Focused Cardiac Ultrasound in the Emergent Setting

A Consensus Statement of the
American Society of Echocardiography
and the
American College of Emergency Physicians

Arthur J. Labovitz, MD, FASE, Chair,* Vicki E. Noble, MD, FACEP,** Michelle Bierig, MPH, RDCS, FASE,* Steven A. Goldstein, MD,* Robert Jones, DO, FACEP,** Smadar Kort, MD, FASE,* Thomas R. Porter, MD, FASE,* Kirk T. Spencer, MD, FASE,* Vivek S. Tayal, MD, FACEP,** Kevin Wei, MD,*
St. Louis, MO; Boston, MA; Washington, DC; Cleveland, OH; Stony Brook, NY; Omaha, NE; Chicago, IL; Charlotte, NC; Portland, OR

From the St. Louis University School of Medicine, St. Louis, Missouri (A.J.L. and M.B.); Massachusetts General Hospital, Boston, Massachusetts (V.E.N.); Washington Hospital Center, Washington, District of Columbia (S.A.G.); MetroHealth Medical Center, Cleveland, Ohio (R.J.); Stony Brook University Medical Center, Stony Brook, New York (S.K.); University of Nebraska Medical Center, Omaha, Nebraska (T.R.P.); University of Chicago Medical Center, Chicago, Illinois (K.T.S.); Carolinas Medical Center, Charlotte North Carolina (V.S.T.); Oregon Health & Science University, Portland, Oregon (K.W.)

Reprint requests: American Society of Echocardiography, 2100 Gateway Centre Boulevard, Suite 310, Morrisville, NC 27560, ase@asecho.org.

*American Society of Echocardiography
**American College of Emergency Physicians

Introduction

The use of ultrasound has developed over the last 50 years into an indispensable first-line test for the cardiac evaluation of symptomatic patients. The technologic miniaturization and improvement in transducer technology as well as the implementation of educational curriculum changes in residency training programs and specialty practice have facilitated the integration of focused cardiac ultrasound (FOCUS) into practice by specialties such as emergency medicine. In the emergency department, FOCUS has become a fundamental tool to expedite the diagnostic evaluation of the patient at the bedside and to initiate emergent treatment and triage decisions by the emergency physician.

This consensus statement by the American Society of Echocardiography (ASE) and the American College of Emergency Physicians (ACEP) delineates the important role of FOCUS in patient care and treatment and emphasizes the complementary role of FOCUS to that of comprehensive echocardiography. We outline the clinical applications where FOCUS could be used, as part of the evolving relationship between echo laboratories and emergency departments. Although cardiac ultrasound performed by emergency physicians in emergency departments in unstable patients**,** is often performed in the context of other focused ultrasound applications (examining the hypotensive patient for abdominal aortic aneurysms, ruptured ectopic pregnancy, or intraperitoneal hemorrhage as a result of trauma), the scope of this consensus statement is limited to cardiac applications of the FOCUS exam. Accordingly, the important role of comprehensive transthoracic echo and transesophogeal echo in the emergency department (ED) will not be discussed in detail in this paper.

Focused cardiac ultrasound versus comprehensive echocardiography

The principle role for FOCUS is the time-sensitive assessment of the symptomatic patient.[1-5] This evaluation primarily includes the assessment for pericardial effusion and the evaluation of relative

chamber size, global cardiac function, and patient volume status (Table 1). Intravascular volume status may be assessed by LV size, ventricular function, and IVC size and respiratory change. In addition, FOCUS is used to guide emergent invasive procedures such as pericardiocentesis or evaluate the position of transvenous pacemaker placement.[3,5]

Other pathological diagnoses (intracardiac masses, left ventricular thrombus, valvular dysfunction, regional wall motion abnormalities, endocarditis, aortic dissection) may be suspected on FOCUS but additional evaluation, including referral for comprehensive echocardiography or cardiology consultation is recommended. Further hemodynamic assessment of intracardiac pressures, valvular pathology and diastolic function requires additional training in comprehensive echocardiography techniques.

