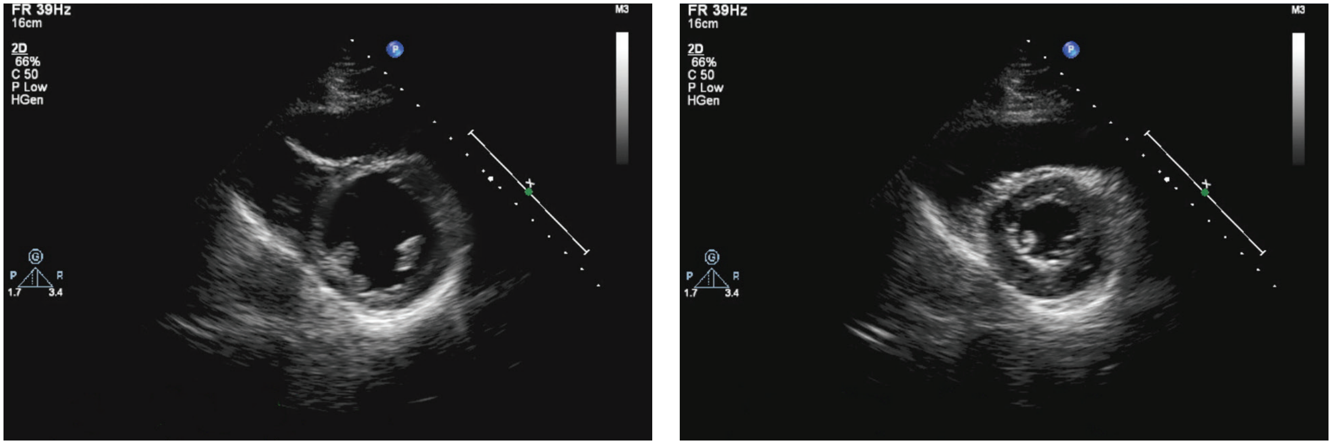
2D imaging for the assessment of LV function

Visual estimation of LV function can provide accurate and reliable information at the bedside. LV function is assessed by visual estimation using wall motion in addition to comparison of the LV size between diastole and systole. Optimal views are required to assess LV function.

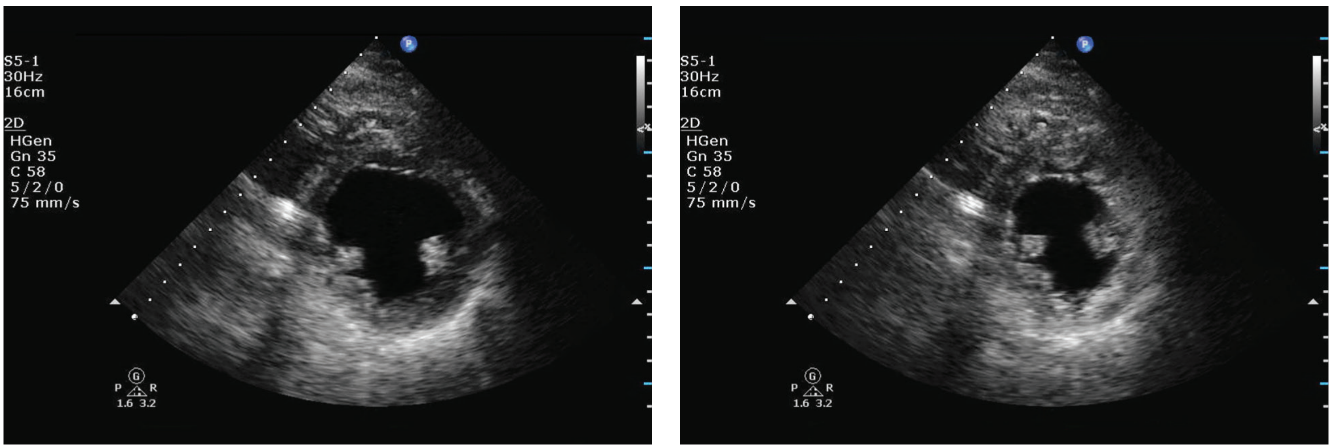
Wall motion refers to both thickening and inward motion of the endocardium during systole. There should be a marked difference between the wall thickness in diastole and wall thickness in systole. As the LV walls thicken and move toward the center of the LV during systole, the LV chamber becomes smaller **(Figures 5-8)**.

Things to consider when assessing LV function

- Carefully note if wall thickening is occurring. Inward motion of a wall may occur because of adjacent wall thickening and motion.
- Patients with moderately depressed cardiac function will exhibit some wall thickening, but the difference in thickness between systole and diastole is not as significant as in normal LV function.
- A patient with moderately depressed cardiac function will show limited movement of the endocardial borders toward each other during systole.
- Wall thickening will be minimal in patients with severely depressed cardiac function.
- Patients with evidence of dilated cardiomyopathy will have dilated ventricles with thin walls and poor systolic function.
- Assessment of LV function can be confounded by other factors such as the hydration status of the patient or valvular abnormalities (such as mitral stenosis and/or aortic regurgitation) and thus must be interpreted within the clinical context of the patient.
- The ability to estimate LV function improves over time after viewing many echocardiograms with varying degrees of LV function.

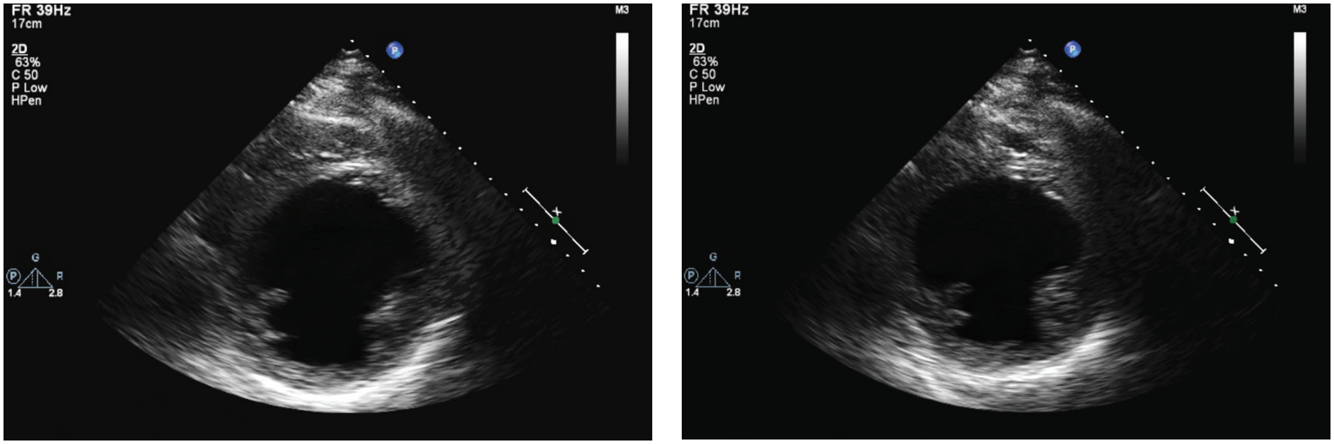


[Figure 5a (diastole) and 5b (systole)] Still frame images of normal LV function using the parasternal short-axis view. The walls thicken and move toward the center of the LV symmetrically. Note the difference in the LV size between diastole and systole.

