# Focused Cardiac Ultrasound

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## ABSTRACT

The use of point-of-care ultrasound of the heart is becoming more widespread. A variety of users have joined traditional users of cardiac ultrasound, cardiologists, and are imaging their patients in real time at the point of care. Patients with undifferentiated shock, hypotension, chest pain, or dyspnea are ideal candidates for focused cardiac ultrasound (FOCUS). In addition, any patient in whom the diagnosis of pericardial effusion or tamponade, pulmonary embolism, or left ventricular dysfunction is suspected would benefit from FOCUS. Of particular importance is the use of FOCUS to rapidly determine the etiology of cardiac arrest. This review will detail the indications, techniques, and limitations of FOCUS in these patients.

Focused cardiac ultrasound (FOCUS) refers to the use of ultrasound to evaluate cardiac pathophysiology at the point of care, by providers actively managing a patient. FOCUS differs from both limited and comprehensive echocardiography with respect to the location where it is done, the providers doing the study, the devices used, and, most importantly, the scope of the examination. FOCUS is used in intensive care units and emergency departments to evaluate patients in shock, with dyspnea and chest pain. Prehospital providers are using ultrasound to evaluate for cardiac trauma [1]. Anesthesiologists, emergency physicians, intensivists, and a growing number of other providers throughout the healthcare system are using cardiac ultrasound in this directed fashion. Rather than wait for a machine or technician to be available, cardiologists are using smaller devices to answer some of the questions that have required comprehensive echo in the past. A growing number of U.S. medical school curricula include point-of-care ultrasound training alongside history and physical courses [2–4]. In coming years, all physicians graduating in the United States will receive training in basic cardiac ultrasound.

With the growth in users of varied training, individual organizations have published guidelines regarding the use of cardiac ultrasound [5–8]. In 2010, the American Society of Echocardiography and the American College of Emergency Physicians published a consensus statement defining the use of FOCUS in patient management [9]. These guidelines and consensus statements provide critical standardization of practice essential to dissemination and appropriate use of FOCUS.

The purpose of the FOCUS examination is to provide at the point of care, timely, repeatable diagnostic information the moment a question arises. When a patient is suddenly symptomatic in the intensive care unit, the emergency department, or the prehospital setting, FOCUS can provide critical information quickly. More than any other application, FOCUS benefits from the advantages of point-of-care ultrasound. For the critically ill patient for whom a less-monitored setting is undesirable, FOCUS at the point of care is ideal. The examination is performed by the provider managing the patient, with no loss of background clinical information as occurs necessarily when a test is ordered by one provider and performed by another. FOCUS is not dependent on personnel or equipment from an outside department, increasing the timeliness with which it is accomplished. The ability to quickly repeat a point-of-care ultrasound examination is most important in evaluation of the heart. It can be used, for example, to determine whether fluid resuscitation has improved an initially hyperdynamic, underfilled heart or to reevaluate left ventricular (LV) function after initiation of inotropic therapy. This allows the provider to observe changes in cardiac physiology in real time.

## FOCUS INDICATIONS

Comprehensive echocardiography answers the specific question the study was ordered to answer, but it also documents a standardized set of measurements and observations. The interpreting cardiologist is responsible for documenting all of these findings, which may help the team managing the patient or may require further evaluation. By definition, FOCUS is limited to specific indications (see Table 1). The goal is to answer very specific questions that have immediate clinical implications. Is there a pericardial effusion or tamponade? Is there right ventricular strain? Is left ventricle systolic function hyperdynamic, hypodynamic, or normal? Is there cardiac contractility in the arrested patient? The answer to these questions is dichotomized. The provider performing the FOCUS examination is looking for a yes or no answer. They are neither looking for, nor responsible for, an incidental finding on a saved clip. Advanced users may use FOCUS to evaluate for tamponade, valvular abnormalities, thoracic aortic dissection and regional wall motion abnormality of myocardial ischemia. This paper will review the basic indications of FOCUS.