Comprehensive echocardiographic examination or other imaging modalities are recommended in any case in which the focused findings and clinical presentations are discordant. Clinical scenarios and the information obtained from the focused use of cardiac ultrasound in emergent situations are distinctly different from those where comprehensive echocardiography are utilized and both types of studies have a role in optimizing patient care as will be outlined in the following sections. The role of emergency ultrasound, including FOCUS and other core emergency ultrasound applications, is discussed in ACEP's Emergency Ultrasound Imaging Compendium as well.[3]

Table 1. Goals of the Focused Cardiac Ultrasound in the Symptomatic Emergency Department Patient

Assessment for the presence of pericardial effusion
Assessment of global cardiac systolic function
Identification of marked right ventricular and left ventricular enlargement
Intravascular Volume assessment
Guidance of pericardiocentesis
Confirmation of transvenous pacing wire placement

Focused Cardiac Ultrasound Exam Findings

Pericardial effusion

Studies have shown a high degree of sensitivity and specificity in the detection of pericardial effusions in both medical and trauma patients using FOCUS.[6-10] Imaging in multiple views or windows provides the most accurate detection of pericardial effusion. It is important to recognize that pericardial tamponade is a clinical diagnosis which includes the visualization of pericardial fluid, blood or thrombus, in addition to clinical signs including hypotension, tachycardia, pulsus paradoxus, and distended neck veins. While FOCUS may be used to visualize delayed right ventricular diastolic expansion and right atrial or ventricular diastolic collapse representing increased pericardial pressures, there are additional 2D and Doppler findings obtained in a comprehensive exam that can confirm or refute the degree of suspected hemodynamic compromise as well as provide a means of serially monitoring its progress.[10,11,12] In addition, small, more focal pericardial effusions can be difficult to recognize with FOCUS, and a comprehensive echocardiogram or other diagnostic imaging testing is indicated whenever the clinical suspicion for the presence of effusion is high and the FOCUS could not demonstrate it.

In trauma patients, hemodynamically significant pericardial effusions may be small or focal and the hemorrhage may exhibit evidence of clot formation, yet the degree of hemodynamic instability may be pronounced. In such hemodynamically unstable patients, a comprehensive echocardiogram will typically not be obtained before initial treatment is provided.

When emergent pericardiocentesis is indicated, ultrasound can provide guidance by first imaging the fluid collection from the subxiphoid/subcostal or other transthoracic windows to define the best

trajectory for needle insertion.[13,14] If the diagnosis of a pericardial effusion that could be drained percutaneously can be made at the bedside expeditiously, ultrasound guided pericardiocentesis in these critically ill patients has been shown to have fewer complications and a higher success rate than if done without ultrasound guidance.[12,13] Injection of agitated saline may be helpful in localizing needle placement during this procedure.[14]

Global Cardiac Systolic Function

FOCUS can be used for global assessment of left ventricular systolic function. This assessment relies on overall assessment of endocardial excursion and myocardial thickening, using multiple windows including the parasternal, subcostal and apical views. It is important to note that FOCUS is performed to assess global function and differentiates patients into "normal" or minimally impaired function versus "depressed" or significantly impaired function. This descriptive nomenclature when used by non-echocardiographers has good correlation with echocardiographer interpretations.[16] The goal of the focused exam is to facilitate clinical decision-making to decide if a patient with acute shortness of breath or chest pain has impaired systolic contractility and thus would benefit from pharmacologic therapies or other interventions.[17] Evaluation of segmental wall motion abnormalities and other etiologies of shortness of breath such as valvular dysfunction can be challenging and should be assessed by performing a comprehensive echocardiogram.

Right Ventricular Enlargement

In an acute massive pulmonary embolus, the right ventricle (RV) can be dilated and have reduced function or contractility. In patients with hemodynamically significant pulmonary embolus, the left ventricle can be underfilled and hyperdynamic as well. The presence of RV enlargement and dysfunction in patients with pulmonary embolus is prognostically important, and is associated with significantly higher in-hospital mortality as well as being one of the best predictors of poor early outcome.[19-21] The role of FOCUS in patients with suspected pulmonary embolus is to prioritize further testing, alter differential diagnosis assessments and assist with treatment decisions in the *severely* compromised patient.[18-22] Since the use of thrombolytic therapy in most patients can safely be delayed, it is recommended to further assess the size and function of the RV using comprehensive echocardiography once the suspicion for the presence of PE is established.[23,24]

