

# CME The Nuts and Bolts of Performing Focused Cardiovascular Ultrasound (FoCUS)

Josh M. Zimmerman, MD, FASE,\* and Bradley J. Coker, MD†

The benefit of focused cardiovascular ultrasound as an adjunct to physical examination has been shown in numerous specialties and in diverse clinical settings. Although the value of these techniques to the practice of anesthesiology is substantial, they have only begun to be incorporated. This article reviews the basic techniques required to perform a bedside focused cardiovascular ultrasound (ie, FoCUS examination). This includes a discussion of patient positioning, breath control, probe position, and manipulation and was supplemented by normal and abnormal examples for review. (Anesth Analg 2017;124:753–60)

This article reviews the basic techniques required to perform a focused cardiovascular ultrasound (FoCUS) examination at the bedside. It begins with indications, limitations, and equipment, then describes in detail the nuts and bolts of physically performing the examination. For each of the views, there is a discussion of patient positioning and technique, a brief review of anatomy, and examples of normal and abnormal images. This article is also accompanied by a Supplemental Video tutorial that demonstrates the techniques described herein (Supplemental Digital Content, <http://links.lww.com/AA/B686>). Obviously, no article is adequate to train a provider without a background in cardiovascular ultrasound. The goal of this article is not to provide comprehensive education but rather a solid introduction and reference for further practice. A broader description of the history, application, value, and training required for anesthesiologists to perform these techniques has been published separately.

FoCUS should be seen as an extension of the physical examination rather than as a limited version of a comprehensive echocardiogram. When viewed in this light, ultrasound can expand dramatically the diagnostic potential of the bedside evaluation. Although there are numerous potential reasons to perform FoCUS, the most common indications in the perioperative period include signs or symptoms of heart failure and hemodynamic instability. The diagnostic targets of FoCUS include evaluation of cardiac structure, biventricular systolic function, valvular function, pericardial effusion, and volume status.

It is important that physicians performing FoCUS have a clear understanding of the limitations inherent to the techniques, as well as the limitations of their individual level of skill, training, and experience. Furthermore,

the pocket-sized devices often used for FoCUS cannot be expected to have the same image quality and resolution of a full-service platform. The FoCUS examination is neither comprehensive nor designed to make quantitative assessments.<sup>1</sup> Subtle abnormalities may be overlooked, and there may be uncertainty regarding the severity of abnormalities that are identified. There is a natural tendency to place a high value on what can be seen, and the practitioner of FoCUS needs to be careful to neither lock in nor exclude diagnoses based on limited ultrasound information. The findings of an examination always should be taken in context, with a healthy suspicion that the interpretation could be flawed or incomplete and with a low threshold to request a second opinion or a formal echocardiogram to confirm findings.

## EQUIPMENT AND ULTRASOUND PROBE SELECTION

Focused ultrasound can be performed with any of a variety of ultrasound machines, from the stand-alone full-service echocardiography platforms, to smaller portable machines, to the smallest pocket-sized ultrasound devices. It is not the type of machine that defines focused ultrasound but the training of the provider and the scope of the clinical questions being addressed. Any ultrasound system can be used so long as it meets the following requirements: availability of a 2-dimensional phased array (cardiac) probe of appropriate frequency for adult patients; the ability to record date, time, and patient identifiers with the images; and the ability to adjust gain and depth. The availability of M-mode, color flow Doppler, spectral Doppler imaging, and measurement tools are not required for a FoCUS examination.<sup>1,2</sup> Electrocardiogram (ECG) capability is not required for FoCUS, and some machines may not be able to display ECG. When machines with this capability are used, however, ECG leads should be connected to ensure that images are acquired appropriately.

## ULTRASOUND PROBE TERMINOLOGY

Because the language used to describe ultrasound probe manipulation is not standardized, the terminology used in this article needs to be defined. For cardiac ultrasound, the probe is held in the left hand so that the right hand can be used to manipulate the machine. All probes will have an indicator, generally a light or a notch, that corresponds to an orientation marker, usually a dot, on the ultrasound image. For cardiac ultrasound, the orientation marker is on

From the \*Department of Anesthesiology, University of Utah, Salt Lake City, Utah; and †Department of Perioperative Medicine and Anesthesiology, University of Alabama at Birmingham, Birmingham, Alabama.

Accepted for publication November 28, 2016.

Funding: None.

The authors declare no conflicts of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website ([www.anesthesia-analgia.org](http://www.anesthesia-analgia.org)).

Reprints will not be available from the authors.

Address correspondence to Josh M. Zimmerman, MD, FASE, Department of Anesthesiology, University of Utah, 30 North 1900 East, Room 3C444, Salt Lake City, UT 84132. Address e-mail to [joshua.zimmerman@hsc.utah.edu](mailto:joshua.zimmerman@hsc.utah.edu).

Copyright © 2017 International Anesthesia Research Society  
DOI: 10.1213/ANE.0000000000001861

the right of the ultrasound image. Although probe orientation can be confusing for new bedside ultrasonographers, it need not be. The ultimate goal is to create the correct orientation on the screen. If the image appears reversed, simply rotate the probe 180°. When describing probe motion, the authors will use the following terminology:

**Sliding.** Motion of the probe to a different position on the body. This will also be described as “window shopping.” This is done to find the optimal position from which to image, particularly when trying to scan between ribs. The sliding motion can be done to move from one interspace to another (larger motions), or to optimize imaging at a given interspace (small motions).

**Tilting.** With the probe kept at the same location on the body, a rocking motion is applied to the probe to image different structures within the same plane (Figure 1). This is done most commonly to center an image on the screen and represents a motion of the “tail” or cord of the transducer toward or away from the probe’s indicator.