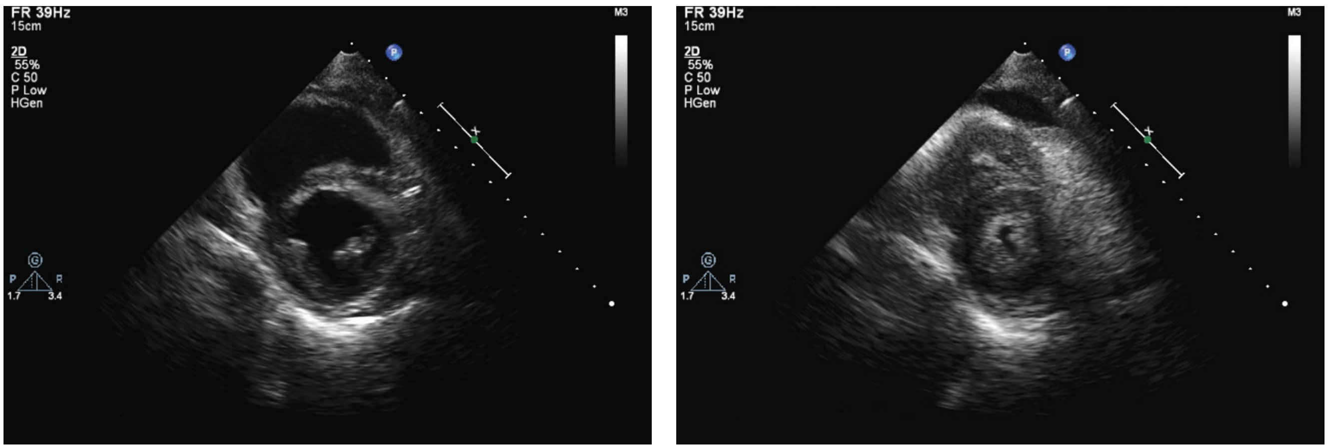


[Figure 6a (diastole) and 6b (systole)] Still frame images of mild-moderate LV dysfunction. There is moderate wall thickening and mild-to-moderate change in LV size between diastole and systole.

Images provided courtesy of Dr. Anne-Sophie Beraud from *"Introduction to transthoracic echo"* tutorial.



[Figure 7a (diastole) and 7b (systole)] **Still frame images of severe LV dysfunction. There is only minimal change in wall thickness and chamber size between diastole and systole.**



[Figure 8a (diastole) and 8b (systole)] **Still frame images of hyperdynamic LV function. Wall thickening and motion almost obliterate the LV in systole.**

Images provided courtesy of Dr. Anne-Sophie Beraud from *"Introduction to transthoracic echo"* tutorial.

[Video 1]

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

Normal LV function. This is a PSLA view of a patient with normal cardiac function. The walls thicken and move toward the center of the LV symmetrically. Note the difference in the LV size between diastole and systole

[Video 2]

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

Moderately depressed LV function. This is a PSLA view of a patient with moderately depressed cardiac function. Myocardial wall thickening, and change in LV size between diastole and systole are reduced compared to Video 1 (normal cardiac function).

[Video 3]

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

Severely depressed LV function. This is a PSLA view of a patient with severely depressed cardiac function. There is only minimal change in wall thickness and chamber size between diastole and systole.

The measurement of ejection fraction (EF) with comprehensive echocardiography is often cited as the gold standard in evaluating a patient's global cardiac function. However, measurement of EF is complex and several assumptions about the shape of the left ventricle are made. Formal calculation of ejection fraction is outside of the scope of practice for most emergency medicine physicians given the time-sensitive nature of the information that is needed. Reliance on visual estimates or semi-quantitative measurements is likely more appropriate in the setting of the emergency department.

Longitudinal systolic shortening (movement along the long axis of the LV) is also an important component of systolic function. Longitudinal systolic shortening of the LV can be appreciated in the parasternal long-axis and apical 2D views. Movement of the mitral annulus toward the apex can be assessed with tissue Doppler or even M-mode using the apical windows. The magnitude of the systolic movement of the mitral annulus reflects the longitudinal shortening of the left ventricle. The normal movement is 12 +/- 2 mm. Values less than 8 mm are usually associated with systolic dysfunction (LV ejection fraction less than 50%). Tissue Doppler is sensitive for systolic dysfunction and is performed in comprehensive echocardiography exams. The use of tissue Doppler is not within the scope of the focused bedside exam to assess LV function.

4 LVH and cardiomyopathies

During the routine evaluation of a patient for assessment of global cardiac function, evidence of left ventricular hypertrophy or cardiomyopathy may be found. The two most common forms of cardiomyopathy are hypertrophic cardiomyopathy and dilated cardiomyopathy.

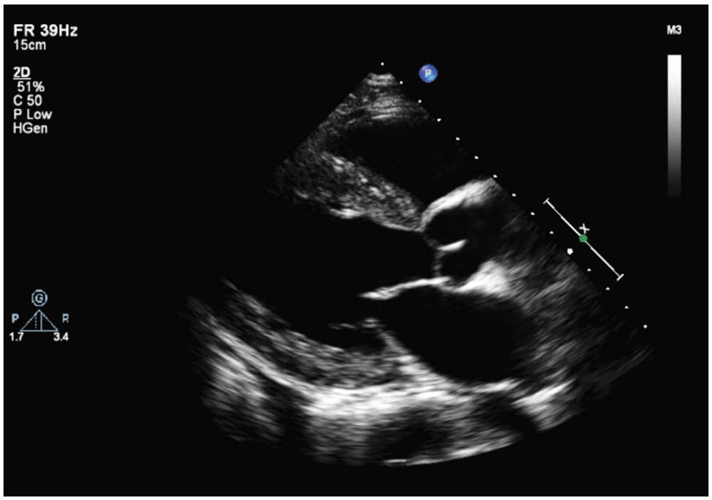
LVH

An LV posterior wall measurement of greater than 12 mm at end diastole, when measured just apical to the mitral valve leaflets, is a strong indicator that left ventricular hypertrophy is present. LVH is typically uniform or concentric, and the most common causes are long-standing hypertension or aortic stenosis. Reduced cardiac function in both the systolic and diastolic phases can be seen with LVH. However, the diastolic dysfunction is often more prominent due to impaired relaxation of the cardiac muscle during the diastolic filling phase.

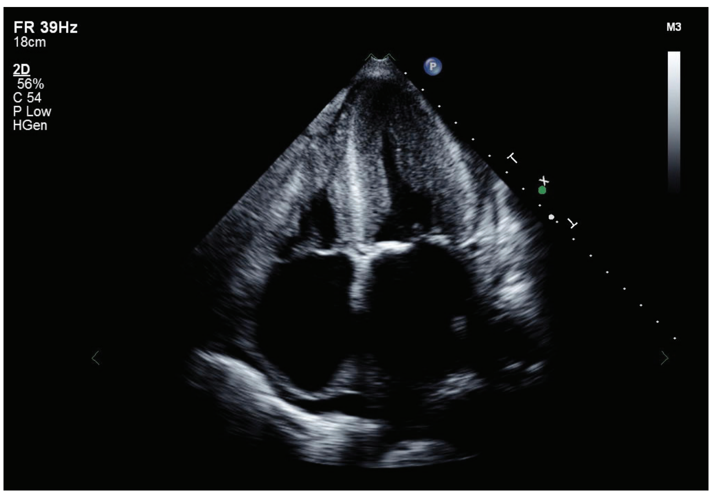
Hypertrophic obstructive cardiomyopathy

Hypertrophic obstructive cardiomyopathy (HOCM) is an inherited autosomal dominant disorder in which a mutation in the B-myosin gene leads to hypertrophy of the cardiac muscle. Typically, the hypertrophy is asymmetric, and often affects the interventricular septum or cardiac apex. This may lead to outflow obstruction at the subaortic level and causes patients to be at risk for syncope, congestive heart failure, and sudden death. Left ventricular hypertrophy is considered necessary but not sufficient to diagnose HOCM, as it differs from other more common causes of LVH such as long-standing hypertension or aortic stenosis.

Young patients presenting with syncope in whom there is concern for having HOCM should undergo a comprehensive echocardiogram. Early identification is critical to prevent life-threatening consequences.