FOCUS can be used to identify hemodynamically significant pulmonary emboli by observing right ventricular dilatation (>1:1 RV/LV ratio), decreased right ventricular systolic function, or occasionally by visualizing free floating thrombus. While an acute submassive pulmonary embolus can result in RV enlargement and dysfunction, the sensitivity of these findings even on comprehensive transthoracic echocardiography is limited (29% and 51%, respectively, 52-56% using both criteria combined).[21,23] As stated in the ACC/ASE appropriateness criteria document, transthoracic echocardiography is not sufficiently sensitive to rule out pulmonary embolism.[25] Likewise, FOCUS may be helpful if positive in the compromised patient but is clearly not sufficient to rule this important diagnosis out or to risk stratify patients with stable hemodynamics. Comprehensive echocardiography can be used to risk stratify patients, while other imaging modalities such as computed tomographic angiography should be the diagnostic modality of choice to exclude the diagnosis.[18,22-24] Additionally, emergency physicians should be aware that an increased RV:LV ratio is not specific for pulmonary embolus and that acute and chronic RV abnormalities may exist in patients with COPD, obstructive sleep apnea, pulmonary hypertension, and right sided myocardial infarction, among others.

Volume Assessment

Right atrial pressures, representing central venous pressure, can be estimated by viewing size and respiratory change in the diameter of the inferior vena cava (IVC).[26-28] This is done by viewing the vena cava below the diaphragm in the sagittal plane and observing the change in the IVC diameter during the respiratory cycle. During inspiration, negative intrathoracic pressure causes negative intraluminal pressure

and increases venous return to the heart. The compliance of the extrathoracic IVC causes the diameter to decrease with normal inspiration. In patients with low intravascular volume, the inspiration to expiration diameter ratios change more than in those patients who have normal or high intravascular volume and therefore a quick assessment of intravascular volume can be made. IVC evaluation can be particularly helpful in those patients with a significant respiratory collapse during inspiration, permitting prompt identification of the hypovolemic patient.[29]

Clinical Applications

Clinical Indications for Focused Cardiac Ultrasound

There are a number of common clinical scenarios where FOCUS has substantial literature support and potential to impact clinical decision making and patient care. Utilization will continue to evolve with technology and the changing needs of the patient. This consensus statement reflects current clinical practice. The following sections review the clinical conditions and applicable techniques of FOCUS.

Cardiac Trauma

FOCUS has been an integral part of the evaluation of the blunt and penetrating trauma patient for over 20 years. Extensive research and literature support has led to the incorporation of FOCUS into the American Trauma Life Support training and treatment algorithm as part of the Focused Assessment with Sonography in Trauma or FAST exam.[2,5] The FAST exam aims to identify active hemorrhage post-trauma by evaluating for the presence of fluid - around the heart, in the thoracic cavity and in the peritoneum. FOCUS is part of the FAST exam and is used to evaluate for the presence of pericardial effusion (and thus the identification of possible cardiac injury which may require immediate surgical attention). Additionally, the presence or absence of organized ventricular contractility can be assessed. Performing emergent FOCUS as part of the FAST exam has improved outcomes by decreasing the time required to diagnose and treat traumatic cardiac and thoracic injury in those patients requiring emergent thorocotomy or laparotomy.[30,31] Not only have trials shown decreased morbidity by incorporating FOCUS into trauma diagnostic evaluations, but use of FOCUS in penetrating trauma has also been shown to have a mortality benefit.[6,7,30,31] The use of FOCUS in trauma patients has since become standard of care in trauma centers.

In addition to the identification of pericardial effusions, cardiac contusions can be identified by depressed wall motion and decreased myocardial contractility. This diagnosis can be difficult, however, since the trauma patient's underlying medical condition is often not known and the evaluation of segmental wall motion abnormalities is challenging. In many cases, these patients will have follow-up comprehensive echocardiograms so that the degree of contractile dysfunction can be quantified and monitored over time.

Cardiac Arrest

The patient in cardiac arrest requires initiation of Advanced Cardiac Life Support (ACLS) treatment algorithms and rapid diagnostic evaluation for potentially treatable or reversible causes of cardiac arrest. The goal of the FOCUS in the setting of cardiac arrest is to improve the outcome of cardiopulmonary resuscitation by: 1. identifying organized cardiac contractility to help the clinician distinguish between asystole, pulseless electrical activity (PEA) and pseudo-pulseless electrical activity, 2. determining a cardiac etiology of the cardiac arrest and, 3. guiding life-saving procedures at the bedside.[10,32-35]

In a patient with no ventricular cardiac contraction and an asystolic electrocardiogram, the survival rate is low despite aggressive ACLS resuscitation. In patients presenting to the emergency department with asystolic rhythms and no ventricular contractility by FOCUS after attempts at resuscitation with pre-hospital ACLS, survival is unlikely.[34,36]

