Focused Cardiac Ultrasound

Uncommon but Critical Diagnoses Made at the Point of Care

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Cardiovascular and respiratory conditions in acute care require rapid, critical decision making, often with limited clinical information. Focused cardiac ultrasound (FOCUS) can aid in diagnosis by providing information that may not be evident from a patient's medical history, physical examination, and ancillary tests. Eight cases are presented in which FOCUS drastically altered the management of patient care, shortened the differential diagnosis, or allowed for the development of a definitive diagnosis. In 3 cases, diagnoses that were not initially suspected were identified by FOCUS. In the remaining cases, uncommon yet critical diagnoses were established at early stages along the patients' courses of care.

Key Words—acute care; echocardiography; emergency medicine; ultrasound

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Abbreviations

CT, computed tomographic; ECG, electrocardiogram; FOCUS, focused cardiac ultrasound

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Although chest pain, shortness of breath, and syncope are among some of the most common conditions evaluated by emergency physicians, the differential diagnoses for these conditions are broad and contain some rare but serious diagnoses, such as pericardial tamponade, aortic dissection, and cardiomyopathies. Even more common diagnoses, such as acute myocardial infarction and pulmonary embolism, may present atypically or be unclear in the early stages of disease. With the use of focused cardiac ultrasound (FOCUS) at the point of care, a wider differential diagnosis can be explored, potentially streamlining the subsequent workup and ultimately improving diagnostic accuracy and clinical decision making. Here we report 8 cases in which FOCUS revealed an uncommon diagnosis, confirmed a suspected but unclear diagnosis, or suggested an alternate diagnosis not initially suspected. Our Institutional Review Board did not deem this study as human subject research; thus, approval was not required.

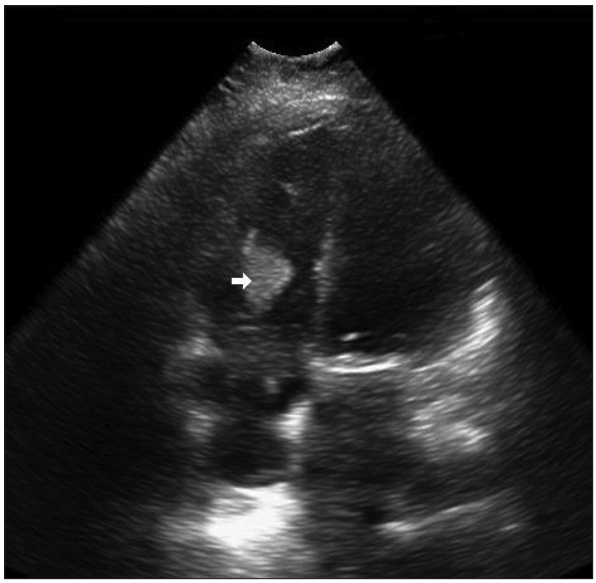
Case Descriptions

Case 1

An 87-year-old man with multiple comorbid conditions presented to the emergency department with subjective fevers, fatigue, shortness of breath, and confusion. His medical history included remote prosthetic mitral and aortic valve endocarditis among many other chronic medical problems. Physical examination revealed an alert elderly man with normal vital signs and crackles in the right lower lung field.

A chest radiograph revealed a small right pleural effusion, and a 12-lead electrocardiogram (ECG) showed no acute findings. Admission was planned, with a preliminary diagnosis of pneumonia. While awaiting transfer to an inpatient bed, a FOCUS examination was performed to exclude pericardial effusion and assess gross left ventricular function. The examination revealed an echogenic mass consistent with a thrombus or vegetation associated with the pacemaker leads, moving back and forth between the right heart chambers (Figure 1 and Video 1). These findings were discussed with and reviewed by the cardiology department, and transesophageal echocardiography was performed, which confirmed the findings and provided further evidence for the diagnosis. Endovascular extraction of the pacemaker leads and catheter-directed removal of the vegetations was performed. Afterward, the patient was treated with anticoagulation and antimicrobials and did well.

Figure 1. In a patient with pacemaker-associated endocarditis, echogenic material (arrow) is shown in the right ventricle from an apical 4-chamber view.



In this case, the diagnosis was not highly suspected but readily made at the bedside by using FOCUS, likely improving the patient's outcome due to an earlier diagnosis and preventing further deterioration. Pacemaker-associated endocarditis is a rare complication of lead placement into the right ventricle. This subacute condition typically presents with fever, chills, and pulmonary manifestations, such as pneumonia, lung abscess, or pulmonary embolism.[1] An accurate diagnosis can be made by using modified Duke criteria and echocardiography.[2] Transthoracic echocardiography is the initial imaging modality and can aid in establishing the diagnosis; however, transesophageal echocardiography is often necessary because of its higher sensitivity and more detailed delineation of the pathoanatomic features.[1]

Although this diagnosis is not specifically mentioned within the scope of FOCUS defined in the 2010 American Society of Echocardiography–American College of Emergency Physicians consensus guidelines,[3] the findings are readily visible on basic 2-dimensional echocardiographic views obtained by noncardiologists. Making such a diagnosis with FOCUS is possible with adequate images, a basic understanding of normal sonographic anatomy, and a systematic approach to interpretation.