**Angulation.** With the probe kept at the same location on the body, the transducer is moved side-to-side to create new imaging planes relatively parallel to the original plane. This motion will be at angles perpendicular to the tilting motion.

**Rotation.** With the probe otherwise held still, it is turned around its central axis similar to turning a key in a lock.

## ULTRASOUND IMAGE TERMINOLOGY

**Window.** The term window is used to describe the location of the ultrasound probe. Just like a window in a house, this is what the transducer transducer looks through to see the heart. The 3 windows described in FoCUS are parasternal, apical, and subcostal (Figure 2).

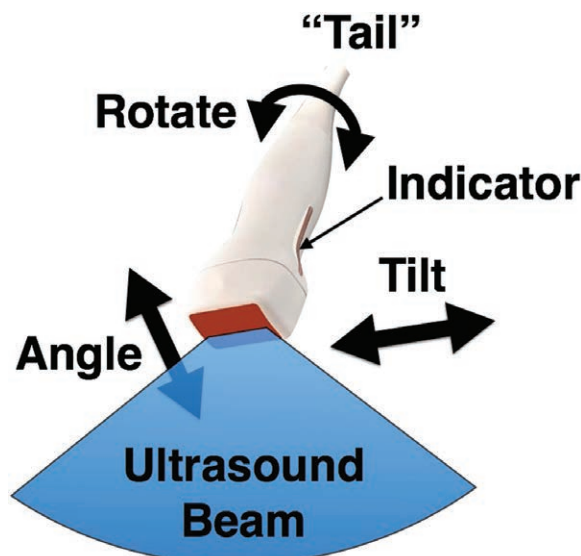
**Plane.** This is the anatomic plane or cross section of the heart that is made by the ultrasound beam. The 3 planes used for the FoCUS examination are the long axis, short axis, and 4 chamber.

1. Long axis: Parallel to the long axis of the left ventricle (LV), simultaneously intersecting the apex of the LV, the center of the aortic valve (AV), and the center of the mitral valve in the anterior–posterior dimension.
2. Short axis: Perpendicular to the long axis of the ventricle, showing a circular cross section of the ventricle. In the case of FoCUS, the LV short axis will be at the level of the papillary muscles.
3. Four chamber: Perpendicular to the short axis, this plane simultaneously transects the apex of the LV, both ventricles and atria, and the mitral and tricuspid valves.

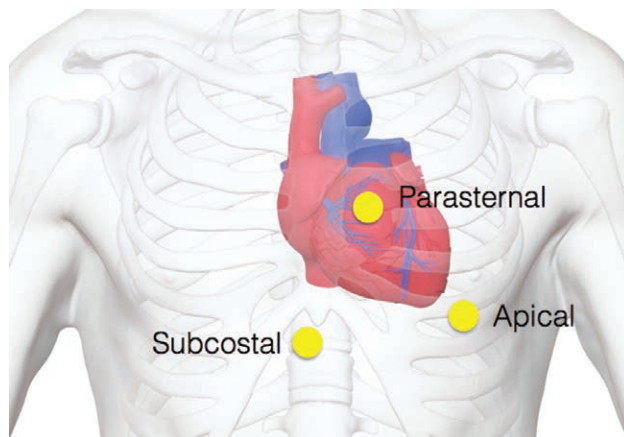
**View.** A combination of window and plane used to describe a particular image. For instance, the parasternal long-axis (PLAX) view is made from the parasternal window and transects the heart in the long axis plane.

## KNOBOLGY AND IMAGE OPTIMIZATION

A detailed understanding of ultrasound physics is not necessary for the practitioner of FoCUS; however, some understanding of image optimization will prove useful. The following settings are available on many of the simplest ultrasound devices.



**Figure 1.** Ultrasound probe manipulation nomenclature. Tilt moves the probe in the plane of the ultrasound beam, angle moves the probe perpendicular to the beam (creating new planes parallel to the original), and rotate turns the probe like a key in a lock.



**Figure 2.** The heart in the chest, with the sternum and ribs to provide orientation. The 3 windows are indicated by the yellow dots.

**Depth.** The depth of scanning for each image should be set to include the structures of interest and nothing else (as shown in the video examples). Inappropriately increasing the depth of scanning both makes relevant structures appear smaller and results in an image that is refreshed less frequently with less temporal resolution and quality.

**Gain.** This setting affects the displayed brightness of the ultrasound image. Gain should be set so that blood appears black rather than gray. A reasonable setting could be achieved by turning gain up until blood appears gray, then decreasing it slightly.

**Time-Gain Compensation.** Some ultrasound systems offer the ability to automatically adjust gain to optimize the display and to provide uniform brightness throughout the image rather than an image that becomes darker at increasing depth due to the lower strength of the returned signal. Sometimes

referred to as the “make it better button,” it can be a quick way to improve the gain and image display settings.

### PARASTERNAL WINDOW

**Patient Positioning.** A complete FoCUS examination often can be performed in the supine patient, and clinical situations in which patients cannot be turned will be encountered frequently. Parasternal imaging, however, would ideally be performed in the full left-lateral decubitus position, with the patient’s left arm extended. It is often comfortable for patient to rest their left forearms under their head (Figure 3). For all FoCUS imaging, the ultrasonographer should be positioned on the patient’s left side with the probe held in the left hand, leaving the right hand free to manipulate the ultrasound machine.