True PEA is defined as the clinical absence of ventricular contraction despite the presence of electrical activity, while pseudo-PEA is defined as the presence of ventricular contractility visualized on

cardiac ultrasound in a patient without palpable pulses.[32,34,35] Therefore, making the diagnosis of pseudo-PEA can be of diagnostic and prognostic importance. Patients with pseudo-PEA have some observable, although minimal, cardiac output and have a higher survival rate, in part because there are often identifiable and treatable causes of their arrest.[32-35,37,38] While there is ample literature to support that causes of PEA and pseudo-PEA can be identified with FOCUS (see hypotension/shock section to follow), research is now focused on patient outcomes. Identification of causes of PEA arrest by FOCUS with zero or minimal interruption in cardiopulmonary resuscitation improves outcomes by decreasing time to treatment and to return of spontaneous circulation.[32-35] FOCUS is only recommended in PEA and asystolic rhythms and should not delay life-saving treatment of ventricular arrhythmias. These patients should be stabilized and a comprehensive echocardiogram**,** looking for potential specific structural abnormalities such as hypertrophic cardiomyopathy or RV dysplasia, can be performed at a later point.[33]

Hypotension/Shock

FOCUS for the hypotensive patient is a continuum from its use in cardiac arrest. For patients presenting with undifferentiated hypotension, the primary advantage of FOCUS is in determining whether the shock is cardiogenic. Shock requires aggressive early intervention in order to prevent organ dysfunction due to inadequate tissue perfusion. Therefore, the distinction of cardiogenic shock from shock of other etiologies is extremely important. The FOCUS exam, as previously stated, should evaluate for the presence of pericardial effusion, global cardiac function, right ventricular size, and inferior vena cava size/collapsibility as a marker of central venous pressure. In the right clinical context, this evaluation can direct the clinician at the bedside in important next treatment interventions, optimize diagnostic efficiency, as well as assess the response to performed interventions.[38,39]

FOCUS can give vital information regarding the presence, size, and functional relevance of a pericardial effusion as a cause of hemodynamic instability and can expedite pericardiocentesis with fewer complications and a higher success rate.[37,41] Evaluation of right ventricular size in the peri-arrest patient may lead the clinician to consider thrombolytics if the clinical scenario and the FOCUS findings (see previous section on right ventricular enlargement) suggest massive pulmonary embolus.[18,25] It is worth reiterating that the absence of these findings cannot be used to exclude the presence of a clinically significant pulmonary embolism, although identifying an enlarged RV in an unstable patient can lead to life-saving therapy.[18] Studies have shown that global systolic function can be assessed accurately by FOCUS.[16,17] Identification of poor but detectable left ventricular systolic function indicates a need for further inotropes or mechanical support. In the peri-arrest patient, assessment of ventricular contraction by FOCUS can determine whether transcutaneous or transvenous pacing is capturing successfully.[42,43] Finally, the finding of a hyperdynamic left ventricle can prompt evaluation for hypovolemia or suggest sepsis or massive pulmonary embolus as a diagnosis in the right clinical scenario.

In those rare but catastrophic instances where pacemaker placement results in ventricular perforation, the ability to identify pericardial effusions can expedite operative repair. In the post resuscitation phase, however, patients can benefit from a comprehensive echocardiogram which can provide essential information in monitoring cardiac function and in assessing the impact of resuscitative measures on a patient's hemodynamics.

In a patient with shock, a collapsed vena cava should prompt an ultrasound evaluation of the peritoneal cavity to look for abdominal hemorrhage.[44,45]

Dyspnea/Shortness of Breath

Dyspnea is a Class I indication for comprehensive echocardiography. For patients presenting with acute dyspnea and shortness of breath, the three main goals for FOCUS in this instance are to rule out pericardial effusion, identify global left ventricular systolic dysfunction, and assess the size of the right ventricle as a proxy for indicating the presence or absence of a hemodynamically significant pulmonary embolus, all discussed above.

However, complete evaluation of dyspnea in patients requires comprehensive echocardiography to evaluate diastolic function, pulmonary artery pressures as well as to evaluate for pericardial disease and valvular heart disease.[25,46] While the presence of significantly stenotic valves or regurgitant lesions using

2D and color Doppler techniques may be suggested by a FOCUS, full evaluation requires the quantitative analysis provided by a comprehensive echocardiogram.[47,48]

Chest pain

The life-threatening chest pain syndromes where FOCUS may be helpful are in the evaluation of patients with a hemodynamically significant pulmonary embolus (discussed above) or in screening patients with suspected aortic dissection.

