Transesophageal Echocardiography: Guidelines for Point-of-Care Applications in Cardiac Arrest Resuscitation

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Cardiac arrest is one of the most challenging patient presentations managed by emergency care providers, and echocardiography can be instrumental in the diagnosis, prognosis, and treatment guidance in these critically ill patients. Transesophageal echocardiography has many advantages over transthoracic echocardiography in a cardiac arrest resuscitation. As transesophageal echocardiography is implemented more widely at the point of care during cardiac arrest resuscitations, guidelines are needed to assist emergency providers in acquiring the equipment and skills necessary to successfully incorporate it into the management of cardiac arrest victims. [Ann Emerg Med. 2017;■:1-7.]

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BACKGROUND: TRANSESOPHAGEAL ECHOCARDIOGRAPHY IN EMERGENCY POINT-OF-CARE APPLICATIONS

Cardiac arrest is one of the most challenging patient presentations managed by emergency care providers. Stress, high stakes, and diagnostic uncertainty lead to challenging management decisions often guided by pulse palpation, auscultation, and guesswork. For these reasons, emergency care providers have increasingly used transthoracic echocardiography tool management of cardiac arrest patients. Although advanced cardiac life support (ACLS) and European Resuscitation Council guidelines have recently endorsed echocardiography in arrest, cardiology and anesthesiology professional societies have endorsed echocardiography since the mid-1990's.[1-4] To date, there has been no official endorsement of the use of transesophageal echocardiography by emergency care providers in cardiac arrest patients.

During the last 20 years, emergency physicians have used transthoracic echocardiography for both diagnosis and prognosis in patients with cardiac arrest.[5-9] However, transthoracic echocardiography has a number of disadvantages. Time spent imaging the heart is time without lifesaving compressions. Transthoracic echocardiography provides inadequate images in up to half of critically ill patients and is even more challenging in patients receiving chest compressions.[10,11] Conversely, transesophageal echocardiography has been shown to provide adequate images in nearly all patients, adding important management-changing information compared with transthoracic echocardiography.[11]

The earliest description of transesophageal echocardiography dates back to 1976, but it was not until 1980 that this tool was used for hemodynamic monitoring in the intraoperative setting.[12-15] In the following decades, its use during cardiac arrest was further explored largely by cardiologists and anesthesiologists.[14,15] Since 2008, 4 studies describing transesophageal echocardiography use during cardiac arrest by emergency medicine providers have demonstrated its feasibility and advantages in this environment.[16-19]

MACHINE ACQUISITION, MAINTENANCE, AND CLEANING

Because transesophageal echocardiography transducers require a significant initial investment, it is important for emergency physicians to understand the procurement and maintenance processes for the equipment. Similar to the purchasing process for other ultrasonographic equipment, vendor selection is best accomplished by a multidisciplinary team that includes the ultrasonographic director, equipment managers, biomedical engineering, administrators, and other transesophageal echocardiography stakeholders in the hospital such as cardiology and anesthesiology. The purchasing process should include obtaining bids from multiple manufacturers and organizing a clinical evaluation process. It is imperative to ensure transesophageal echocardiography transducer

compatibility with the existing or prospective emergency department's (ED's) point-of-care ultrasonographic equipment. Other criteria for equipment selection should include the cost and expected life span of the transducer, preventive maintenance costs, quality of the warranty, reputation of the vendor, and information technology systems integration.[20]

Preventive maintenance is essential in establishing a point-of-care transesophageal echocardiography program because the transducers are delicate and more easily damaged than other ultrasonographic transducers. Service agreements for transesophageal echocardiography probes from vendors should be considered and may be cost-effective for hospitals with biomedical engineering departments that do not have the resources or expertise to perform planned or urgent maintenance. There is a high probability a probe will require repair within the first 5 years of purchase, and a service agreement will minimize expenses associated with probe replacement. Qualified biomedical personnel should perform inspections of the transducers regularly according to the manufacturer's specifications. When not in use, transesophageal echocardiography transducers should be stored at room temperature in protective cases or dedicated cabinets to prevent damage.[20]

Transesophageal echocardiography transducers come in contact with mucous membranes; thus, high-level disinfection is required between patients. The process for cleaning and disinfection of transesophageal echocardiography probes is similar to that for endoscopy equipment, and should be available within a hospital system.[21] Immediately after performance of the study, the probe should be cleaned with soap and water to remove visible material before disinfection. High-level disinfection is then performed in a disinfectant solution (eg, glutaraldehyde) for a specific period according to the manufacturer's guidelines. The transducer should be subsequently rinsed with sterile or filtered water to remove residual chemicals and wiped dry with a soft towel. Use of cleaning solutions or lubricants not recommended by the manufacturer may damage probes and void the warranty. Proper documentation of cleaning is required to ensure adherence to infection control standards and should follow hospital policy for high-level disinfection.