**Breath Control.** Imaging from every window is better if patients can breathe shallowly. In spontaneously ventilating patients, parasternal images are often best at end-exhalation when there is less lung interposed between the probe and the heart. If possible, having patients briefly hold their breath at a low lung volume can improve imaging from the parasternal window. The authors’ technique is to instruct the patient to “Take a deep breath in, now breathe all the way out and hold it...hold it...hold it...now breathe.” This reminds the patient not to begin breathing in until adequate images have been obtained. In intubated patients, it can help to briefly pause the ventilator to allow a passive exhalation.

### Parasternal Long Axis (Supplemental Digital Content, Video 1, <http://links.lww.com/AA/B611>)

**Probe Position and Manipulation.** The PLAX image is made with the probe placed just to the left of the sternum in the third to fifth intercostal space with the indicator pointed toward the patient’s right shoulder (Figure 4). The technique referred to by the authors as “window shopping” should be used. This entails moving the probe briefly across the left parasternal interspaces to select the one that provides the best image. After identifying the best window, small changes in rotation, tilt, and angle should be made to optimize the image.

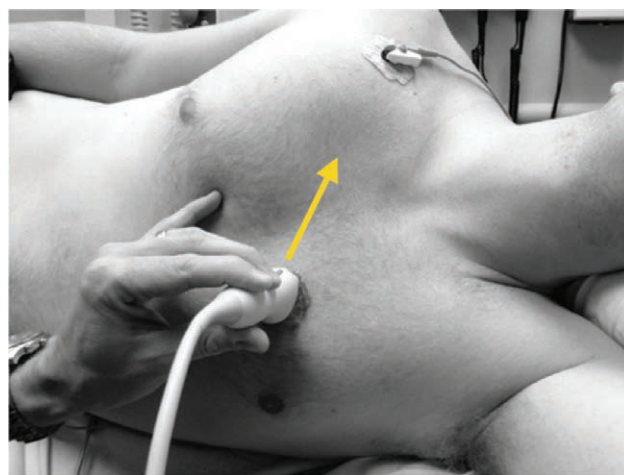
**Anatomy.** The PLAX shows the right ventricular outflow tract (RVOT), the AV and proximal ascending aorta, the left atrium, mitral valve, and the basal and mid segments of the anteroseptal and inferolateral walls of the LV (Supplemental Digital Content, Video 1, <http://links.lww.com/AA/B611>; Figure 5).

**Assessment.** A great deal of valuable information is available from the PLAX image. The authors recommend a consistent approach to evaluating this image, starting with the RVOT and moving clockwise.

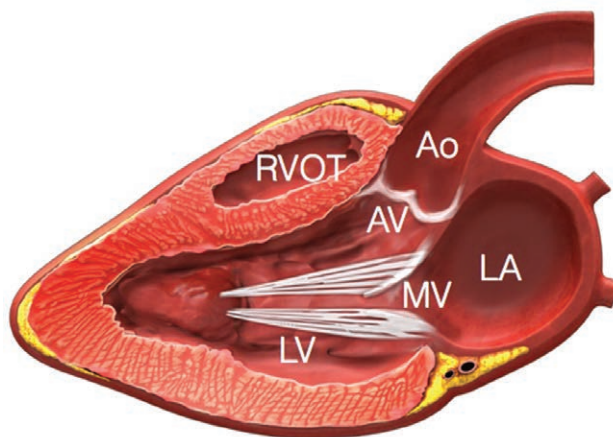
1. Right ventricle (RV): Although this image is not the best to quantify the size or function of the RV, the sonographer can get a sense of significant RV enlargement or dysfunction. The RVOT should appear similar in size to the aortic root in this view. As discussed previously, all assessment of chamber size with FoCUS is qualitative but nonetheless valuable.
2. AV: The structure and opening of the AV can be assessed. A valve that opens well, even if calcified, is not likely to have clinically significant stenosis. An AV



**Figure 3.** Optimal patient positioning for the parasternal window. The patient is in the left lateral decubitus position with his left arm extended.



**Figure 4.** Probe position for the parasternal long axis (PLAX.) The probe is just to the left of the sternum, in the fourth intercostal space (though this location will vary), with the indicator pointing toward the patient’s right shoulder. The indicator location and direction is shown by the yellow arrow.



**Figure 5.** Anatomy of the PLAX. At the top of the screen, closest to the ultrasound probe, is the right ventricular outflow tract (RVOT). Moving clockwise, the aortic valve (AV) and proximal ascending aorta (Ao) are seen, then the left atrium (LA), mitral valve (MV) and left ventricle (LV). PLAX indicates parasternal long axis.

that is heavily calcified and opens poorly should alert the provider to the possibility of significant aortic stenosis (Supplemental Digital Content, Video 2, <http://links.lww.com/AA/B612>).