Whereas comprehensive echocardiography could provide information about the extent of dissection and complications, the role of FOCUS in patients with suspected aortic dissection is to look for pericardial or pleural effusions and to assess the diameter of the aortic root. An aortic root greater than 4 cm is suggestive of type A dissection and should raise the clinical suspicion for disease, although it is important to state that a negative FOCUS or even a negative comprehensive transthoracic echocardiogram does not rule out aortic dissection and further imaging and diagnostic studies should be considered for definitive diagnosis and characterization.

Chest pain is also a Class I indication for the use of comprehensive echocardiography in patients with chest pain due to suspected acute myocardial ischemia when the baseline electrocardiogram is non-diagnostic.[25,49] Given that segmental wall motion and wall thickening analysis are some of the most technically demanding aspects of echocardiographic interpretation, FOCUS should not be used primarily for this purpose. Comprehensive echocardiography interpreted by experienced readers is recommended for evaluation of segmental wall motion.

Training and Performance

Both the American Society of Echocardiography and the American College of Emergency Physicians have produced written guidelines and documents on the training of physicians and sonographers using cardiac ultrasound and echocardiography. It is recognized that the training requirements for comprehensive echocardiography are not the same as those for FOCUS, and therefore each society is responsible for maintaining the integrity of their training protocols and for ensuring the responsible practice and use of these imaging techniques.

Comprehensive echocardiography training guidelines have been described by the American Society of Echocardiography and are documented in the position paper ACC/AHA Clinical Competence Statement on Echocardiography. These training guidelines are applicable for those physicians and practitioners who perform comprehensive echocardiography.[25,48]

Emergency ultrasound training guidelines for all emergency ultrasound examinations, including the FAST and FOCUS exams, have been described by the American College of Emergency Physicians and are documented in their position paper Emergency Ultrasound Guidelines.[1-3]

For all “minimum” training numbers, it is essential that the trainee have acquired and interpreted ultrasound images that represent the full range of diagnostic possibilities for that training level. Therefore, both focused cardiac ultrasound and comprehensive echocardiography trainees are required to have a case mix of positive and negative studies that include the breadth of pathology expected to be recognized by a given level of training. In the event this is not achieved with the minimum number of cases required for training (and indeed even if it is), trainees should complement their learning by using a library of educational cardiac ultrasound cases that depict the various pathologies outlined in this document. It is also understood that the performance of FOCUS requires standards consistent with the quality assurance processes for all diagnostic imaging performed within the hospital. Any program that utilizes FOCUS to make clinical decisions must have quality assessment reviews of scan quality both internally and externally comparing interpretations to pathologic and surgical data as well as clinical outcomes and final diagnoses, preferably on an annual basis. Quality assurance for FOCUS is essential and can be performed by correlating FOCUS findings with non-ultrasound imaging results (i.e., computed tomography), comprehensive echocardiography findings, or with over-read review by qualified experts (physicians with

fellowship training or credentialing in either echocardiography or emergency ultrasound). It is strongly recommended that training occur in conjunction with a comprehensive echo lab whenever possible.

In addition, it is recognized that expertise in both FOCUS and echocardiography requires ongoing continuing education programs. Competency assessment, including ongoing performance assessment reviews and didactic educational programs, are required by both ASE and ACEP. Both organizations are committed to maintaining high standards and are responsible for ensuring maintenance of proficiency in their respective organizations.

Device Selection

The major issues that define compact ultrasound (CUS) device selection involve cost, portability, image quality, and user expertise. If users are available who can operate and interpret the advanced cardiac imaging tools, a full featured, high-end platform may be appropriate. Cart based or handheld portable devices are smaller, simpler to use and less expensive. The small size of these platforms allows their use in nearly any emergent setting and has shown potential for pre-hospital diagnostic use.[50] In the emergency department, physician use of portable machines substantially increases the detection of cardiovascular abnormalities over physical examination alone and increases diagnostic accuracy.[51-56] The need to use the same ultrasound platform to image non-cardiac structures will have the greatest influence over platform selection, as not all devices suitable for cardiac use will accommodate the transducers required for other imaging applications.