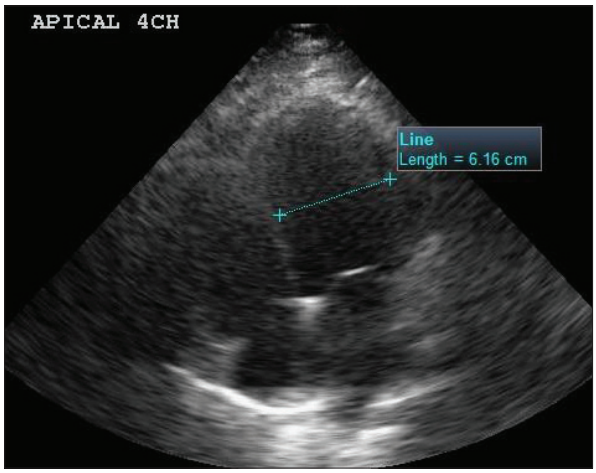
Case 2

A 35-year-old man presented with increasing exertional dyspnea, along with cough and upper abdominal pain. He had been treated previously with antimicrobials and bronchodilators for the same condition and was scheduled for esophagogastroduodenoscopy for further evaluation. Despite these treatments, his symptoms were worsening. Physical examination revealed normal vital signs and pulse oximetric values. He was obese and appeared somewhat dyspneic with bibasilar crackles heard on lung examination.

A mobile chest radiograph was interpreted as negative by the radiology department, and his ECG was unremarkable. A FOCUS examination was performed to evaluate suspected congestive heart failure and revealed a dilated, diffusely hypokinetic left ventricle with a severely reduced ejection fraction and myopathic motion of the mitral valve (Figure 2 and Videos 2–5). Medical therapy for congestive heart failure was initiated; he was admitted and nonischemic dilated cardiomyopathy of idiopathic etiology was ultimately diagnosed. His symptoms improved with medical therapy; an automatic internal cardioverter-defibrillator was eventually inserted; and he was placed on a cardiac transplant list.

In this case, congestive heart failure was included in the differential diagnosis but was able to be confirmed at the bedside, allowing a more focused downstream evaluation, likely decreasing subsequent investigations, and possibly preventing further deterioration of the patient's condition. It is possible that the diagnosis could have been established sooner had FOCUS been incorporated earlier in the course of his illness.

Figure 2. In a patient with dilated cardiomyopathy, this image, captured at end diastole in an apical 4-chamber view, shows that the internal diameter of the left ventricle is estimated at 6.16 cm, which is dilated.



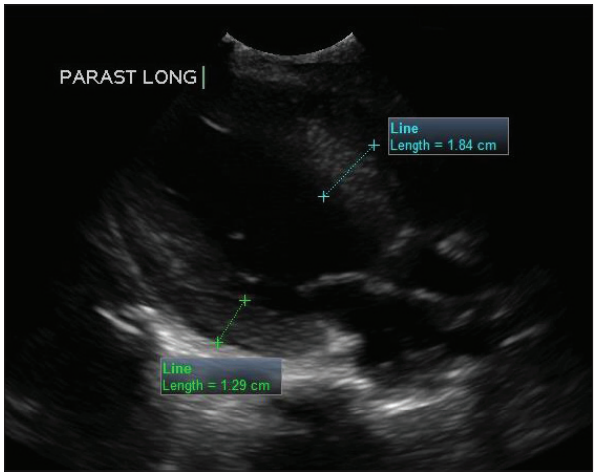
Case 3

A 5-year-old boy presented to the emergency department after 2 episodes of unprovoked syncope without associated dyspnea, chest discomfort, or palpitations. His medical history was unremarkable other than being small for his age, and there was no family history of sudden cardiac death. On physical examination, he appeared pale and was tachycardic, with a II/VI systolic murmur at the left sternal border. An ECG revealed a left axis and borderline increased left ventricular voltages, and portable chest radiography showed cardiomegaly. A FOCUS examination was performed to exclude pericardial effusion and assess gross left ventricular function. The examination revealed a hypokinetic left ventricle with symmetric left ventricular hypertrophy (Figure 3 and Videos 6 and 7). On admission, further evaluation confirmed a diagnosis of hypertrophic nonobstructive cardiomyopathy. Medical therapy was initiated, and he was advised to avoid strenuous athletic activities.

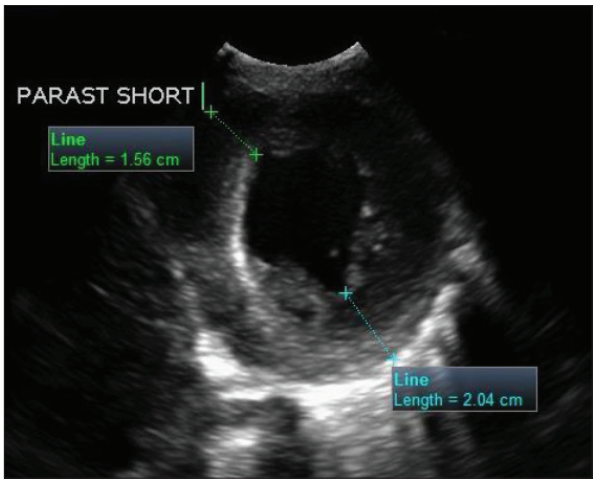
In this case, there were concerning yet nonspecific findings, and FOCUS was able to establish an accurate, although preliminary, diagnosis early in the patient's course, leaving less uncertainty and likely decreasing subsequent ancillary testing. Hypertrophic cardiomyopathy is a genetic disorder with variable expression that can cause sudden cardiac death, especially among athletes, and should always be part of the differential diagnosis for patients presenting with cardiovascular conditions.[4]