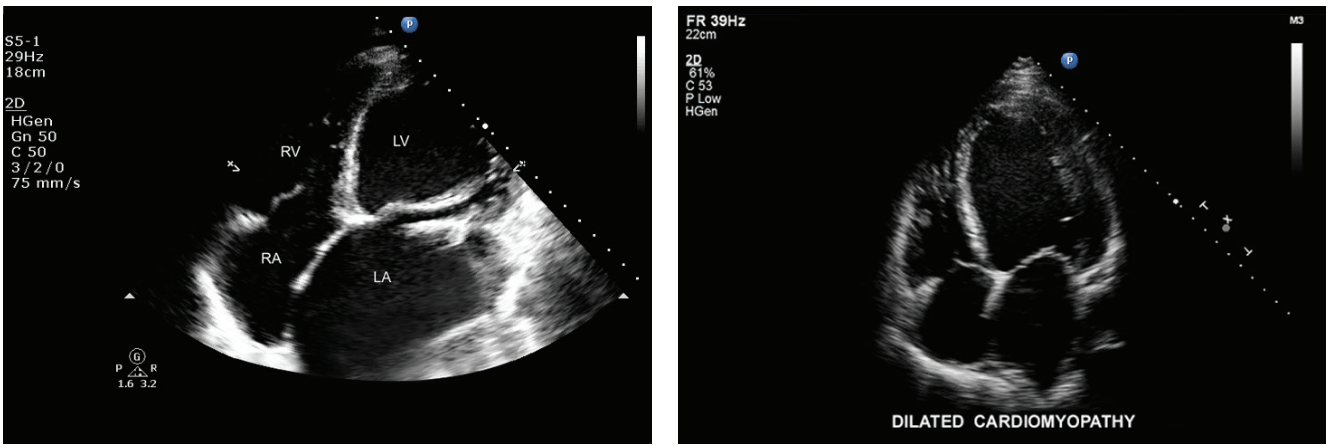
[Figure 9a] **LVH. This PSLA view shows hypertrophy of the left ventricular posterior wall as well as the interventricular septum.**



[Figure 9b] **HOCM. This apical four chamber view displays marked hypertrophy of the septum and lateral wall of the left ventricle. Left ventricle wall thickness is approximately 30 mm. The left ventricle volume is diminished.**

Dilated cardiomyopathy

Dilated cardiomyopathy is associated with poor systolic function. Echo findings include large, dilated cardiac chambers, thin LV walls and abnormal systolic/diastolic function. Dilated cardiomyopathy is often idiopathic in nature but may result from other etiologies such as excessive alcohol consumption, toxic effects of certain prescription and illicit drugs, and genetic abnormalities. A common metric used for the determination of dilated cardiomyopathy is a left ventricular end diastolic diameter >6 cm when measured in the PSLA view.



[Figure 10a] **Dilated cardiomyopathy. Notice the large dilated chambers in this apical four-chamber view. In this 2D image, the chambers are so large that it is difficult to view the heart in its entirety with a single view.** **[Figure 10b]** **Another example of a dilated cardiomyopathy.**

5 M-mode for the assessment of LV function

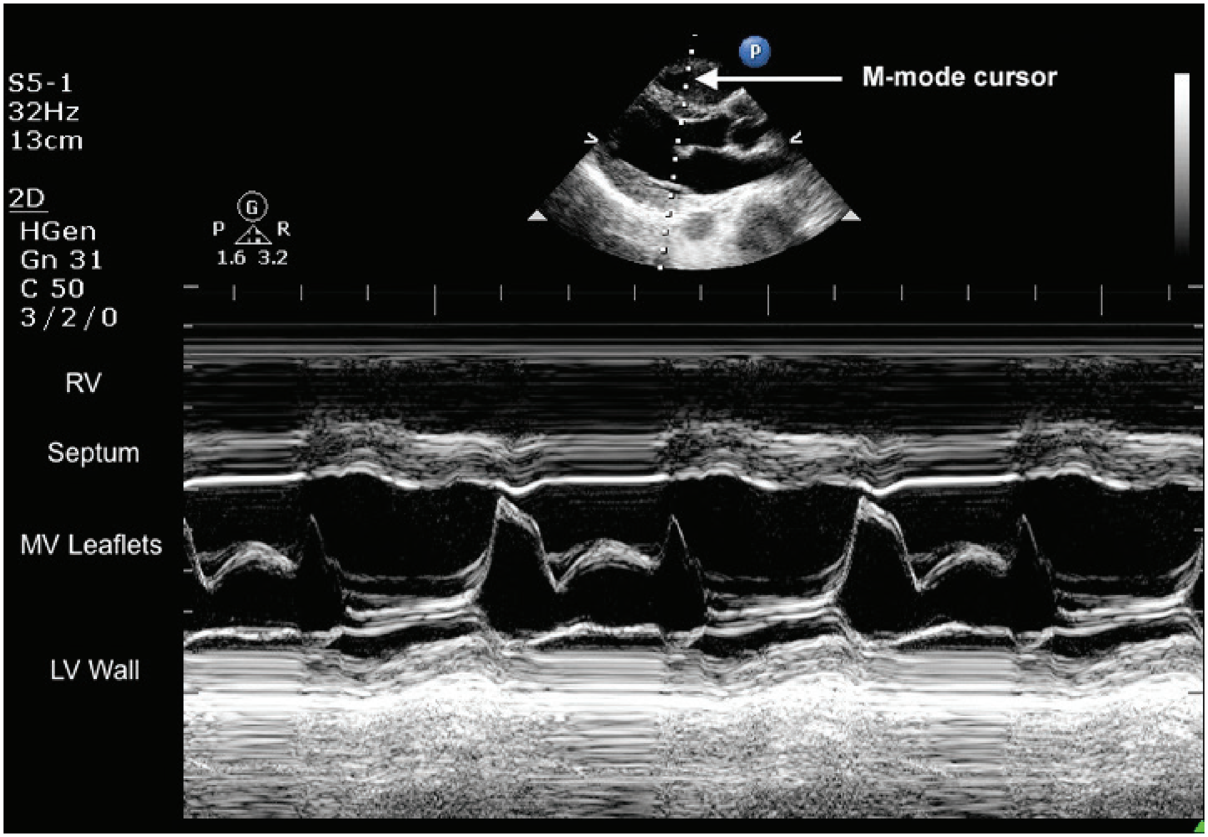
In addition to 2D imaging, the use of M-mode (motion mode) can be a useful tool that allows measurement of what previously had only been assessed by visual estimation. M-mode is a high fidelity "motion" image of a single slice of cardiac anatomy over time. M-mode is useful for assessing wall motion and valve motion over an entire cardiac cycle.

Typically M-mode is acquired from the parasternal long-axis and parasternal short-axis views. An optimal 2D image is required to ensure that the M-mode trace is accurate. Using the 2D image as a reference, the M-mode cursor (also called an M-line) is placed on the structures of interest. When the M-mode is activated a scrolling display of the motion of the structures is plotted along the vertical axis and time is plotted on the horizontal axis.

One of the more common applications of M-mode is evaluating the motion of the mitral valve leaflets. The M-mode cursor should be placed so both the anterior and posterior mitral valve leaflets are seen on the M-mode tracing. A normal mitral valve trace of the anterior leaflet is an “M” shape (the posterior leaflet motion is a mirror image of the anterior leaflet only smaller).

The first peak of the “M” is referred to as the E-wave and represents early passive diastolic filling of the LV (the mitral valve opens and the anterior leaflet moves toward the interventricular septum). With normal left ventricular function, the anterior leaflet of the mitral valve will nearly touch the septum during early diastole.

The late peak of the “M” represents active filling from atrial contraction and is referred to as the a-wave.