Image Archival and Report Generation for Focused Cardiac Ultrasound

Given that the increasing use of FOCUS in the emergency department is a result of its impact on patient care and clinical decision making in both treatment and follow-up diagnostic testing, image archival is essential during regular hospital operations. All hospital based ultrasound systems used for FOCUS should possess a method for recording data onto a media format that allows for offline review and archiving. The ultrasound examination should be documented within the medical record and depending on the individual hospital's documentation system can include paper records or computer generated reports. A written or electronic description of the findings should be completed before the patient leaves the emergency department unless the patient's condition requires emergent transfer to another department, at which time verbal reporting of the findings is acceptable, followed by the written or electronic report at a later time. Official reports should be consistent with the real-time interpretation provided or a notification of substantive changes should be forwarded to medical records, as well as the patient or the patient's physicians as appropriate.

Reports should include:

1. Date and time of study
2. Name and hospital ID number of patient
3. Patient age (date of birth) and gender
4. Indication for study
5. Name of the person who performed the study
6. Findings
7. Limitations and recommendations for additional studies
8. Impression
9. Name of the person who interpreted the study
10. Date and time the report was signed
11. Mode of archiving the data.

Integration and Evolution in Focused Cardiac Ultrasound

The use of FOCUS requires knowledge of the strengths and limitations of this imaging modality. There are limitations of the FOCUS exam secondary to both the nature of the exam and the training of the individual interpreting the study. Evaluation of valvular heart disease, diastolic function and segmental wall motion analysis are examples of cardiac abnormalities that should eventually be assessed by

comprehensive echocardiography. Abnormal findings on FOCUS should be referred for comprehensive echocardiography, other testing, or consultation when the situation allows for this to be done safely. However, FOCUS can identify pathologic processes which can guide resuscitative interventions and be life-saving. In the end, patient care will be assisted by cooperation between these two professional groups who are both dedicated to the rapid and accurate diagnosis and treatment of patients utilizing this valuable technology.

NOTICE AND DISCLAIMER: This report is made available by ASE as a courtesy reference source for its members. This report contains recommendations only and should not be used as the sole basis to make medical practice decisions or for disciplinary action against any employee. The statements and recommendations contained in this report are primarily based on the opinions of experts, rather than on scientifically-verified data. ASE makes no express or implied warranties regarding the completeness or accuracy of the information in this report, including the warranty of merchantability or fitness for a particular purpose. In no event shall ASE be liable to you, your patients, or any other third parties for any decision made or action taken by you or such other parties in reliance on this information. Nor does your use of this information constitute the offering of medical advice by ASE or create any physician-patient relationship between ASE and your patients or anyone else.

References

1. American College of Emergency Physicians. Use of Ultrasound Imaging by Emergency Physicians. Policy statement. http://www.acep.org
2. American College of Emergency Physicians. Emergency Ultrasound Guidelines 2008. Policy statement. http://www.acep.org
3. American College of Emergency Physicians. Emergency Ultrasound Imaging Compendium. 2006. Policy statement. http://www.acep.org
4. Society for Academic Emergency Medicine. Ultrasound Position Statement. http://www.saem.org.
5. American College of Surgeons (ACS). Advanced Trauma Life Support for Physicians. Chicago: ACS; 1997.
6. Rozycki GS, Feliciano DV, Ochsner MG, et al. The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multi-center study. *J Trauma.* 1999; 46:543-51.
7. Rozycki GS, Ballard RB, Feliciano DV, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg*. 1998;39:492-8.
8. Mandavia DP, Hoffner RJ, Mahaney K, et al. Bedside echocardiography by emergency physicians. *Ann Emerg Med*. Oct 2001;38:377-382.
9. Jones AE, Tayal VS, Kline JA. Focused training of emergency medicine residents in goal-directed echocardiography: a prospective study. *Acad Emerg Med*. 2003;10:1054-1058.
10. Mayron R, Gaudio FE, Plummer D, et al. Echocardiography performed by emergency physicians: impact on diagnosis and therapy. *Ann Emerg Med.* 1988;17:150-4.
11. Picard MH, Sanifilippo AJ, Newell JB, et al: Quantitative relation between increased intrapercicardial pressure and Doppler flow velocities during experimental cardiac tamponade. *J Am Coll Cardiol.* 18:234-242, 1991.
12. Seferović PM, Ristić AD, Imazio M, et al. Management strategies in pericardial emergencies. *Herz.* 2006; 891-900.
13. Tsung T, Enriquez-Sarano M, Freeman WK, et al. Consecutive 1127 therapeutic echocardiographically guided pericardiocenteses: clinical profile, practice patterns, and outcomes spanning 21 years. *Mayo Clin Proc*. 2002;77:429-36.
14. Callahan JA, Seward JB, Nishimura RA, et al. Two-dimensional echocardiographically guided pericardiocentesis: experience in 117 consecutive patients. *Am J Cardiol*. 1985; 55:476-9.
15. Silvestry FE, Kerber RE, Brook MM, et al. Echocardiography-Guided Interventions. *J Am Soc Echocardiog*. 2009;22: 213-31.