3. Left atrium: A qualitative assessment of left atrial size can be obtained by visually comparing the diameter of the atrium to that of the aortic root. A left atrium that is much larger than the aortic root suggests a history of elevated left atrial pressures (from diastolic dysfunction, mitral valve disease, or atrial fibrillation). (Supplemental Digital Content, Video 2, <http://links.lww.com/AA/B612>).
4. Mitral valve: A normal mitral valve should open briskly in diastole and should close completely in systole, with no portion of the valve prolapsing above the annulus in this view. Leaflet tissue that extends above the annulus in systole suggests mitral valve prolapse or flail (Supplemental Digital Content, Video 3, <http://links.lww.com/AA/B613>). An anterior mitral leaflet that does not open briskly and come near the anteroseptal wall in diastole should alert the provider to the possibility of decreased cardiac output or mitral stenosis (Supplemental Digital Content, Video 4, <http://links.lww.com/AA/B614>). Mitral annular calcification (MAC), particularly at the base of the posterior leaflet, is a common finding in patients with hypertension, vascular disease, and renal failure (Supplemental Digital Content, Video 2, <http://links.lww.com/AA/B612>). Because MAC affects the base of the valve rather than the coaptation, it is a rare cause of hemodynamically significant stenosis. Rheumatic mitral valve disease, on the other hand, affects the subvalvular apparatus, commissures, and coaptation early in the disease process and creates what is described as a “hockey stick” deformity with stenosis resulting from a much smaller degree of leaflet thickening (Supplemental Digital Content, Video 5, <http://links.lww.com/AA/B615>). Another important abnormality that can be identified from the PLAX is systolic anterior motion (SAM) of the anterior leaflet of the mitral valve. The identification of SAM should alert the practitioner to the possibility of dynamic left ventricular outflow tract obstruction. This pathology can be seen in hypertrophic cardiomyopathy but also can be seen in patients with small, thick ventricles and abnormal mitral leaflet tissue. The findings can be subtle but should be sought when patients present with hemodynamic instability, syncope, or heart failure symptoms. It should be suspected when a portion of the mitral valve appears to be drawn into the left ventricular outflow tract during late systole (Supplemental Digital Content, Video 6, <http://links.lww.com/AA/B616>).
5. LV: Although only a portion of the anteroseptal and inferolateral walls are viewed in this image, a good sense of global and regional function can be obtained in the PLAX. There should be brisk thickening of the myocardium in systole. Other qualitative signs of normal global LV systolic function include a brisk anterior-posterior motion of the aortic root caused

by the filling and emptying of the LV and LA, brisk opening of the anterior mitral leaflet in diastole, and the descent of the base of the LV toward the apex, representing the piston-like effect of longitudinal myocardial fibers. Decreased global function will be seen as decreased aortic root excursion, decreased excursion of the anterior mitral leaflet, decreased descent of the base of the MV, and decreased thickening of the myocardium (Supplemental Digital Content, Video 4, <http://links.lww.com/AA/B614>).

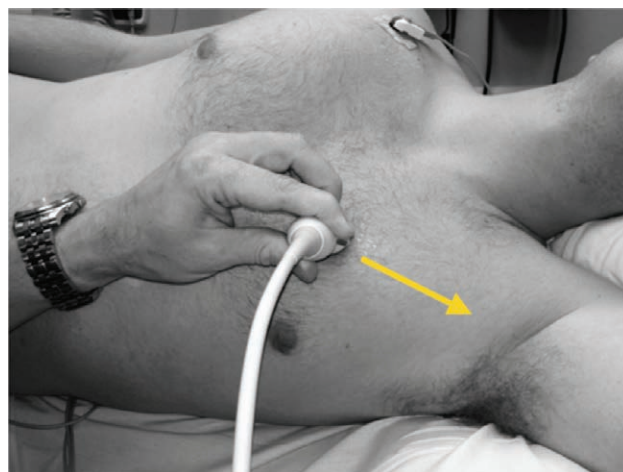
6. Effusions: Pericardial effusion can sometimes be identified in this view and can be distinguished from pleural effusion based on the relationship of the fluid to the descending thoracic aorta. A pericardial effusion will come between the aorta and the heart, whereas a left pleural effusion will appear behind the aorta (toward the bottom of the image) (Supplemental Digital Content, Video 7, <http://links.lww.com/AA/B617>). To ensure that effusion is not overlooked, the sonographer should begin imaging the PLAX with adequate depth to visualize at least 5 cm beyond the descending aorta.

### Parasternal Short Axis (PSAX) (Supplemental Digital Content, Video 8, <http://links.lww.com/AA/B618>)

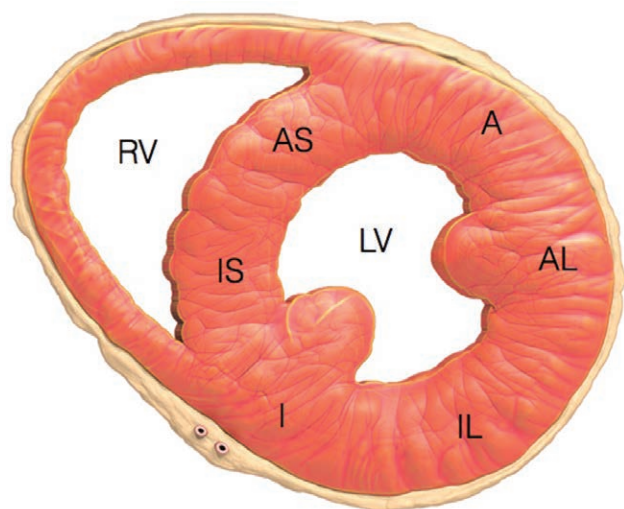
**Probe Position and Manipulation.** Starting with the PLAX view, the short-axis image is made by keeping the probe in the same location and rotating 90° clockwise so the indicator points toward the patient's left shoulder (Figure 6).

**Anatomy.** The PSAX view transects the left and right ventricles at the level of the papillary muscles (the mid-portion of the LV). The short-axis section is like slices in a loaf of bread. The mid-segments of each of the 6 ventricular walls can be seen, representing myocardial territories perfused by each of the 3 main coronary arteries (Figure 7).

**Assessment.** The PSAX gives important information about global and regional ventricular function and filling and is useful particularly in the hemodynamically unstable patient.



**Figure 6.** Probe position for the parasternal short axis (PSAX.) The probe is just to the left of the sternum, in the fourth intercostal space (though this location will vary), with the indicator pointing toward the patient's left shoulder. The indicator location and direction is shown by the yellow arrow.