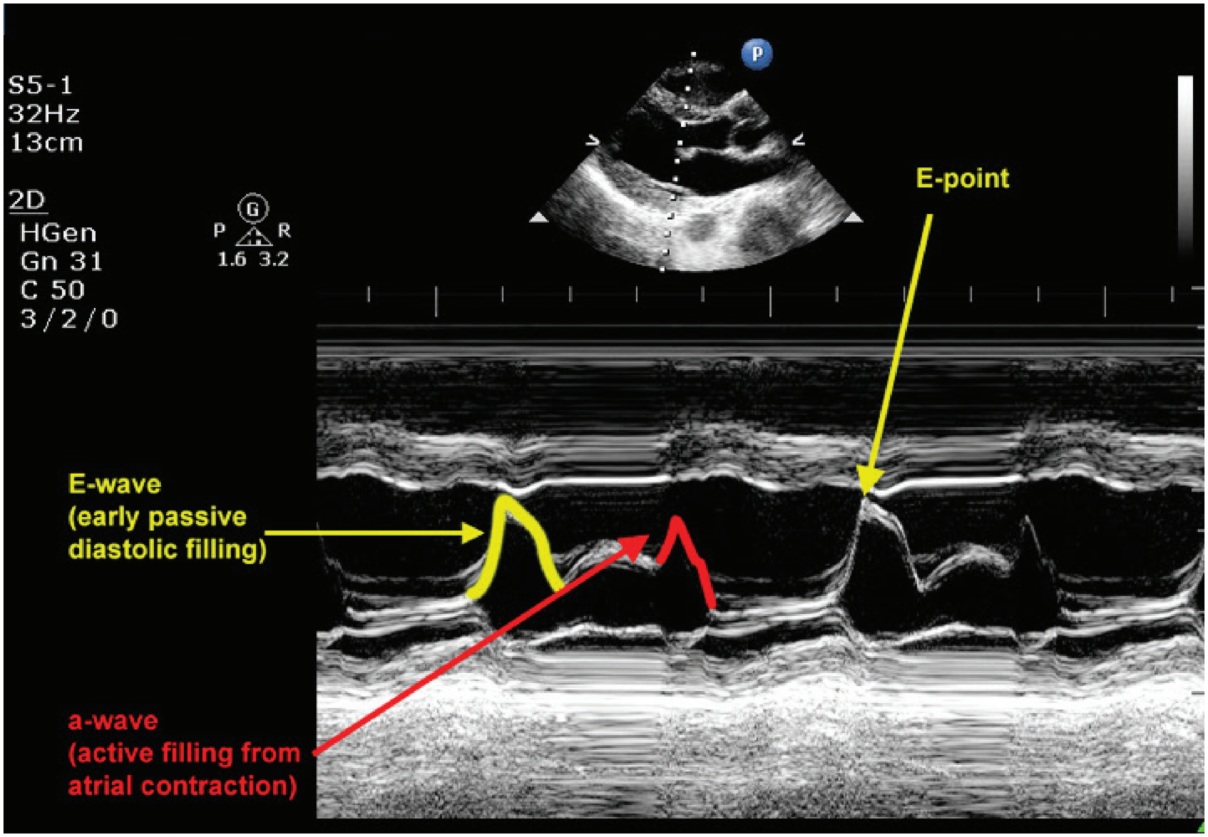
[Figure 11] **M-mode of the mitral valve. Note the 2D reference image above the M-mode trace. After obtaining an optimal 2D image the M-mode cursor is placed through the tips of the mitral valve leaflets. Movement of the mitral valve leaflets is plotted over time (from left to right) on a scrolling display. The labels to the left of the M-mode trace correspond to the structures in this M-mode trace. RV = Right Ventricle; MV = Mitral Valve; LV = Left Ventricle.**

6 E-Point Septal Separation (EPSS)

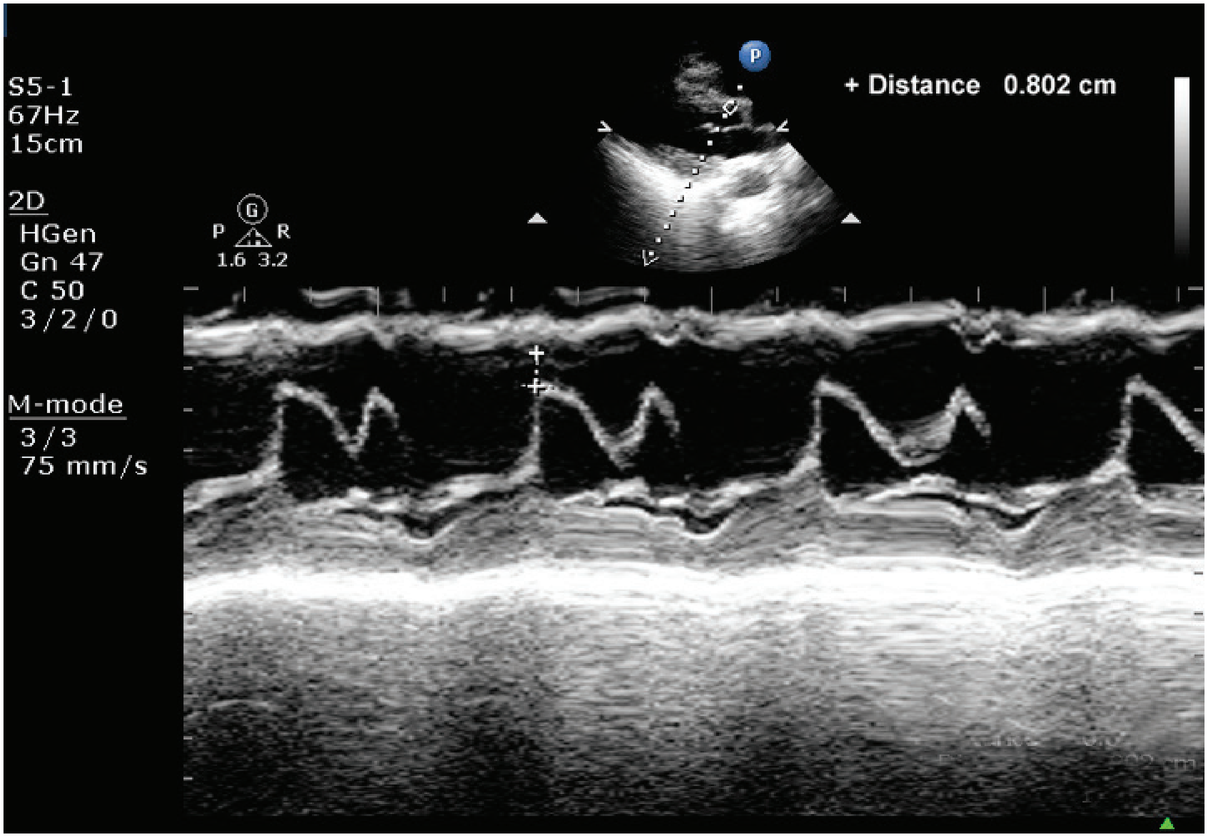
The distance between the tip of the mitral valve E-wave and the interventricular septum is the E-Point Septal Separation (EPSS). The EPSS can be measured using M-mode.

The EPSS can be a useful indication of LV function. In patients with depressed left ventricular function the EPSS will increase. Reduced stroke volume results in a decrease in the amount of blood moving through the mitral valve in early diastole, hence the mitral valve opening is reduced. Consequently, the distance between the maximal opening of the anterior leaflet of the mitral valve and the interventricular septum will be increased. The EPSS will also increase as the left ventricle dilates.

To measure the EPSS, the M-line is placed through the tips of mitral valve leaflets in the parasternal long-axis view. The resulting M-mode image shows the motion of the mitral valve leaflets over time. The EPSS is measured from the top of the E-wave (E-Point) to the septum. A normal EPSS is less than 7 mm. An EPSS greater than 7 mm can be associated with LV systolic dysfunction, dilated LV, aortic regurgitation and mitral stenosis.