16. Moore CL, Rose GA, Tayal VS, et al. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. *Acad Emerg Med*. 2002;9:186-93.
17. Sabia P, Abbott RD, Afrookteh A, et al. Importance of two-dimensional echocardiographic assessment of left ventricular systolic function in patients presenting to the emergency room with cardiac-related symptoms. *Circulation.* 1991;84:1615-24.
18. Goldhaber S. Pulmonary embolism thrombolysis: broadening the paradigm for its administration. *Circulation.* 1997;96:716-8.
19. Ten Wolde M, Söhne M, Quak E, et al. Prognostic value of echocardiographically assessed right ventricular dysfunction in patients with pulmonary embolism. *Arch Int Med.* 2004;164:1685-1689
20. Ribiero A, Lindmarker P, Juhlin-Dannfelt A, et al. Echocardiography Doppler in pulmonary embolism: right ventricular dysfunction as a predictor of mortality rate. *Am Heart J*. 1997;134:479-87.
21. Bova C, Greco F, Misuraca G, et al. Diagnostic utility of echocardiography in patients with suspected pulmonary embolism. *Am J Emerg Med.* 2003;21:180-183
22. Kasper W, Konstantinides S, Geibel A, et al. Management strategies and determinants of outcome in acute major pulmonary embolism: results of a multicenter registry. *J Am Coll Cardiol*. 1997;30:1165–71.
23. Miniati M, Monti S, Pratali L, et al. Diagnosis of pulmonary embolism: results of a prospective study in unselected patients. *Am J Med.* 2001;110:528-535
24. Mansencal N, Vieillard-Baron A, Beauchet A, et al. Triage patients with suspected pulmonary embolism in the emergency department using a portable ultrasound device. *Echocardiogr*. 2008;25:451-456.
25. Douglas PS, Khandheria B, Stainback RF, et al. 2007 appropriateness criteria for transthoracic and transesophageal echocardiography: a report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group. *J Am Soc Echocardiogr*. 2007;20:787-805.
26. Brennan JM, Ronan A, Goonewardena S, et al. Handcarried ultrasound measurement of the inferior vena cava for assessment of intravascular volume status in the outpatient hemodialysis clinic. *Clin J Am Soc Nephrol.* 2006;1:749-753.
27. Kircher BJ, Himelman RB, Schiller NB. Noninvasive estimation of right atrial pressure from the inspiratory collapse of the inferior vena cava. *Am J Cardiol*. 2005;66:493-496.
28. Natori H, Tamaki S, Kira S. Ultrasonographic evaluation of ventilatory effect on inferior vena caval configuration. *Am Rev Respir Dis*. 1979;120:421-5.
29. Brennan JM, Blair JE, Goonewardena A, et al. Reappraisal of the use of inferior vena cava for estimating right atrial pressure. *J Am Soc Echocardiogr.* 2007;20:857-61.
30. Plummer D, Brunette D, Asinger R, et al. Emergency department echocardiography improves outcomes in penetrating cardiac injury. *Ann Emerg Med*. 1992;21:709-12.
31. Symbas NP, Bongiorno PF, Symbas PN. Blunt cardiac rupture: the utility of emergency department ultrasound. *Ann Thorac Surg*. 1999;67:1274-1276.
32. Breitkreutz R, Walcher F, Seeger FH. Focused echocardiographic evaluation in resuscitation management: Concept of an advanced life support-conformed algorithm. *Crit Care Med.* 2007;15(Suppl 5): S150-S161.
33. Soar J, Deakin CD, Nolan JP, et al. European Resuscitation Council guidelines for resuscitation 2005:section 7. Cardiac arrest in special circumstances. *Resuscitation.* 2005;67(Suppl 1):S135-S170.
34. Salen P, Melniker L, Chooljian C, et al. Does the presence or absence of sonographically identified cardiac activity predict resuscitation outcomes of cardiac arrest patients? *Am J Emerg Med*. 2005; 23:459-62.
35. Bocka JJ, Overton DT, Hauser A. Electromechanical dissociation in human beings: an echocardiographic evaluation. *Ann Emerg Med.* 1988;17:450-452.
36. Blaivas M, Fox J. Outcomes in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. *Acad Emerg Med*. 2001;8:616-21.