FOCUS is designed to answer specific questions, but frequently these focused questions will be incorporated into an algorithmic approach to the patient with a specific

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**TABLE 1.** FOCUS indications

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|---|---|
| Basic indications | |
| | Evaluation for pericardial effusion |
| | Evaluation of left ventricular systolic function |
| | Evaluation for pulmonary embolism |
| | Management of cardiac arrest |
| Advanced indications | |
| | Evaluation for cardiac tamponade |
| | Evaluation for valvular abnormalities |
| | Evaluation for aortic dissection |
| | Evaluation for myocardial ischemia |

FOCUS, focused cardiac ultrasound.

complaint. These algorithmic examinations go beyond evaluation of the heart and may include views of the peritoneum, lungs, pleura, aorta, inferior vena cava (IVC), and deep veins. The most well-known algorithmic examination is the focused assessment with sonography in trauma [10,11]. For the cardiac portion of this examination, a subxiphoid view is obtained to evaluate for traumatic pericardial effusion. As a point-of-care exam, the focused assessment with sonography in trauma is not intended to be comprehensive. Hypotensive trauma patients with hemoperitoneum require immediate operative intervention, but stable patients proceed to definitive evaluation with computed tomography. This is the operative paradigm for FOCUS as well. When there is any discrepancy between clinical presentation and FOCUS findings, comprehensive echocardiography should be obtained.

Several algorithmic approaches to the medical patient with undifferentiated shock or hypotension have been described [12—15]. The RUSH (Rapid Ultrasound for Shock/Hypertension) examination described by Weingart et al. [14] in 2009 incorporates the parasternal long-axis and apical 4-chamber views to evaluate for pericardial effusion, LV function, and right ventricular strain. Although this examination was designed for patients with shock or hypotension, it is also an approach appropriate for the patient with dyspnea or chest pain, where pericardial effusion, tamponade, and pulmonary embolism (PE) are concerns.

## TECHNIQUE AND LOGISTICS OF FOCUS

The views obtained for the FOCUS examination will be familiar to the experienced echocardiographer. For all providers, this is a skill like any other, which takes far longer to master than to learn. The ideal probe for this examination is a phased-array probe with a small footprint and beam steering that allows optimal imaging between ribs. The acoustic windows used in FOCUS are the parasternal long axis (PSLA), parasternal short axis (PSSA), apical 4-chamber (A4C), and subxiphoid (SX). Briefly, the PSLA view is obtained by identifying the plane formed by the mitral and aortic valves and the apex. The PSSA is a 90° plane from PSLA. The A4C view is perpendicular to both PSLA and PSSA and includes views of 4 chambers: the right and left atria and ventricles. The SX view is another 4-chamber view imaging from below the xiphoid process pointing toward the left shoulder. From the SX view, a 90° rotation on the axis of the right atrium provides a view of the IVC in long axis through the liver. Other views such as the 2-chamber, 5-chamber, and suprasternal approaches are reserved for advanced applications.

Because FOCUS is performed by providers of various training backgrounds, there is some controversy regarding orientation conventions [16]. Standard cardiology orientation will put the probe marker on the right of the screen, whereas general ultrasound convention is to place the marker on the left of the screen. This can lead to a reversed image if the screen marker is in the general ultrasound orientation, but the probe is not reversed for the parasternal long-axis view. To maintain consistency with standard cardiology orientation, if you are using a machine with the screen marker fixed on the left of the screen, simply reverse your probe so that the indicator is pointing to the patient's left hip for the parasternal long-axis view. Use whichever convention works best in your setting and produces an image intelligible by all providers.

FOCUS is usually done on machines smaller than those used in the echocardiography lab to perform comprehensive assessments. These devices may be small, wheeled carts; laptops; handhelds; or pocket-sized machines the size of a cell phone. Compared with full-service echocardiography platforms, there may be limitations in image resolution, control over focal zone, Doppler functions, and more. Whichever device you use, it is crucial to understand its benefits and limitations.