Figure 3. In this young male patient, a hypokinetic left ventricle with symmetric left ventricular hypertrophy was seen. **A**, At end diastole in a parasternal long-axis view, both the septal and free walls measure greater than 1.2 cm in thickness, which is consistent with left ventricular hypertrophy. **B**, At end-diastole in a parasternal short-axis view in the mid ventricle, both the septal and free walls measure greater than 1.2 cm in thickness, which is consistent with left ventricular hypertrophy.

A



B



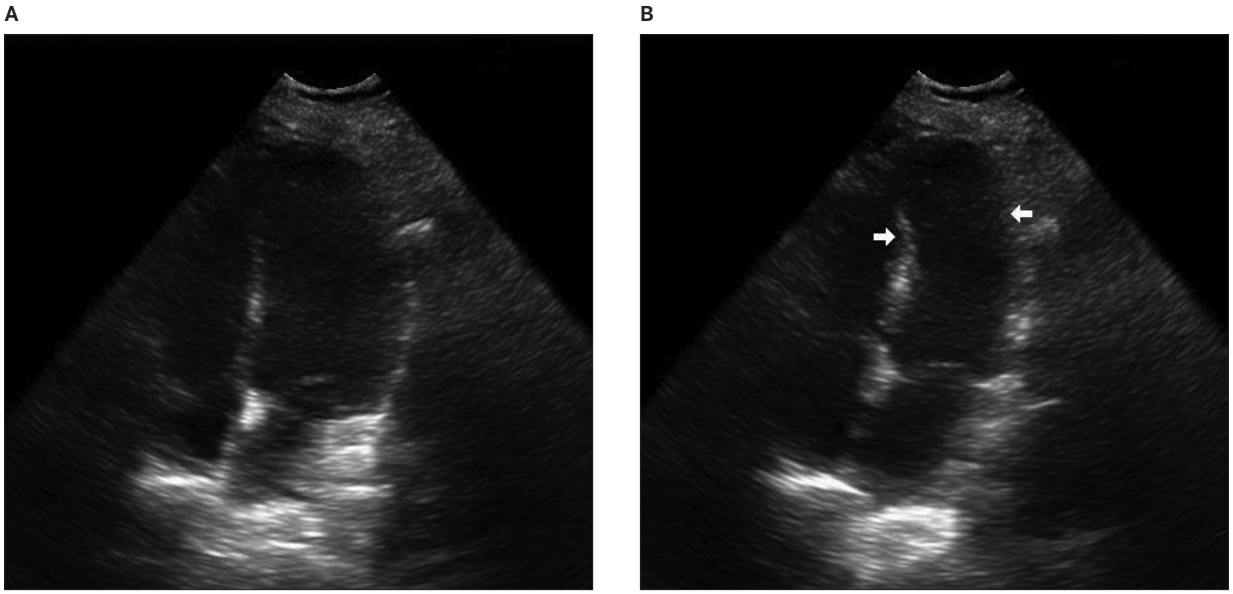
A thorough history, physical examination, and ECG may identify most patients with a high risk for sudden death, but echocardiography is necessary for a specific diagnosis.[5] A limited 2-dimensional echocardiogram should be adequate to identify most high-risk patients. In small studies, physicians with limited training in echocardiography have demonstrated their ability to acquire the proper views and measurements.[6]

Case 4

A 51-year-old man presented with acute chest aching that began after running to a resuscitation in the hospital where he worked as a nurse. His medical history was unremarkable. Vital signs were normal, but he was pale and diaphoretic on examination. An ECG showed ST-segment elevation of less than 1 mm in leads V2 through V4 and no reciprocal changes. His symptoms improved with nitroglycerin, and serial ECGs remained nondiagnostic. A FOCUS examination was performed to further investigate his chest pain and evaluate for further diagnostic evidence of suspected myocardial ischemia. The examination revealed hypokinesis of the left ventricular apex (Figure 4 and Video 8). With resolving symptoms, the patient was hesitant to undergo emergent cardiac catheterization but agreed to the procedure after reviewing the sonographic findings with the emergency physician. He was found to have complete occlusion of the left anterior descending coronary artery, which was successfully stented. Of note, initial troponin was undetectable and later peaked at 29 ng/mL.

In this case, FOCUS added valuable diagnostic information to an already concerning clinical picture and helped provide vital information for the patient's care, allowing prompt intervention and likely limiting the extent of myocardial injury, resulting in a better long-term functional outcome. Diagnosing regional wall motion abnormalities with FOCUS can be challenging and should not be used to exclude ischemia.[7,8] Even among experienced cardiologists, there is considerable inter-rater variability in diagnosing these abnormalities.[9] However, in patients with acute symptoms and initially inconclusive findings, FOCUS may offer additional diagnostic information regarding ischemia or alternate diagnoses and facilitate prompt intervention if necessary.[3] Higher-risk ischemic lesions involving larger myocardial territories should be recognizable by nontraditional users when adequate views can be obtained.