37. Tayal VS, Kline JA. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. *Resuscitation* 2003;59:315-318.
38. Toosi MS, Merlino JD, Leeper KV. Prognostic value of the shock index along with transthoracic echocardiography in risk stratification of patients with acute pulmonary embolism. *Am J Cardiol.* 2008;101:700-705
39. Rose JS, Bair AE, Mandavia D, et al. The UHP protocol: a novel ultrasound approach to the empiric evaluation of the undifferentiated hypotensive patient. *Am J Emerg Med*. 2001;19:299-302.
40. Jones AE, Tayal VS, Sullivan DM, et al. Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. *Crit Care Med.* 2004;32:1703-8.
41. Mazurek B, Jehle D, Martin M. Emergency department echocardiography in the diagnosis and therapy of cardiac tamponade. *J Emerg Med.* 1991; 9:27-31.
42. Ettin D, Cook T. Using ultrasound to determine external pacer capture. *J Emerg Med*. 1999; 17:1007-9.
43. Macedo W, Sturman K, Kim LM, et al. Ultrasonographic guidance of transvenous pacemaker insertion in the emergency department: a report of three cases. *J Emerg Med*. 1999; 17:491-6.
44. Lyon M, Blaivas M, Brannam L. Sonographic measurement of the inferior vena cava as a marker of blood loss. *Am J Emerg Med*. 2005; 23:35-50.
45. Moore C, Todd WM, O'Brien E, et al. Free fluid in Morison's Pouch on bedside ultrasound predicts need for operative intervention in suspected ectopic pregnancy. *Acad Emerg Med*. 2007; 14:755-8.
46. Nienaber CA, von Kodolitsch Y, Nicolas V, et al. The diagnosis of thoracic aortic dissection by noninvasive imaging procedures. *N Engl J Med.* 1993; 328:1-9
47. Zoghbi WA, Enriquez-Sarano M, Foster E, et al: Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. *J Am Soc Echocardiogr*. 2003;16:777-802.
48. Baumgartner H, Hung J, Bermego J, et al: Echocardiographic assessment of valve stenosis: EAE/ASE Recommendations for Clinical Practice. *J Am Soc Echocardiogr*. 2009;22:1-23.
49. Cheitlin MD, Alpert JS, Armstrong WF, et al. ACC/AHA guidelines for the clinical application of echocardiography: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on clinical Application of Echocardiography). *Circulation.* 1997; 95:1686-1744
50. Lapostolle F, Petrovic T, Lenoir G, et al. Usefulness of hand-held ultrasound devices in out of hospital diagnosis performed by emergency physicians. *Am J Emerg Med*. 2006; 24:237-42.
51. Liu SC, Chang WT, Huang CH, et al. The value of portable ultrasound for evaluation of cardiomegaly patients presenting at the emergency department. *Resuscitation.* 2005; 64:327-331.
52. Weston P, Alexander JH, Patel MR, et al. Hand-held echocardiographic examination of patients with symptoms of acute coronary syndromes in the emergency department: the 30-day outcome associated with normal left ventricular wall motion. *Am Heart J*. 2004;148:1096-1101.
53. Kobal SL, Tolstrup K, Luo H, et al. Usefulness of a hand-carried cardiac ultrasound device to detect clinically significant valvular regurgitation in hospitalized patients. *Am J Cardiol.* 2004;93:1069-1072.
54. Scholten C, Rosenhek R, Binder T, et al. Hand-held miniaturized cardiac ultrasound instruments for rapid and effective bedside diagnosis and patient screening. *J Eval Clin Prac*. 2005;11:67-72.
55. Senior R, Galasko G, Hickman M, et al. Community screening for left ventricular hypertrophy in patients with hypertension using hand-held echocardiography. *J Am Soc Echocardiogr.* 2004;17:56-61.
56. Vourvouri EC, Schinkel AF, Roelandt JR, et al. Screening for left ventricular dysfunction using a hand-carried cardiac ultrasound device. *Eur J Heart Fail.* 2003;5:767-774.