## PERICARDIAL EFFUSION AND TAMPONADE

One of the most well-established uses of FOCUS is the search for pericardial effusion in the patient at risk. Emergency physicians trained with 1 h of didactics and 4 h of hands-on practice had excellent specificity and sensitivity for detecting pericardial effusion [17]. To assess for pericardial effusion, obtain $\geq$2 of the basic cardiac ultrasound views looking for a hypoechoic collection surrounding the heart. Use of only 1 window may miss a smaller effusion that is dependent or loculated. An important confounder is the pleural effusion that surrounds the heart. To distinguish between pleural and pericardial effusions, obtain a parasternal long-axis view. Pericardial fluid will be restricted by the pericardium to the space anterior to the aorta, whereas pleural fluid will wrap anteriorly from behind the aorta (see Fig. 1).

Cardiac tamponade should be suspected in any hemodynamically unstable patient with pericardial effusion. In these patients, immediate pericardiocentesis is indicated. If they are stable, advanced users of point-of-care ultrasound may use M-mode evaluation of chamber collapse, respiratory variation of Doppler inflow, and IVC plethora to diagnose tamponade [18]. In these patients, formal echocardiography should be sought to better assess the effusion and the possibility of impending or frank tamponade.

Pericardiocentesis is no longer a blind procedure. When pericardiocentesis is indicated, cardiac ultrasound can guide the procedure safely. First, ultrasound can guide the choice of an entry point that provides the shortest path to pericardial fluid without interposed lung [19,20]. Rather than approaching the pericardial space from the SX window, necessarily traversing liver and diaphragm, we can use whatever safe path is available. Most commonly, the safest path will be directly through the anterior chest wall avoiding the internal mammary artery. Second, visualization of agitated saline on ultrasound can be used to confirm that the needle or drain has been placed in the pericardial space [21]. A more elegant, and perhaps safer, approach is placement of the needle under direct ultrasound guidance [22]. Using the phased-array probe or switching to a linear transducer, we can visualize the needle in long axis entering the pericardial space. Confirm again with agitated saline or withdrawn fluid and then proceed with drainage.

## PULMONARY EMBOLISM

FOCUS should be considered if there is concern for pulmonary embolism. Although the examination will be normal in many patients with PE, FOCUS is far more sensitive at identifying patients with massive or submassive PE. In these patients, timely management is critical. Studies of short-term prognosis in all comers with pulmonary embolism have shown considerable variability. In patients with right ventricular dysfunction on FOCUS, however, Taylor et al. [23] found that mortality is significantly higher. Signs of right ventricular dysfunction on ultrasound should prompt consideration of thrombolysis or catheter or surgical thrombectomy [24–26]. Signs of right ventricular dysfunction that may be seen on focused cardiac ultrasound include right ventricular dilation, right ventricular hypokinesis, septal flattening, septal paradoxical motion, or a hyperdynamic LV with a full IVC. Occasionally, actual embolus may be noted in transit through the right atrium or right ventricle or in the main pulmonary artery [27,28].

When performing FOCUS for PE, in particular, it is important to obtain a correct parasternal long-axis view. If the plane of this view is not properly aligned, then subsequent views may be skewed resulting in the left and right ventricular chambers appearing either artificially enlarged or diminished. In parasternal long axis, it is possible to note a significantly enlarged right ventricle, but the true value of this window is to ensure proper alignment. Once PSLA has been established, rotate 90° to obtain a PSSA view. This cross-sectional view can be translated up to the base of the heart to visualize the main pulmonary artery. Saddle emboli may be visible in this view [27]. Chamber sizes can be compared by returning the probe to the level of the ventricles. Normally the right ventricle is significantly smaller than the left. Right ventricular strain is seen when the right/left ventricular ratio is 1:1 or greater [29]. Be careful attributing right ventricular dysfunction to PE in patients who may have chronic RV strain (chronic lung disease, left ventricular dysfunction, congenital heart disease, or other causes of chronic pulmonary hypertension).