**Figure 7.** Anatomy of the PSAX. The right ventricle is seen on the left side of the screen and defines the 2 septal walls of the left ventricle. The papillary muscles are seen, identifying this as the midportion of the ventricle. Six segments of the ventricle are shown, representing distributions of all 3 coronary arteries. A, mid-anterior segment of the LV; AL indicates mid-anterolateral segment of the LV; AS, mid-anteroseptal segment of the LV; I, mid-inferior segment of the LV; IL, mid-inferolateral segment of the LV; IS, mid-inferoseptal segment of the LV; LV, left ventricle; PSAX, parasternal short axis; RV, right ventricle.

1. LV: In a ventricle with normal regional function, the PSAX will have symmetrical thickening of each of the myocardial segments. Decreased thickening (hypokinesis) or absence of thickening (akinesis) suggests coronary ischemia or infarction. Typically, the left anterior descending coronary artery perfuses the anterior portion of the LV, the circumflex coronary artery perfuses the lateral portion of the ventricle, and the right coronary artery perfuses the inferior portion of the ventricle (Supplemental Digital Content, Video 9, <http://links.lww.com/AA/B619>). In hypovolemic states, the LV will appear relatively small in diastole with hyperdynamic systolic function (Supplemental Digital Content, Video 10, <http://links.lww.com/AA/B620>). In low afterload states, the ventricle will be fuller in diastole but will still be empty in systole reflecting increased cardiac output (Supplemental Digital Content, Video 11, <http://links.lww.com/AA/B621>).
2. Right ventricle: The right ventricle is not the focus of the PSAX, but if it appears significantly larger than the LV, it should trigger further evaluation of the RV from the apical 4 chamber.
3. Interventricular septum (IVS): The behavior and position of the IVS can give important information about the balance of pressures in the two ventricles. Normally the LV appears circular throughout the cardiac cycle, reflecting the fact that LV pressures are higher than RV pressures. If the IVS is flat in diastole but returns to normal (concave to the LV) in systole, it suggests an RV volume overload state (often tricuspid regurgitation.) If the IVS stays flattened throughout systole and diastole, it suggests a pressure overload state of the RV.<sup>3</sup> Septal flattening in systole is an

ominous sign that is often seen in severe pulmonary hypertension (Supplemental Digital Content, Video 12, <http://links.lww.com/AA/B622>).

### APICAL WINDOW

**Patient Positioning.** Like the parasternal window, the apical window is best imaged with the patient in the left lateral decubitus position. Apical images are often more challenging than parasternal images when performed in the supine position and even a small amount of left tilt of the patient can improve the images. This can be achieved in some cases by a towel or pillow bump under the right side of the patient. With the patient in the full left-lateral decubitus position, it can be challenging to place the ultrasound probe at the true apex. This problem can result in an image with the right ventricle at the apex of the screen, giving the false impression of RV enlargement. This can be overcome either by moving the patient all the way to the edge of the bed or by tipping the patient slightly back from a true left lateral position.

**Breath Control.** Unlike the parasternal window, the optimal lung volume for apical images is less predictable. The LV apex generally moves slightly caudally as the patient inhales. After finding a reasonable window, the patient can be asked to breathe in or out slowly until the best apical image is achieved. They can then be asked to hold their breath using the same “hold it...hold it...hold it, now breathe” technique described earlier.

### Apical 4-Chamber (A4) (Supplemental Digital Content, Video 13, <http://links.lww.com/AA/B623>)

**Probe Position and Manipulation.** The A4 image generally is more challenging than the parasternal or subcostal images. The first step is to identify the correct window for imaging. Again, this will involve a degree of window shopping. In some cases, palpation of the point of maximal impulse can be useful, though the authors generally identify the apex with ultrasound alone. The apex is usually just inferior and lateral to the nipple in men, and under the inferolateral quadrant of the left breast in women. Starting slightly medial to the expected location and moving the probe cephalad and caudad over several interspaces while slowly sliding laterally can help identify the apex. For the 4-chamber plane, the probe indicator will be often be pointed to the 5 o'clock position when viewed from above (Figure 8).

**Anatomy.** The apex of the LV should be at the top of the screen. The inferoseptal and anterolateral walls of the LV can be seen, and 6 myocardial segments (basal, mid-, and apical) can be identified. The longer anterior mitral leaflet can be seen medially with the shorter posterior leaflet laterally. The right ventricle can be seen as well, with the tricuspid valve displaced slightly toward the apex relative to the mitral valve. The left and right atrial should be visualized at the bottom of the image (Figure 9).

### Assessment.

1. Left ventricle: This is another excellent view to assess global and regional left ventricular systolic function. A normal ventricle will have symmetrical thickening,

a brisk opening of the mitral valve, and a brisk descent of the mitral valve toward the LV apex (Supplemental Digital Content, Video 13, <http://links.lww.com/AA/B623>). Ischemia or infarction of the left anterior descending coronary artery can often be recognized in this view as wall motion abnormalities in the apical portion of the ventricle (Supplemental Digital Content, Video 14, <http://links.lww.com/AA/B624>).