Figure 4. These sequential apical 4-chamber views from a 51-year-old man with chest pain show hypokinesis in the left ventricular apex. **A**, This image from an apical 4-chamber view was captured at end diastole. When compared to **B**, which was captured during peak systole, distal hinge points and hypokinesis of the left ventricular apex can be seen. **B**, This image, captured at peak systole, displays hinge points (arrows) at the distal septal and lateral walls of the left ventricle. Also, in comparison to **A**, the left ventricular apical walls have not thickened appropriately, and the area at the left ventricular apex has not decreased substantially. These signs indicate a regional wall motion abnormality at the left ventricular apex, consistent with ischemia.



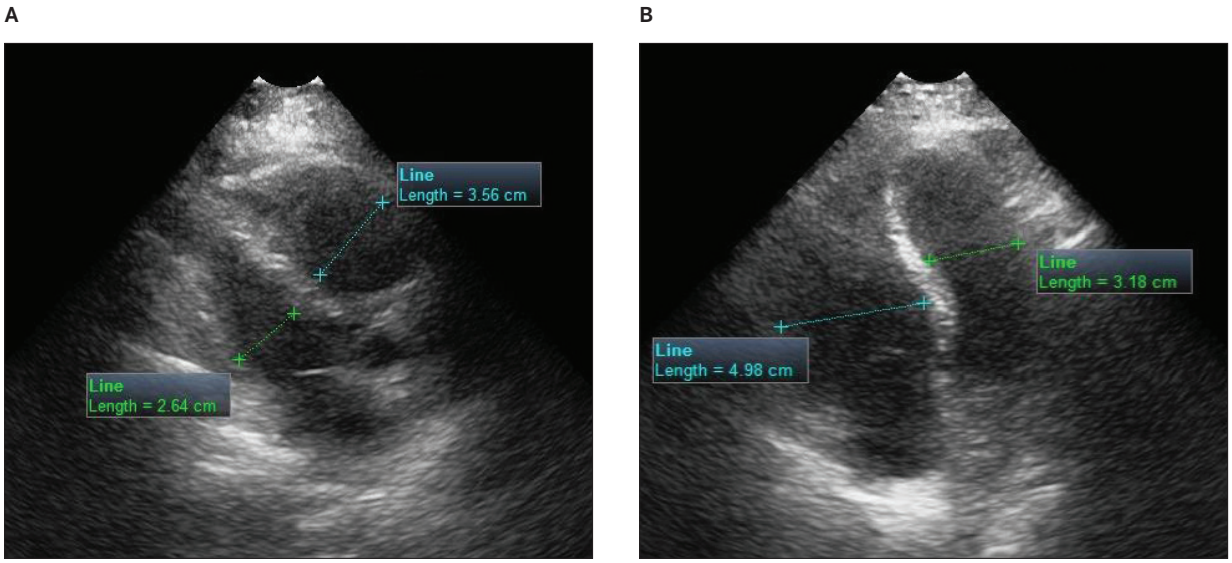
Case 5

A 49-year-old man presented with dyspnea on exertion and chest pressure for several days. He reported a remote history of deep venous thrombosis while working as a truck driver, but was no longer receiving anticoagulation therapy. He denied symptoms of deep venous thrombosis or hemoptysis, and he was a smoker. Vital signs, pulse oximetric values, and physical examination findings were normal. Chest radiographic and ECG findings were also normal. His troponin level was elevated into the diagnostic range for acute myocardial infarction.

Admission was planned for non–ST-elevation myocardial infarction when a FOCUS examination was performed to assess gross left ventricular function. The examination revealed a massively dilated right ventricle with abnormal septal motion (Figure 5 and Videos 9 and 10), prompting the physician to order a pulmonary computed tomographic (CT) angiogram, which revealed large central, bilateral pulmonary emboli. Treatment with anticoagulation was continued, and the patient was admitted to the hospital.

In this case, FOCUS suggested a diagnosis that was initially thought unlikely, prompting further evaluation, an accurate diagnosis, and a change in the care plan. Focused cardiac ultrasound is a useful diagnostic tool for patients with suspected or confirmed cases of pulmonary embolism. In patients with suspected pulmonary embolism without preexisting cardiopulmonary disease, right ventricular dilatation has been shown to be a specific yet insensitive finding for the diagnosis.[10] When incorporating this modality, it is important that clinicians be aware of other causes of right ventricular dilatation and consider the entire clinical picture when interpreting sonographic findings and making care decisions. Some findings that are more suggestive of acute right ventricular dilatation include a right ventricular free wall thickness of less than 5 mm and the McConnell sign, which is the presence of a hyperkinetic right ventricular apex in the setting of a dilated and hypokinetic right ventricle. Focused cardiac ultrasound may provide prognostic information in acute pulmonary embolism and can assist in therapeutic decision making, specifically in selecting candidates for thrombolytic therapy.[11]

Figure 5. Dilated right ventricle and abnormal septal motion in a 49-year-old man with pulmonary embolism. **A**, From a parasternal long-axis view, the left ventricle appears small in comparison to the more superficial, dilated right ventricle, and the right ventricular-to-left ventricular diameter ratio is greater than 1. **B**, From an apical 4-chamber view, the right ventricular-to-left ventricular diameter ratio is greater than 1. In addition, the proximal septal wall can be seen bulging, paradoxically toward the left ventricle.