[Figure 12] **M-mode of the mitral valve demonstrating normal E-Point Septal Separation. The anterior leaflet of the mitral valve nearly contacts the interventricular septum during early passive diastolic filling (when the LV is filling rapidly), indicating normal global cardiac function.**

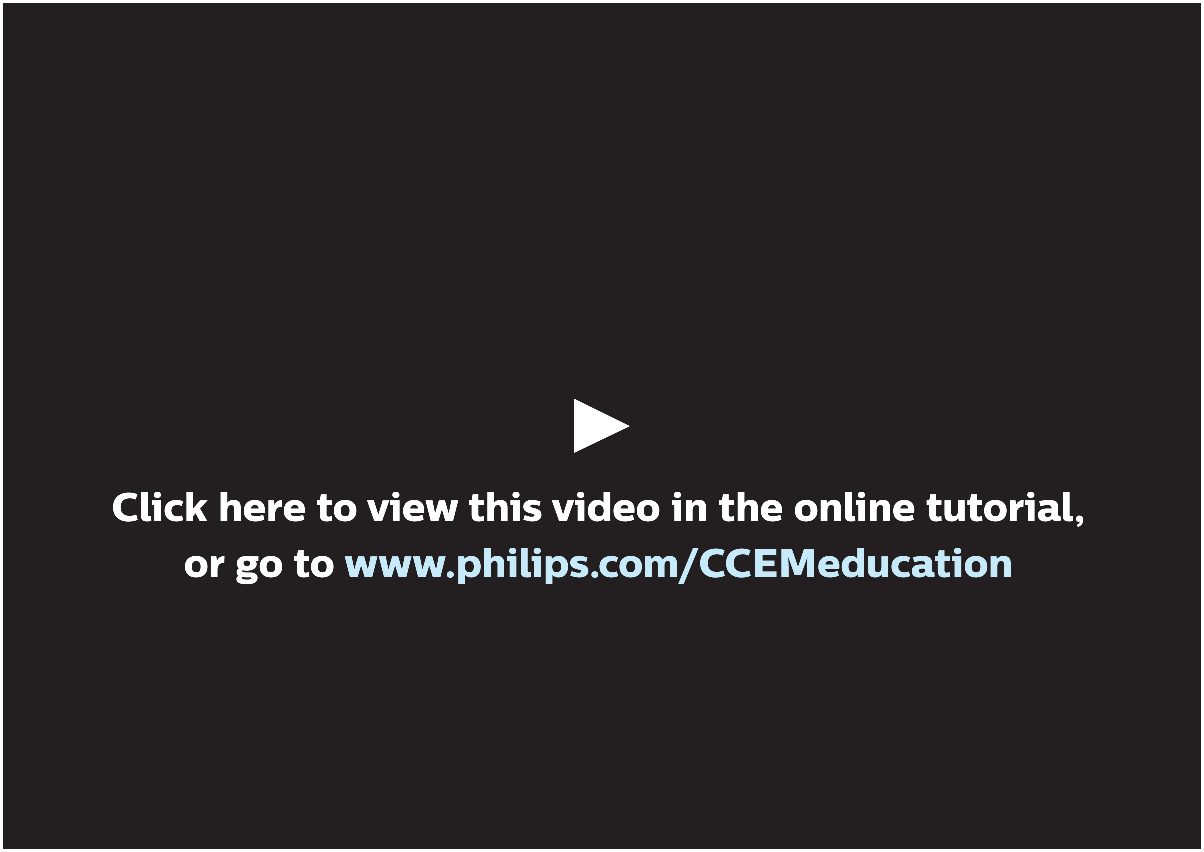


[Figure 12b] M-mode of the mitral valve demonstrating a mildly increased E-Point Septal Separation. The EPSS is measured at 8 mm.

Important things to remember

- Valvular dysfunction, including mitral stenosis and aortic regurgitation, may cause a falsely elevated EPSS due to impaired motion of the anterior leaflet of the mitral valve. This must be considered in patients with these pre-existing abnormalities.
- EPSS measurements may be decreased in conditions not associated with systolic function such as septal hypertrophy, paradoxical septal wall motion, and septal diverticula, which are often associated with aging.

[Video 4]



Note the motion of the anterior leaflet of the mitral valve in the examples of normal LV function, moderately depressed LV function and severely depressed LV function.

7 Fractional shortening (FS)

Just as EPSS helped to semi-quantify mitral valve motion, fractional shortening helps to semi-quantify LV function. Fractional shortening (FS) is calculated using M-mode measurements. It is a measure of the percentage change in LV dimensions between diastole and systole. In patients with normal left ventricular geometry and no regional wall motion abnormalities, FS should reflect overall function of the LV.

To measure fractional shortening, obtain an M-mode trace of the LV using a parasternal view. The M-line is placed just below the mitral valve leaflets. The diameter of the LV at end-diastole (EDD) and at end-systole (ESD) is measured. The diameters are inserted into the following the equation.

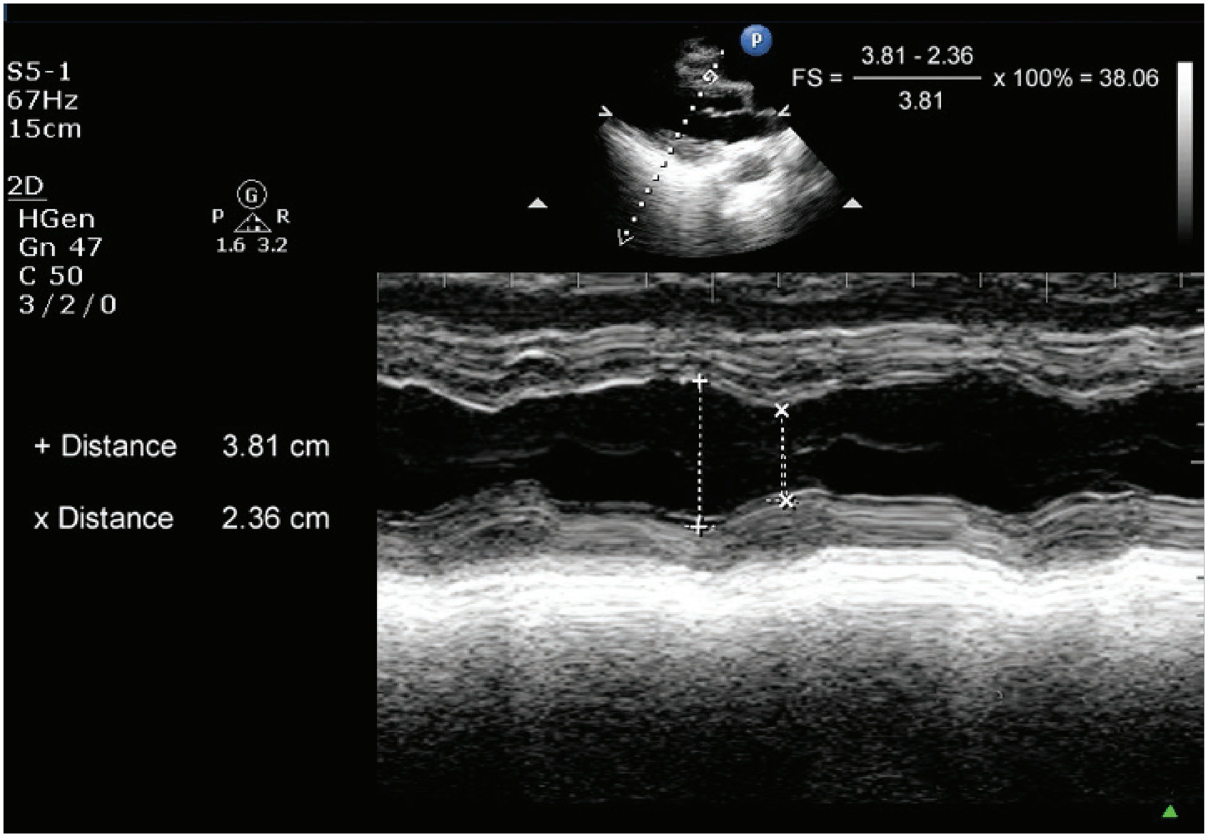
$$\frac{\text{EDD-ESD}}{\text{EDD}} \times 100\% = \text{Fractional shortening}$$

The analysis package on the ultrasound system will automatically calculate the fractional shortening using the M-mode measurements.