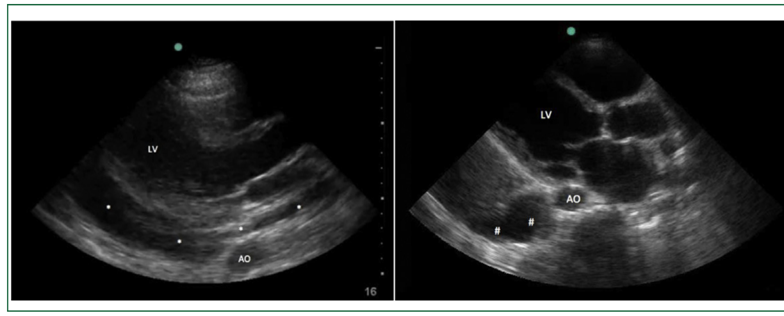


**FIGURE 1. Distinguishing pericardial (*) from pleural (#) effusion.** AO, aorta; LV, left ventricle.

Morphology is as important as chamber size. An acute change in right ventricular pressure will frequently result in a “D-shaped,” flattened septum or septal paradoxical motion (see Fig. 2) [30]. These findings are best seen in parasternal short axis. The A4C view offers another opportunity to compare chamber sizes and evaluate the septum. In addition, this view may reveal McConnell’s sign, right ventricular hypokinesis with preserved apical motion [31,32]. The last FOCUS view is the subxiphoid, which offers limited information, but does provide an axis to rotate through to assess the IVC.

## LEFT VENTRICULAR SYSTOLIC FUNCTION

In patients with shock or hypotension, rapid evaluation of systolic LV function can help categorize a patient’s shock state. A full, hypocontractile LV points toward decompensated chronic heart failure, an acute insult such as myocardial infarction or sepsis-related myocardial dysfunction. A hypercontractile LV may be seen in distributive or hypovolemic shock. Obstructive causes, such as tamponade, PE, or pneumothorax will result in a hypercontractile, but empty, LV. When additional information is obtained by a point-of-care provider imaging the IVC, thorax, and abdomen, the etiology of shock can be further narrowed.

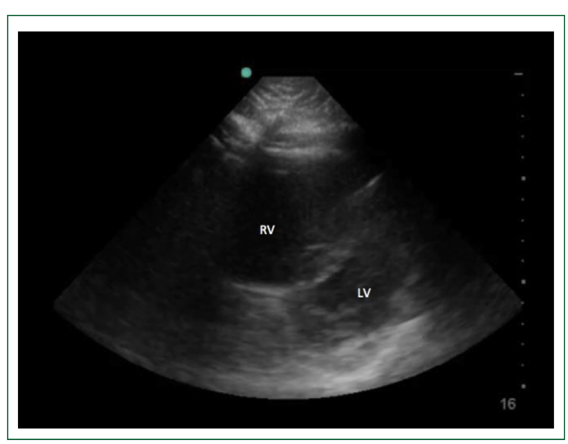


**FIGURE 2. D-shaped septum of right ventricular strain.** LV, left ventricle; RV, right ventricle.

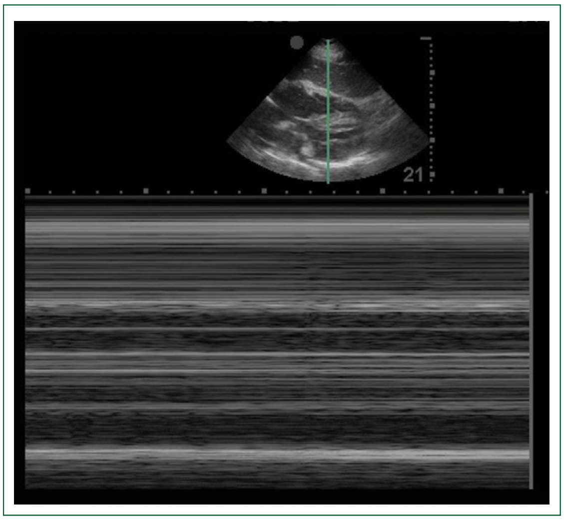

**FIGURE 3. M-mode view of cardiac standstill in an arrested patient.**

Echocardiographers perform quantitative evaluation of LV function in the noninvasive cardiology lab. At the point of care, visual qualitative estimation of LV function with 2-dimensional echocardiography has been proven accurate when performed by intensivists, emergency physicians, and internal medicine residents [33].