Case 6

A 48-year-old man presented to the emergency department for left shoulder pain and dyspnea, which worsened when lying flat. He had been seen 2 days previously for the same symptoms, but the symptoms were worsening. His medical history was unremarkable. During a recent admission for chest pain, a myocardial perfusion scan showed a region of ischemia, and a chest radiograph had shown small pleural effusions.

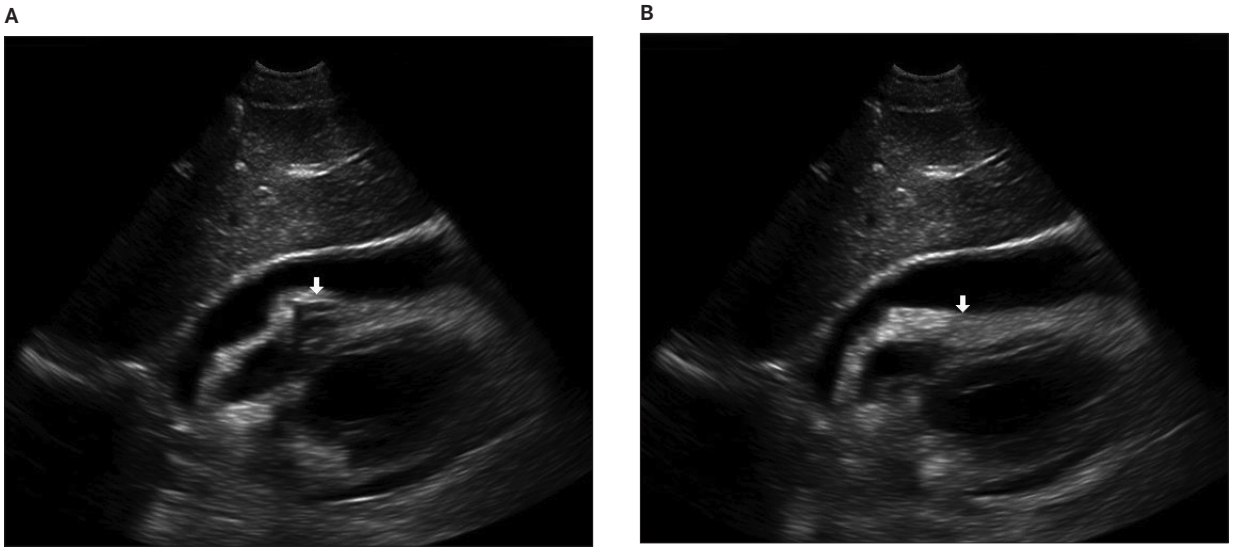
At the time of his visit to the emergency department, a chest radiograph showed an increased yet small left pleural effusion, and the ECG was unremarkable. A FOCUS examination was performed to further evaluate his symptoms and showed a large pericardial effusion with right ventricular diastolic collapse (Figure 6 and Video 11). Since he was hemodynamically stable, he was taken to the cardiac procedures laboratory and underwent successful pericardiocentesis, where 640 mL of serous fluid was drained. Pathologic examination revealed nonmalignant inflammatory cells, and he was treated with indomethacin and did well.

In this case, the patient presented with atypical symptoms and a nondiagnostic workup. Focused cardiac ultrasound allowed an accurate diagnosis to be made when it was not evident on the basis of the other available information. It is possible that earlier incorporation of FOCUS would have resulted in a more timely diagnosis. Pericarditis is usually diagnosed on the basis of the patient's history, physical examination, and classic ECG findings, which were not present in this case.[12] Pericardial effusions from etiologies other than acute pericarditis also do not typically have classic ECG findings.[13] The incidence of pericardial effusion is quite variable, depending on the underlying disease process, but may be as high as 20% in patients with renal disease, up to 37% in some malignancies, and even higher in patients with human immunodeficiency virus infection or AIDS. Thus, clinicians should consider and evaluate for pericardial effusion in symptomatic patients, especially those with known high-risk disease states.[14–16]

Case 7

A 60-year-old man presented to the emergency department after having a syncopal event preceded by "indigestion." His only symptom on presentation was right leg pain. His medical history was notable for remote colon cancer in remission and hypertension, and he was a former smoker. During the physical examination, the patient was bradycardic, with a heart rate of 40 beats per minute. Although he was not in any distress, his right leg was pale with diminished pulses and delayed capillary refill. A FOCUS examination was performed and showed a dilated aortic root (Figure 7A and Video 12). Additional views of the abdominal aorta revealed a mobile flap, consistent with aortic dissection (Figure 7B and Video 13). A Stanford type A aortic dissection was suspected, and the