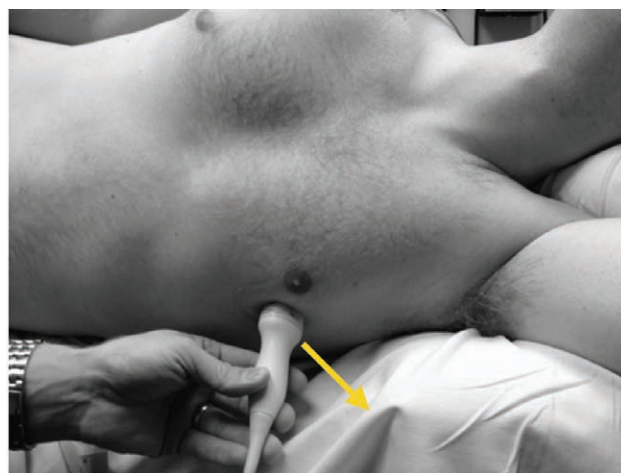
2. Mitral valve: The leaflets of a normal valve should remain below the mitral annulus with adequate coaptation in systole. Significant prolapse or flail, or an obvious lack of valve coaptation should raise the possibility of significant mitral regurgitation (Supplemental Digital Content, Video 15, <http://links.lww.com/AA/B625>). MAC and rheumatic valve changes can also be identified, as described in the PLAX assessment (Supplemental Digital Content, Video 2, <http://links.lww.com/AA/B612>; and Supplemental Digital Content, Video 16, <http://links.lww.com/AA/B626>).
3. Atria: The relative sizes of the atria can be assessed qualitatively in this view. They should be similar in size and should not appear larger than the ventricles in diastole (Supplemental Digital Content, Video 16, <http://links.lww.com/AA/B626>).
4. Right ventricle: This is the preferred view to assess RV size and global systolic function.<sup>3</sup> The RV should appear smaller than the LV in the A4, and the apex of the heart should be made up of only LV. An RV that contributes to the apex or that appears similar in size to the LV in this view is an indication of RV enlargement. A normal RV will have thickening of the free wall and a brisk descent of the base of the tricuspid valve toward the apex in systole (Supplemental Digital Content, Video 17, <http://links.lww.com/AA/B627>).
5. Tricuspid valve: This is also the preferred view to assess structure and function of the tricuspid valve. A normal TV will open fully in diastole, and will remain below the annulus with good coaptation in systole. The appearance of significant prolapse or a lack of valve coaptation should suggest the presence of significant tricuspid regurgitation (Supplemental Digital Content, Video 18, <http://links.lww.com/AA/B628>).

### SUBCOSTAL WINDOW

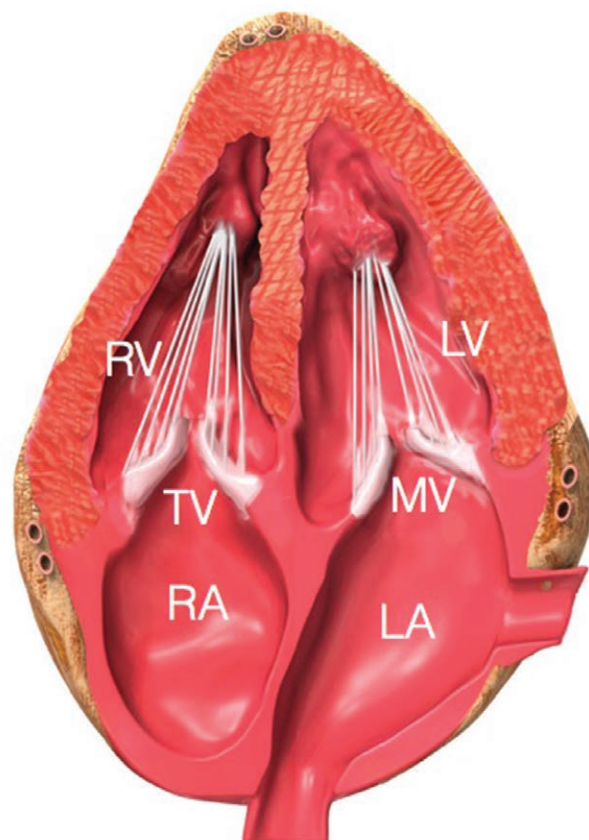
**Patient Positioning.** Subcostal images are obtained with the patient in the supine position. In patients who are awake, the tone of the abdominal muscles can occasionally make imaging difficult. In these cases, the patient should place a pillow behind his/her knees or rest his/her feet on the bed.

### Subcostal 4-Chamber (SC4) (Supplemental Digital Content, Video 19, <http://links.lww.com/AA/B629>)

**Probe Position and Manipulation.** The subcostal window is usually found 1 to 2 cm below the xiphoid process or slightly to the right of midline. There is a tendency for the probe to drift toward the patients left because this is where the heart is known

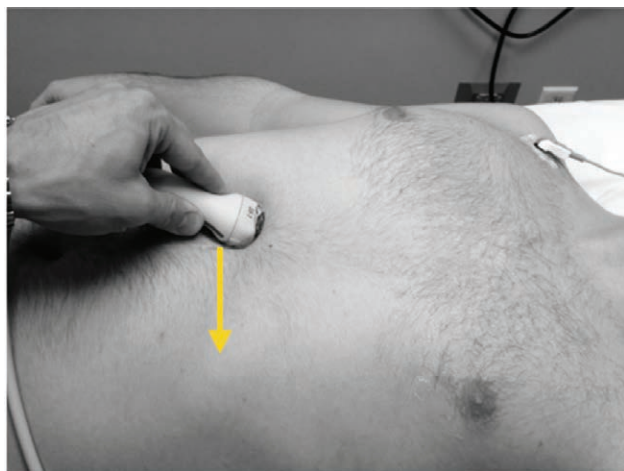


**Figure 8.** Probe position for the apical 4 chamber. The patient is in the left lateral decubitus position with their left arm extended. The probe is located just inferior and lateral to the left nipple, with the indicator pointed toward 5 o'clock (as viewed from above.) The indicator location and direction is shown by the yellow arrow.