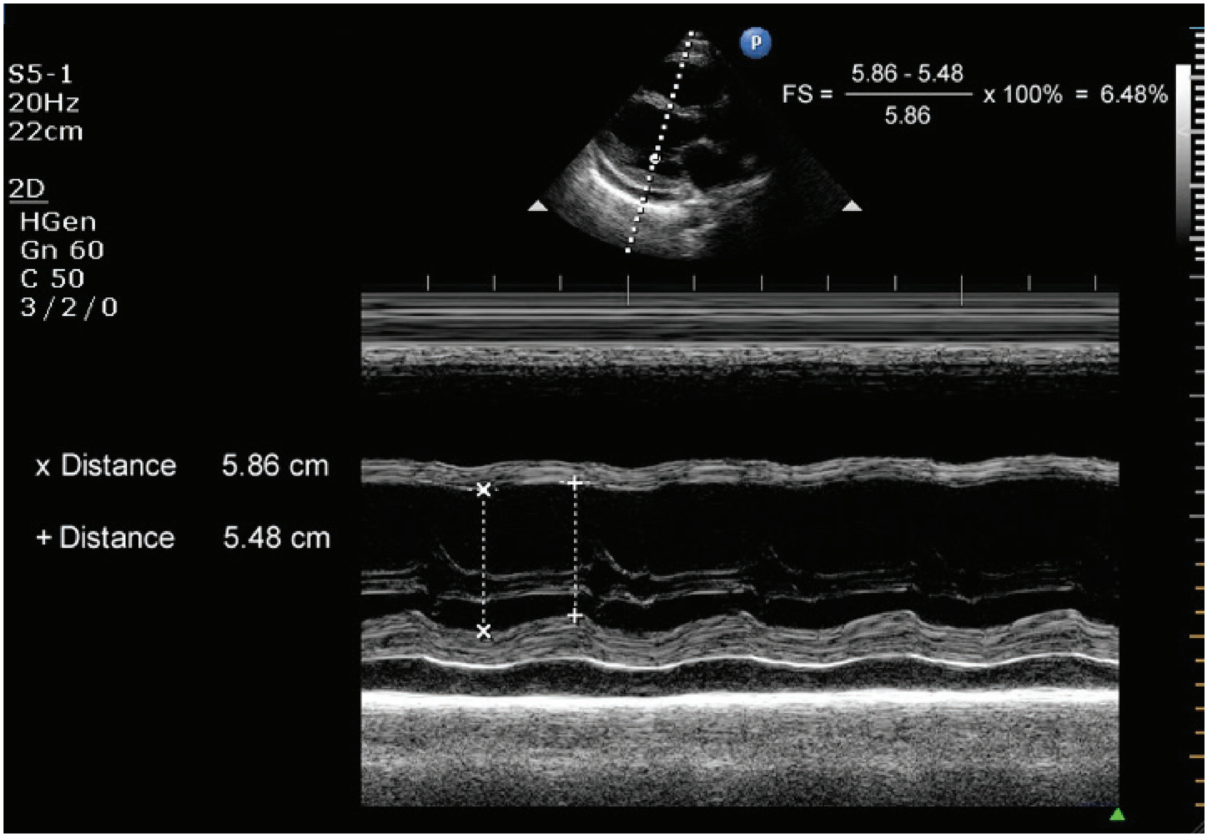
A normal value for fractional shortening is approximately 43-25%. Please note that this value is not interchangeable with ejection fraction and has a different reference range.

Left ventricular systolic function

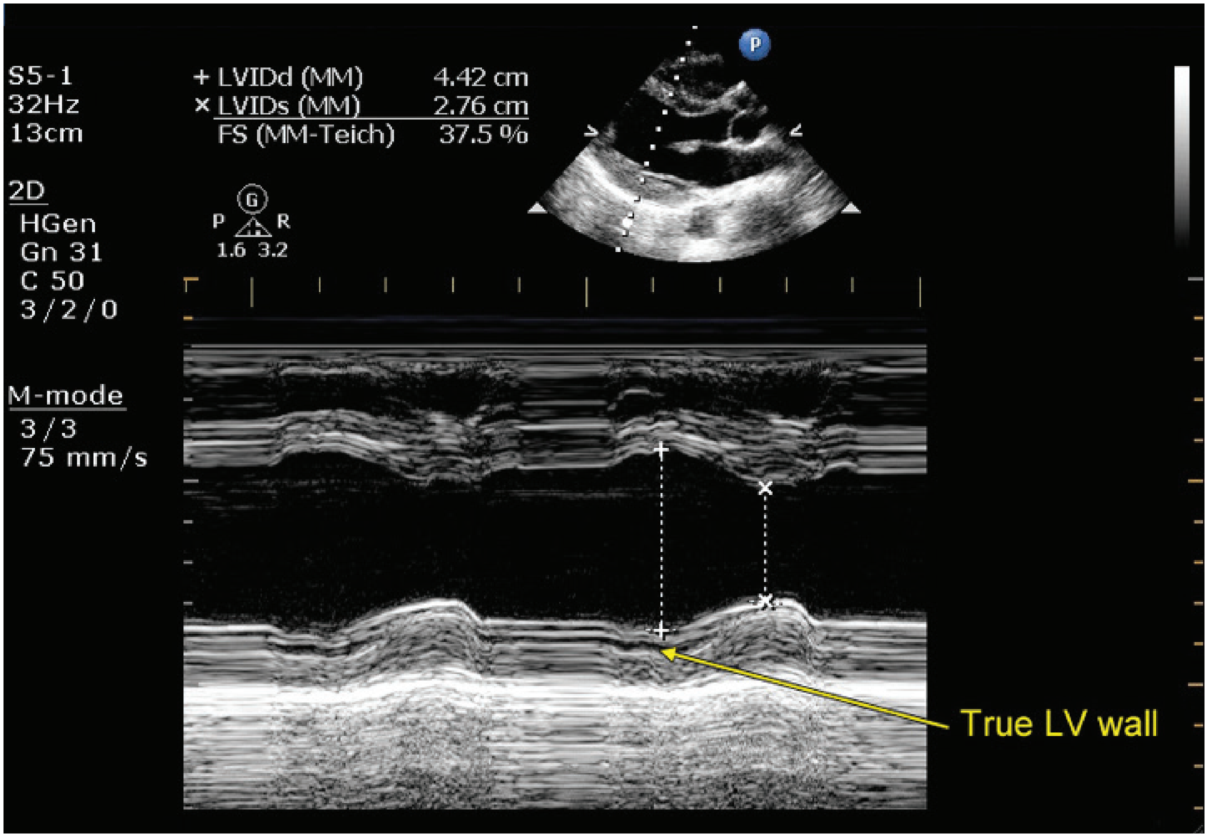
	Normal range	Mildly decreased	Moderately decreased	Severely decreased
M-mode fractional shortening of LV chamber (%)	43-25	24-20	19-15	≤14
2-dimensional ejection fraction (%)	≥55	54-45	44-30	<30



[Figure 13a] **Fractional shortening using an M-mode tracing of the LV in a PSLA view. The M-line is placed slightly apical of the mitral valve leaflets. Measure the left ventricular internal diameter in both diastole (LVIDd) and systole (LVIDs). Fractional shortening is then calculated using the equation in the upper right hand corner of the figure.**



[Figure 13b] Fractional shortening. M-mode tracing of the LV in a PSLA view demonstrating severely decreased LV function. The fractional shortening in this patient is 6.48%. There is a small pericardial effusion seen on this M-mode tracing and 2D reference image.