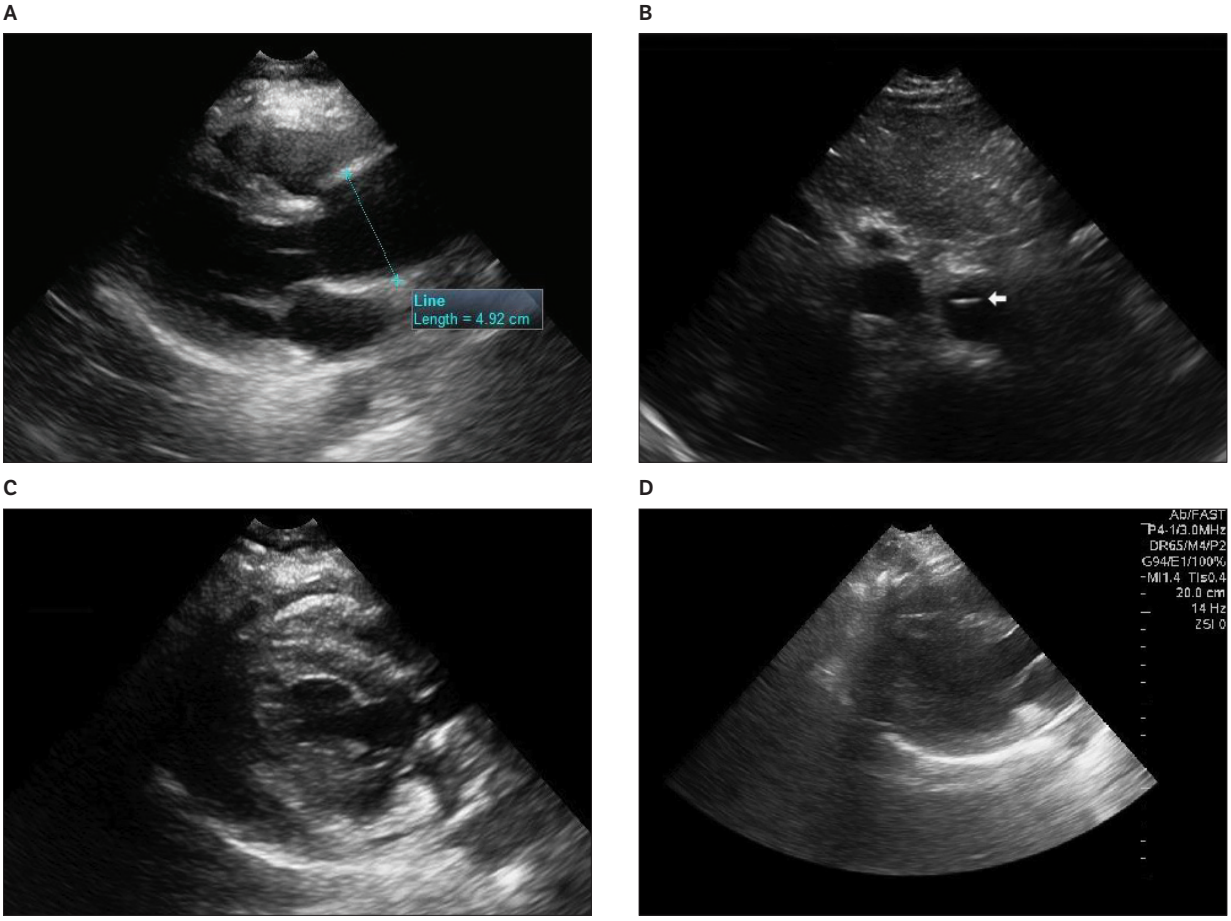
Figure 6. Large pericardial effusion with diastolic collapse of the right ventricle in a 48-year-old man. **A**, In this image from a subcostal view, a large pericardial effusion is shown, which is more prominent anteriorly but circumferential to the heart. The right ventricle (arrow) is shown at the most dilated point to be filling poorly. **B**, From a subcostal view captured during diastole, a large pericardial effusion is shown, which is more prominent anteriorly but circumferential to the heart. The right ventricle (arrow) appears collapsed, consistent with tamponade.



patient was taken immediately for a CT scan while the cardiothoracic service was consulted. Unfortunately, the patient had cardiac arrest minutes later. Another ultrasound examination showed a new pericardial effusion and very poor global ventricular function (Figure 7C and Video 14). Pericardiocentesis was successfully performed under echocardiographic guidance (Figure 7D and Video 15), and advanced cardiac life support measures were performed. The cardiothoracic team was present at the bedside during the resuscitation, but it was ultimately unsuccessful, and the patient died in the emergency department.

Despite the poor outcome of this patient, FOCUS was critical in his care, allowing a diagnosis to be made within seconds of emergency department arrival despite an atypical presentation, expediting his care. Focused cardiac ultrasound was also useful for monitoring the progression of the disease moment to moment and helping guide pericardiocentesis. Acute aortic dissection is an uncommon disease with high mortality once symptomatic, and diagnosis can be challenging. Although transthoracic echocardiography lacks adequate sensitivity to exclude aortic dissection, it can be helpful in establishing an early diagnosis, identifying high-risk features and complications and guiding intervention.[17]

Figure 7. Parasternal long-axis echocardiographic views and proximal abdominal aortic view from a 60-year-old man presenting to the emergency department after syncope. **A**, This image, taken from a parasternal long-axis view, shows a dilated ascending aorta measuring 4.92 cm. No definitive flap is seen. **B**, In this transverse view of the abdominal aorta, a flap consistent with dissection is shown (arrow). This finding, in combination with the dilated aortic root shown in **A**, suggests a Stanford type A aortic dissection. **C**, This parasternal long-axis image, taken after the patient had cardiac arrest, shows a moderately sized circumferential pericardial effusion, which is one of the known complications of type A aortic dissection. **D**, This parasternal long-axis image was captured after successful pericardiocentesis, which was performed under echocardiographic guidance. The effusion appears smaller compared to **C**.