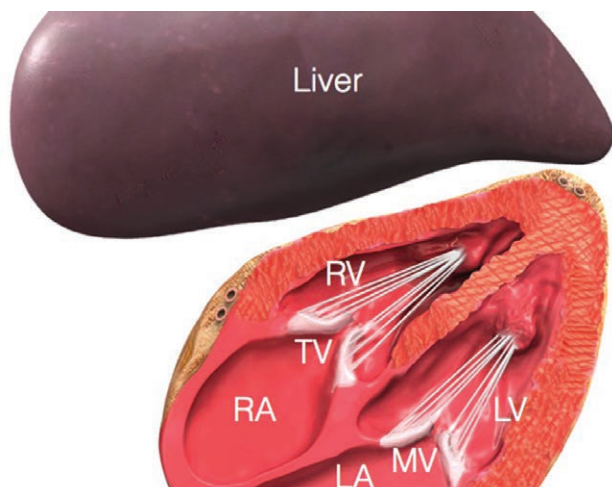


**Figure 9.** Anatomy of the apical 4 chamber. The apex of the LV should be under the probe, and the right and left atria and ventricles should be seen as well as the mitral and tricuspid valves. LA indicates left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve.

to be, but to make the best subcostal images the liver needs to be used as the window rather than the stomach or spleen. To create the SC4 image, the probe is placed on the abdomen nearly horizontally with the indicator pointing directly to the patient's left (Figure 10). The technique of creating the subcostal window



**Figure 10.** Probe position for the subcostal 4 chamber. The patient is supine with a pillow under his/her knees to relax the abdominal muscles. The probe is 1 to 2 cm below the xiphoid process with the indicator pointing directly toward the patient's left (toward the sonographer.) The indicator location and direction is shown by the yellow arrow.

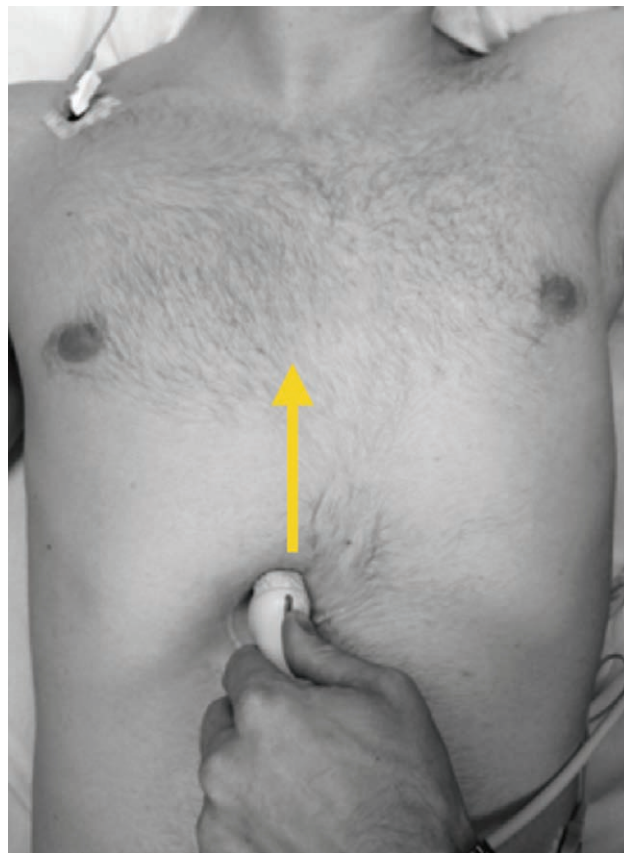


**Figure 11.** Anatomy of the subcostal 4 chamber. The liver is at the top of the screen. The right and left atria and ventricles can be visualized, along with the mitral and tricuspid valves. It should be noted that this is not the same cross-section as the apical 4 chamber. LA indicates left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve.

for this image is reminiscent of placing a subclavian central line. The probe is pushed down into the abdomen and forward to create a window that looks toward the heart (located directly under the ribs) rather than a window that looks down into the abdomen. Slight changes in angulation and rotation are then used to create an appropriate SC4.

**Breath Control.** The subcostal 4 chamber can be improved in some cases by having the patient take a partial or full breath in and hold it. As the diaphragm falls, the probe comes closer to the heart.

**Anatomy.** Although the view is called the subcostal 4 chamber, and it may indeed show all 4 chambers of the heart, the cross section is not identical to that obtained from the apical window (Figure 11). This view transects a more inferior



**Figure 12.** Probe position for the subcostal IVC image. The probe is 1–2 cm below the xiphoid process with the indicator pointing toward the patient's head. The indicator location and direction is shown by the yellow arrow. IVC indicates inferior vena cava.

portion of the right ventricle, and although it may show the inferoseptal and anterolateral walls of the LV, this is less predictable. The benefit of this view is that it shows the free wall of the right ventricle very well. It is a view that complements the information obtained from the other windows. For some patients, particularly those with tubes and drains or those with severe chronic obstructive pulmonary disease, the subcostal window may be the only one that provides adequate imaging, and a detailed 2D assessment of the cardiac structures can often be obtained from this window alone.