To estimate LV function, a minimum of 4 views (PSLA, PSSA, A4C, SX) should be obtained. On PSLA, in a normal or hyperdynamic heart, you will see the anterior mitral valve opening widely, hitting the septum. On all views, the walls of the LV should contract inward toward a central point, thickening with each contraction. The LV is hypodynamic when there is little contraction and the mitral valve does not open widely. The hyperdynamic LV will contract strongly with end-systolic effacement of the LV walls. The mitral valve will open widely.

## CARDIAC ARREST

In cardiac arrest, FOCUS can provide important prognostic, diagnostic, and procedural guidance. The prognostic value of cardiac standstill on ultrasound in the arrested patient has been studied by Blaivas and Fox [34] and Salen et al. [35,36] (Fig. 3). No survivors to hospital discharge were reported in their total of 341 patients across 3 studies. If the FOCUS examination in the arrested patient shows no organized cardiac activity, resuscitative efforts should be weighed against their risks to providers and consumption of critical resources that may benefit other patients. Another benefit of this cardiac imaging during resuscitation is the impact on family. Family members, who otherwise might not understand why the team is calling a code, are more likely to appreciate the futility of further efforts when they see a still heart on ultrasound.

Perhaps the most important role of FOCUS in cardiac arrest is the rapid identification of a reversible etiology of arrest in the patient with pulseless electrical activity (PEA). Patients with true PEA, electrical activity on the monitor but no pulse and no cardiac activity, do not survive as noted by Blaivas and Fox [34] and Salen et al. [35,36]. Patients with pseudo PEA, electrical activity on the monitor with no pulse but with some organized cardiac activity on ultrasound are more likely to benefit from resuscitative efforts. FOCUS can uncover reversible etiologies of arrest such as pericardial tamponade, thromboembolism, and hypovolemia. In these patients, intervention with pericardiocentesis, thrombolysis, or rapid volume infusion may be life-saving [37,38].

Resuscitative ultrasound goes beyond imaging the heart, however, and a comprehensive assessment requires imaging the thoraces for pneumothorax and hemothorax, the aorta for aneurysmal disease, the abdomen for hemoperitoneum, and the deep veins for thrombosis.

When interventions are made, ultrasound provides real-time guidance. In cardiac arrest, point-of-care ultrasound can guide peripheral, central venous, and arterial line placement. Ultrasound can confirm appropriate positioning of intraosseous lines as well. Even pneumothorax resolution can be tracked under ultrasound guidance. It follows logically that pericardiocentesis in the arrested patient should be done under ultrasound guidance.

## SUMMARY

Point-of-care ultrasound is now being performed by a wide variety of providers across our healthcare systems. FOCUS,

**TABLE 2.** FOCUS pitfalls

| Pitfall | Solution |
|---|---|
| Overestimating accuracy of portable ultrasound | FOCUS is specific, not sensitive, and should be followed by formal echocardiography. |
| Unfamiliarity with limitations of portable ultrasound | Providers should be aware of the benefits and limitations of FOCUS and of the specific device used. |
| Skewed PSSA and A4C views leading to poor chamber-size comparisons | Begin your exam with a well-aligned PSLA view to be sure that views that follow are well aligned. |
| Attributing all RV strain to acute pulmonary embolism | Consider alternate etiologies of RV dysfunction in patients with chronic lung disease, left ventricular dysfunction, congenital heart disease, etc. |

A4C, apical 4-chamber; FOCUS, focused cardiac ultrasound; PSLA, parasternal long axis; PSSA, parasternal short axis; RV, right ventricular.

performed with a smaller format device at the bedside by the provider actively managing a patient, offers the potential for timely, repeatable, nonionizing diagnostic information and procedural guidance. Providers picking up a phased-array probe and imaging the heart should be aware of the pitfalls of FOCUS (see Table 2). This is a specific but insensitive test. Any technical challenge to the examination or discrepancy between clinical impression and FOCUS findings should prompt a request for comprehensive echocardiography. Providers aware of both its benefits and limitations can use FOCUS to make significant interventions in patient management.

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