Case 8

An 87-year-old woman who had recently undergone hip surgery presented to the emergency department from a nursing home with 1 day of dyspnea. Her medical history was unremarkable. She was neither a smoker nor receiving estrogen therapy. Vital signs and physical examination findings were unremarkable while she was in the emergency department, and there was no new leg swelling, redness, or pain. A FOCUS examination was performed to evaluate gross left ventricular function and revealed a mobile mass in the right atrium adherent to the free wall, which was thought to be a thrombus (Figure 8 and Video 16). There was no right ventricular dilatation, and the remainder of the examination findings were negative. Pulmonary CT angiographic findings were negative for pulmonary embolism. It was believed that the patient may have had either multiple small pulmonary emboli versus a pulmonary embolus that autolysed before performance of the CT scan. Anticoagulation was initiated, and she was admitted to the hospital and did well. Follow-up imaging revealed a decreasing size of the mass, further solidifying the likelihood that a thrombus was the correct diagnosis.

In this case, FOCUS rapidly revealed an unusual diagnosis that would have been difficult considering the negative CT result. With the accurate diagnosis, proper therapy and follow-up were provided, and the patient did well. A right atrial thrombus is an uncommon problem, and optimal treatment has not been clearly defined.[18,19] The diagnosis can usually be made by transthoracic echocardiography, and the differential diagnosis should include other intracardiac masses and vegetations. Transesophageal echocardiography is likely more sensitive in making the diagnosis.[20]

Figure 8. In this apical 4-chamber view from an elderly patient with dyspnea, an echogenic clot is shown in the right atrium (arrow). This mass was mobile and appeared adherent to the right atrial free wall.

Discussion

The cases above demonstrate how the addition of FOCUS to a standard clinical workup can improve patient care by identifying both rare conditions as well as serious but unexpected diagnoses in patients with atypical presentations. Such a strategy allows for early identification of important clinical problems and life-threatening conditions while also directing immediate management decisions and guiding critical procedures.

Although it may appear that a liberal FOCUS strategy could increase medical costs, we argue that it could decrease the need for subsequent ancillary testing and result in earlier, more accurate diagnoses, thus allowing better stewardship of limited resources. Additionally, this strategy should also lead to earlier interventions with less complicated, more efficient clinical courses and, ultimately, better patient outcomes. This belief is demonstrated in cases 2 and 6, in which 1 or more patient visits for the same conditions occurred before accurate diagnoses were made by incorporating FOCUS into the evaluation. For other applications, the use of point-of-care ultrasound can decrease the use of more expensive CT scans, in addition to decreasing the length of stay as well as avoiding unnecessary ionizing radiation.[21–23]

Although it is true that echocardiography is an operator-dependent skill and that diagnostic accuracy improves with experience, it is likely that as ultrasound training continues to advance in medical school curricula and graduate medical education, a larger pool of experienced clinicians will be competent in making less common and more challenging diagnoses.[24] The power and utility of FOCUS as a clinical tool has been demonstrated in multiple studies in which nontraditional users with limited training were able to obtain and accurately interpret limited echocardiograms, resulting in more accurate, earlier diagnoses and changes in the patient care.[25–27] Specifically, medical students with limited echocardiographic training were able to make more accurate diagnoses than experienced cardiologists using a standard physical examination.[28]

Although we are enthusiastic about the growing incorporation of FOCUS into standard clinical practice for noncardiologists, it is important to recognize some of the limitations of this modality. The first and likely most important is a current heterogeneity in the level of training among noncardiologists. Many practicing clinicians have minimal training in FOCUS. Increased standardization in undergraduate and graduate medical education is needed to fully implement this modality into standard practice. The next limitation is equipment. Although portable ultra-

sound equipment has improved considerably in the past decade, there remains a narrowing gap in quality compared to larger units used in echocardiography laboratories. Last, acutely ill patients and the time demands of acute care work environments present their own unique challenges that contribute to decreased image quality and can contribute to interpretation errors. Again, improvements and standardization in the training of noncardiologists should help in mitigating these limitations.

Larger controlled studies are needed to examine whether a liberal FOCUS strategy would lead to widespread improvements in patient outcomes and be cost-effective. It would be premature to recommend performing FOCUS in every patient with these types of conditions. However, we believe that FOCUS should be considered in every acutely ill patient with cardiovascular and respiratory conditions and that training in clinical ultrasound for a wide range of clinicians should continue and expand.