#### Assessment.

1. **Right ventricle:** The SC4 is an excellent view to assess global RV systolic function as described earlier. Although an RV that appears larger than the LV in this view likely represent RV dilation, it is possible for this image to underestimate the size of the right ventricle (Supplemental Digital Content, Video 20, <http://links.lww.com/AA/B630>). That means an RV that appears normal in size from the SC4 could be falsely reassuring.
2. **Pericardial effusion:** This is an excellent view to identify the presence of a pericardial effusion. An effusion will appear as an echolucent (dark) space around the right heart (Supplemental Digital Content, Video 21, <http://links.lww.com/AA/B631>). Findings of tamponade physiology may include right atrial inversion

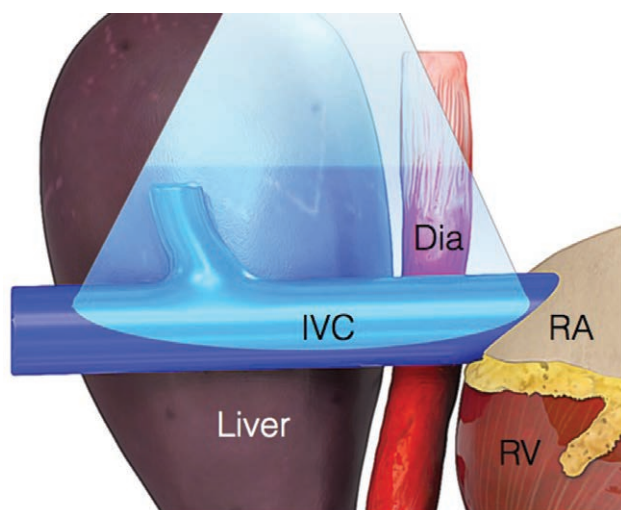
during ventricular systole, right ventricular compression during diastole, and inferior vena cava (IVC) dilation (see next section.) As with other complex clinical scenarios, findings of effusion and tamponade should be evaluated within the clinical context.

### Subcostal IVC Long Axis (Supplemental Digital Content, Video 22, <http://links.lww.com/AA/B632>)

**Probe Position and Manipulation.** Starting from the SC4, the probe should be tilted to center the right atrium in the screen. Then a slow counterclockwise rotation of the probe by 60 to 90° should show the IVC entering the right atrium. (Figure 12).

**Anatomy.** At the top of the image is the liver, with the IVC appearing near-horizontal on the screen as it enters the right atrium. It is important to distinguish the IVC from the abdominal aorta in this view. The aorta is thick-walled and will often have obviously systolic pulsatility. The IVC is thin-walled, can be seen to enter the right atrium, and has hepatic veins draining into it. The left hepatic vein can often be identified entering the IVC at the 12-o'clock position near the right atrium (Figure 13).

**Assessment.** The utility of this view is to evaluate the relative size and behavior of the IVC to aid in the assess-



**Figure 13.** Anatomy of the subcostal IVC. At the top of the image is the liver. The IVC can be seen entering the right atrium. The left hepatic vein is seen entering the IVC near the right atrium. Dia indicates diaphragm; IVC, inferior vena cava; RA, right atrium; RV, right ventricle.

ment of volume status and fluid responsiveness.<sup>3</sup> An IVC that appears large with minimal change in diameter with ventilation (spontaneous or controlled) suggests relatively greater right atrial pressures and a lower likelihood of volume responsiveness (Supplemental Digital Content, Video 23, <http://links.lww.com/AA/B633>). A very

small appearing IVC suggests a patient that is likely volume responsive (Supplemental Digital Content, Video 24, <http://links.lww.com/AA/B634>). Because assessment of volume status is one of the more complex aspects of cardiac ultrasound, it is important to view this information in the broader clinical context and not to use IVC assessment as the sole determinant.

### IMAGE STORAGE AND REPORTING

The days when perioperative echocardiographers could make images, act on the findings, store no images, and report no findings are gone. At this early stage of the adoption of point-of-care ultrasound, the authors recommend applying the current standards for medical imaging to all forms of point-of-care ultrasound and to FoCUS in particular. That means images should always be archived, either on an imaging server or on disks, for review and quality assurance. Every currently available ultrasound device has some mechanism for image storage. Likewise, there should be some mechanism for reporting the findings of each FoCUS examination. Paper forms can be used (an example used by the authors is included in the Supplemental Digital Content, <http://links.lww.com/AA/B687>), electronic forms can be created, or information can be reported in the anesthetic record.

### CONCLUSIONS

The field of perioperative echocardiography is broad, complex, and takes years to master. FoCUS, on the other hand, can provide significant value in the care of complex patients with substantially less time and experience. This article provides a brief introduction to the techniques of FoCUS and the reader with further interest is strongly encouraged to seek further instruction. ■■

### DISCLOSURES

**Name:** Josh M. Zimmerman, MD, FASE.

**Contribution:** This author was the primary author, and was responsible for writing and editing this article.

**Name:** Bradley J. Coker, MD.

**Contribution:** This author helped with the writing and editing of the article.

**This article was handled by:** Nikolaos J. Skubas, MD, DSc, FACC, FASE.

### REFERENCES

1. Spencer KT, Kimura BJ, Korcarz CE, Pellikka PA, Rahko PS, Siegel RJ. Focused cardiac ultrasound: recommendations from the American Society of Echocardiography. *J Am Soc Echocardiogr.* 2013;26:567–581.
2. Via G, Hussain A, Wells M, et al; International Liaison Committee on Focused Cardiac UltraSound (ILC-FoCUS); International Conference on Focused Cardiac UltraSound (IC-FoCUS). International evidence-based recommendations for focused cardiac ultrasound. *J Am Soc Echocardiogr.* 2014;27:683.e1–683.e33.
3. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr.* 2015;28:1–39.e14.