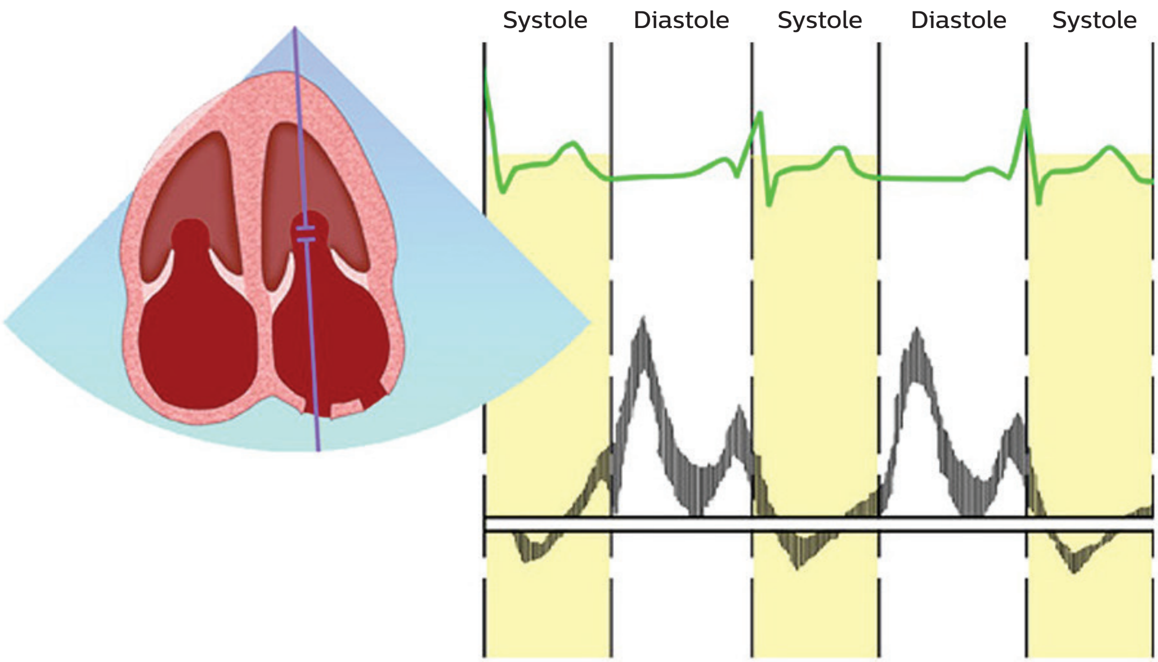
[Figure 13c] Fractional shortening: common error. In this image, the chordae tendinae, the hyperechoic line seen just above the left ventricular posterior wall, is inadvertently included in the measurement of LVID (rather than truly measuring to the left ventricular posterior wall). This leads to an incorrect calculation of fractional shortening. Therefore, care must be taken to ensure that the LVIDd and LVIDs are carefully measured to ensure accurate results.

8 Pulsed wave Doppler for the assessment of LV diastolic function

Doppler technology is commonly used in echo to measure the direction and velocity of blood over time.

Evaluation for diastolic dysfunction is an important component when assessing cardiac function. A significant portion of heart failure is due to impaired relaxation of the left ventricle rather than a decrease in the systolic or contractile phase. Diastolic dysfunction cannot be evaluated using 2D imaging, although the presence of ventricular hypertrophy may suggest its presence. Diastolic dysfunction, however, can be evaluated using pulsed wave (PW) Doppler of flow through the mitral valve.

In the previous section, the normal M-mode mitral valve pattern was described. The normal pattern of blood flow across the mitral valve using Doppler is similar. In patients with normal cardiac function, the contribution from early passive filling (E-wave) is greater than the contribution from atrial contraction (a-wave).