References

1. Karchmer AW. Infections involving cardiac implantable electronic devices. UpToDate website. http://www.uptodate.com/contents/infections-involving-cardiac-implantable-electronic-devices#H38. Accessed March 13, 2014.
2. Durack DT, Lukes AS, Bright DK. New criteria for diagnosis of infective endocarditis: utilization of specific echocardiographic findings. Duke Endocarditis Service. *Am J Med* 1994; 96:200–209.
3. 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* 2010; 23:1225–1230.
4. Shah SN. Hypertrophic cardiomyopathy. Medscape website. http://emedicine.medscape.com/article/152913-overview. Accessed March 13, 2014.
5. Asif IM, Drezner JA. Sudden cardiac death and preparticipation screening: the debate continues—in support of electrocardiogram-inclusive preparticipation screening. *Prog Cardiovasc Dis* 2012; 54:445–450.
6. Yim ES, Gillis EF, Ojala K, MacDonald J, Basilico FC, Corrado GD. Focused transthoracic echocardiography by sports medicine physicians: measurements relevant to hypertrophic cardiomyopathy. *J Ultrasound Med* 2013; 32:333–338.
7. Hoffmann R, von Bardeleben S, Barletta G, et al. Comparison of two- and three-dimensional unenhanced and contrast-enhanced echocardiographies versus cineventriculography versus cardiac magnetic resonance for determination of left ventricular function. *Am J Cardiol* 2014; 113:395–401.
8. Taylor RA, Moore CL. Accuracy of emergency physician–performed limited echocardiography for right ventricular strain. *Am J Emerg Med* 2014; 32:371–374.
9. Hoffmann R, von Bardeleben S, Kasprzak J, et al. Analysis of regional left ventricular function by cineventriculography, cardiac magnetic resonance imaging, and unenhanced and contrast-enhanced echocardiography: a multicenter comparison of methods. *J Am Coll Cardiol* 2006; 47:121–128.
10. Dresden S, Mitchell P, Rahimi L, et al. Right ventricular dilation on bedside echocardiography performed by emergency physicians aids in the diagnosis of pulmonary embolism. *Ann Emerg Med* 2014; 63:16–24.
11. Kline JA, Nordenholz KE, Courtney DM, et al. Treatment of submassive pulmonary embolism with tenecteplase or placebo: cardiopulmonary outcomes at 3 months (TOPCOAT)—multicenter double-blind, placebo-controlled randomized trial. *J Thromb Haemost* 2014; 12:459–468.
12. Spangler S. Acute pericarditis. Medscape website. http://emedicine.medscape.com/article/156951-overview. Accessed March 4, 2014.
13. Meyers DG, Bagin RG, Levene JF. Electrocardiographic changes in pericardial effusion. *Chest* 1993; 104:1422–1426.
14. Bussani R, De-Giorgio F, Abbate A, Silvestri F. Cardiac metastases. *J Clin Pathol* 2007; 60:27–34.
15. Meenakshisundaram R, Sweni S, Thirumalaikolundusubramanian P. Cardiac isoform of alpha 2 macroglobulin: a marker of cardiac involvement in pediatric HIV and AIDS. *Pediatr Cardiol* 2010; 31:203–207.
16. Lind A, Reinsch N, Neuhaus K, et al. Pericardial effusion of HIV-infected patients? Results of a prospective multicenter cohort study in the era of antiretroviral therapy. *Eur J Med Res* 2011; 16:480–483.
17. Meredith EL, Masani ND. Echocardiography in the emergency assessment of acute aortic syndromes. *Eur J Echocardiogr* 2009; 10:i31–i39.
18. Lazar L, Dave R, Tabibiaszar R. Dilemma of right atrial thrombi, to dissolve or to extract. *Proc UCLA Healthcare* 2012; 16:1–4.
19. Sobhy E, Alamaldine T, Sabti HA. Successful treatment of right-sided heart thrombus with pulmonary embolism with thrombolytic therapy. *J Cardiovasc Dis Diagn* 2013; 1:121.
20. Chartier L, Bera J, Delomez M, et al. Free-floating thrombi in the right heart: diagnosis, management, and prognostic indexes in 38 consecutive patients. *Circulation* 1999; 99:2779–2783.
21. Peris A, Tutino L, Zagli G, et al. The use of point-of-care bedside lung ultrasound significantly reduces the number of radiographs and computed tomography scans in critically ill patients. *Anesth Analg* 2010; 111:687–692.
22. Jang T, Chauhan V, Cundiff C, Kaji AH. Assessment of emergency physician–performed ultrasound in evaluating nonspecific abdominal pain. *Am J Emerg Med* 2014; 32:457–460.
23. Blaivas M, Harwood RA, Lambert MJ. Decreasing length of stay with emergency ultrasound examination of the gallbladder. *Acad Emerg Med* 1999; 6:1020–1023.
24. Greenberg R. Making waves: ultrasound use increases in medical education. *AAMC Reporter* December 2012. AAMC website. https://www.aamc.org/newsroom/reporter/dec2012/323592/ultrasound.html. Accessed March 5, 2014.

25. Manasia AR, Nagaraj HM, Kodali RB, et al. Feasibility and potential clinical utility of goal-directed transthoracic echocardiography performed by noncardiologist intensivists using a small hand-carried device (SonoHeart) in critically ill patients. *J Cardiothorac Vasc Anesth* 2005; 19:155–159.
26. Panoulas VF, Daigeler AL, Malaweera AS, et al. Pocket-size hand-held cardiac ultrasound as an adjunct to clinical examination in the hands of medical students and junior doctors. *Eur Heart J Cardiovasc Imaging* 2013; 14:323–330.
27. Decara JM, Kirkpatrick JN, Spencer KT, et al. Use of hand-carried ultrasound devices to augment the accuracy of medical student bedside cardiac diagnoses. *J Am Soc Echocardiogr* 2005; 18:257–263.
28. Kobal SL, Trento L, Baharami S, et al. Comparison of effectiveness of hand-carried ultrasound to bedside cardiovascular physical examination. *Am J Cardiol* 2005; 96:1002–1006.