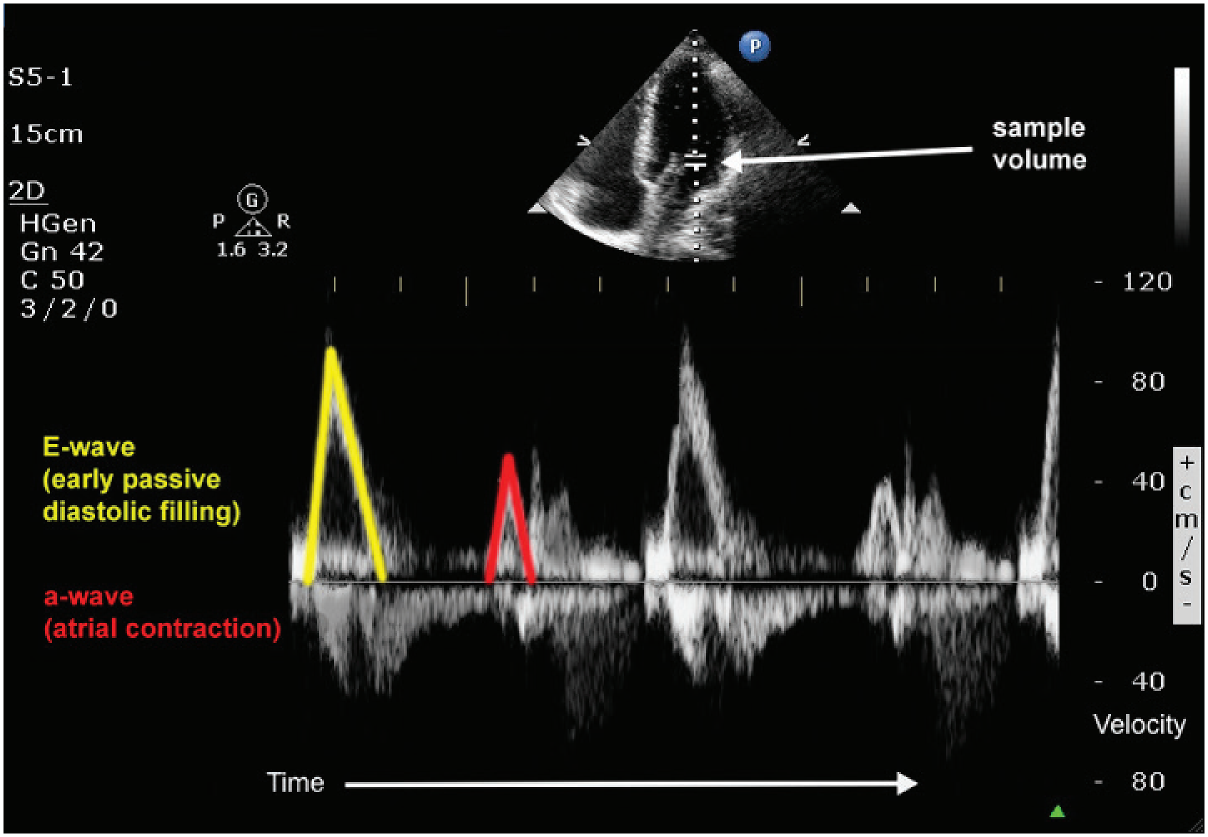


Mitral valve Doppler waveform

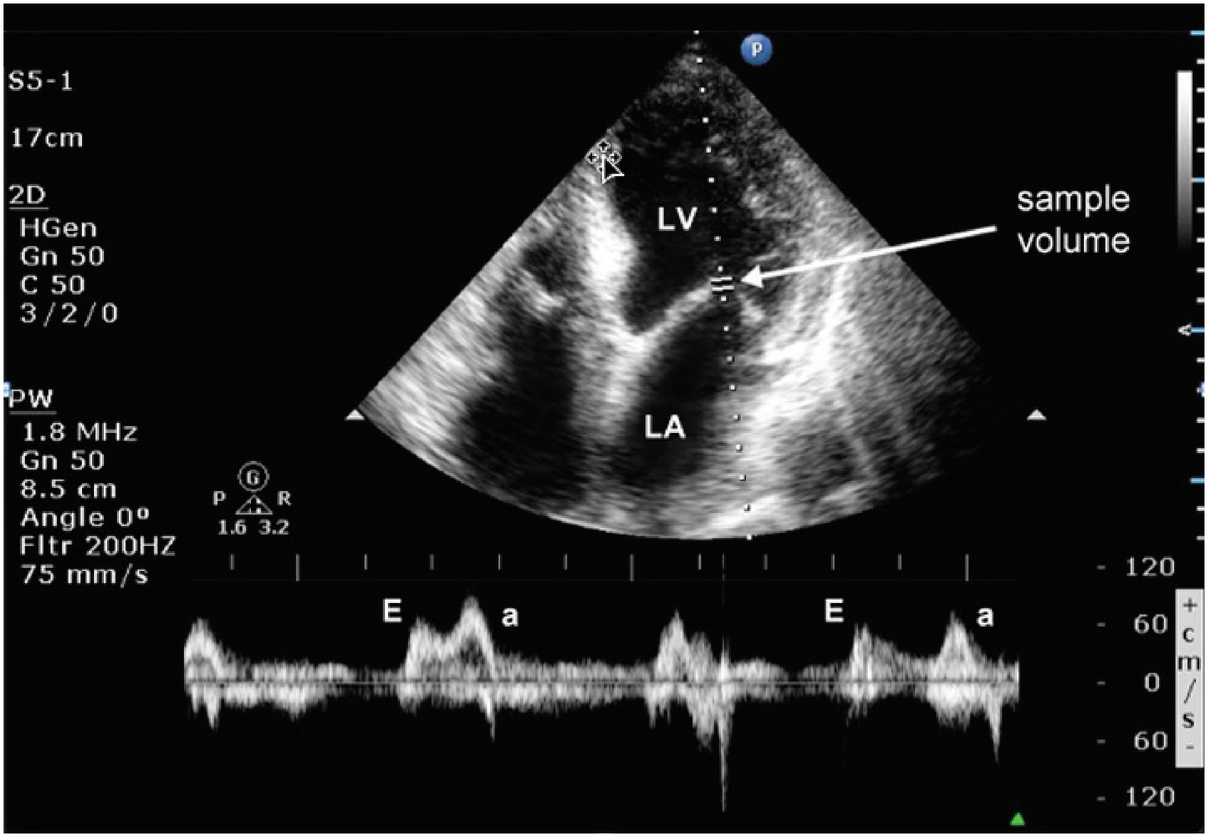
[Figure 14a] Illustration demonstrating placement of sample volume in left ventricular inflow track and a normal mitral valve Doppler waveform.

In patients with diastolic dysfunction, impaired relaxation of the left ventricle during diastole leads to a reversal of this pattern. Over time, the contribution of blood flow across the valve due to atrial contraction increases due to the inability of an increasingly stiff ventricle to relax and passively fill. Eventually, the a-wave becomes larger than the E-wave indicating the presence of diastolic dysfunction. Note that progression of diastolic dysfunction can lead to a reversal of the E/a patterns into a pseudo-normal E-wave greater than an a-wave profile.

To evaluate for diastolic dysfunction using pulsed wave Doppler, the sample volume is placed between the tips of the mitral valve leaflets in the apical four-chamber view. The pattern of blood flow is noted, and the E/a wave ratios are recorded **(Figure 14a and 14b)**. If a reversal of the normal E/a ratio is seen, this is an indication of the presence of diastolic dysfunction.



[Figure 14b] Pulsed wave Doppler. Note the 2D reference image at the top. The reference image is optimized first, then the sample gate is placed just beyond the tips of the mitral valve leaflets in the LV and the PW spectral display is turned on. The spectral display plots the velocity of the blood cells on the y-axis and time on the x-axis.



[Figure 14c] Diastolic dysfunction. This is a pulsed wave Doppler evaluation of the mitral valve in the apical four-chamber view. The reversal in E/a wave ratio suggests the presence of diastolic dysfunction.

9 Summary and clinical pearls

In summary, the use of focused echo is rapidly increasing in the emergency department as more physicians discover its utility in the rapid assessment of cardiac function. A global qualitative estimation using 2D imaging performed at the bedside may provide valuable information that can optimize patient care in critical situations and identify previously undiagnosed cardiomyopathies. More advanced technology, such as M-mode and pulsed wave Doppler, can be used to provide quantitative assessment of cardiac function, and to evaluate for diastolic dysfunction as well.

Familiarity with standard cardiac views and ultrasound modes are a prerequisite to becoming proficient in bedside echo, and all data obtained must be used carefully within the clinical context of the patient's presentation.

Listed below are clinical pearls that should be considered when evaluating cardiac function at the bedside.

- The discovery of systolic dysfunction and its effect on the differential diagnosis and clinical management needs to be interpreted judiciously and within the clinical context.
- Normal LV systolic function does not rule out congestive heart failure.
- Severe systolic dysfunction may be chronic.
- Serial assessment of LV function can be helpful when monitoring changes of hemodynamic status or when monitoring therapeutic interventions, especially with the use of adrenergic agents.
- Quantitative measurements using fractional shortening and EPSS may be compromised or even unreliable in the presence of:
  - an unstable or absent cardiac rhythm
  - advanced cardiac life support protocol in progress
  - atrial fibrillation or flutter
  - known mitral valve disease or aortic insufficiency
  - prosthetic or mechanical mitral valve
  - bundle branch block on electrocardiogram
  - presence of left ventricular assist device or pacemaker

10 Bibliography and references

1. Shoemaker WC, Wo CC, Bishop MH, Thangathurai D, Patil RS. Noninvasive hemodynamic monitoring of critical patients in the emergency department. Acad Emerg Med. Jul 1996;3(7):675-681.
2. McGee S, Abernethy WB, 3rd, Simel DL. The rational clinical examination. Is this patient hypovolemic? JAMA. Mar 17 1999;281(11):1022-1029.
3. American College of Emergency Physicians. Emergency Ultrasound Imaging Criteria Compendium 2006 and Emergency Ultrasound Guidelines 2008. http://www.acep.org. Accessed March 28, 2011.
4. Cheitlin MD, Alpert JS, Armstrong WF, et al. ACC/AHA Guidelines for the Clinical Application of Echocardiography. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Clinical Application of Echocardiography). Developed in collaboration with the American Society of Echocardiography. Circulation. Mar 18 1997;95(6):1686-1744.
5. Cheitlin MD, Armstrong WF, Aurigemma GP, et al. ACC/AHA/ASE 2003 guideline update for the clinical application of echocardiography: summary article: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/ASE Committee to Update the 1997 Guidelines for the Clinical Application of Echocardiography). Circulation. Sep 2 2003;108(9):1146-1162.
6. Moore CL, Rose GA, Tayal VS, Sullivan DM, Arrowood JA, Kline JA. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. Acad Emerg Med. Mar 2002;9(3):186-193.
7. Randazzo MR, Snoey ER, Levitt MA, Binder K. Accuracy of emergency physician assessment of left ventricular ejection fraction and central venous pressure using echocardiography. Acad Emerg Med. Sep 2003;10(9):973-977.
8. Labovitz AJ, Noble VE, Bierig M, et al. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. J Am Soc Echocardiogr. Dec;23(12):1225-1230.

Additional resources

For additional resources related to
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.

www.philips.com/CCEMeducation

Published in the USA. * SEP 2015

PHILIPS