DIRECTED IMAGING PROTOCOL FOR TRANSESOPHAGEAL ECHOCARDIOGRAPHY

An essential tenet of point-of-care ultrasonography is the ability to scale the complexity of the ultrasonographic examination to the clinical scenario and indications.[22] Although a comprehensive transesophageal echocardiography examination may consist of 28 views, in cardiac arrest a less complex, goal-directed protocol is essential to the integration of transesophageal echocardiography into this resuscitative scenario.

Our recommended imaging sequence is designed for efficiency and should be considered the minimum standard of care for transesophageal echocardiography in ED cardiac arrest patients. We have developed a 3-view protocol that was based on the following values:

1. Preservation of the endorsed scope of ED echocardiography
2. Views that are anatomically familiar and relatable to commonly used transthoracic echocardiography views
3. The need for efficiency
4. The need for redundancy to corroborate important findings across multiple planes of interrogation

The protocol includes the following views (Table and Video E1 [available online at http://www.annemergmed.com]): midesophageal 4-chamber view (Figure 1), midesophageal long-axis view (Figure 2), and transgastric short-axis view (Figure 3).

In a recent report articulating the application of transesophageal echocardiography in critically ill patients presenting to the ED, the majority of patients received 3 views (midesophageal 4-chamber, midesophageal long-axis, and transgastric short-axis views) to impart a diagnostic and

Table. Goals of ED echocardiography and the corresponding transesophageal echocardiography views and findings.

Goal	Transesophageal Echocardiography View	Findings
Identification of organized cardiac activity	Midesophageal 4 chamber, midesophageal long axis, transgastric short axis	Organized cardiac contractility versus cardiac standstill
Gross assessment of left-sided systolic function	Midesophageal 4 chamber, transgastric short axis, midesophageal long axis	Evaluation of myocardial thickening, endocardial excursion, and mitral valve movement
Assessment for right ventricular enlargement	Midesophageal 4 chamber, transgastric short axis	Increased RV:LV ratio, septal flattening
Intravascular volume status	Midesophageal 4 chamber, transgastric short axis, midesophageal long axis	Underfilled ventricles
Identification of pericardial effusion	Midesophageal 4 chamber, transgastric short axis	Presence of pericardial fluid

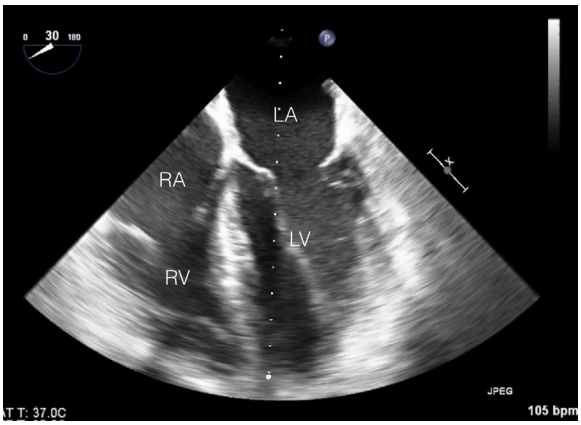

Figure 1. Midesophageal 4-chamber view. *LA*, Left atrium; *RA*, right atrium; *LV*, left ventricle; RV, right ventricle.

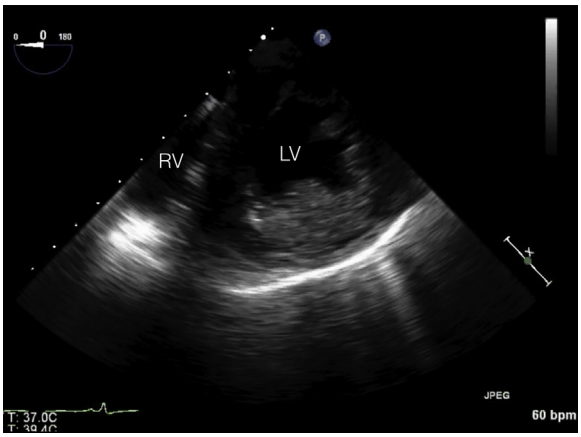

Figure 3. Transgastric short-axis view.

therapeutic influence,[18] supporting the premise of an examination consisting of a small number of views. In the setting of cardiac arrest, it may be that as few as 1 or 2 views will suffice to rapidly evaluate for reversible causes of arrest while also guiding cardiopulmonary resuscitation (CPR) efforts and prognosis.[18]

INDICATIONS, FINDINGS, AND UTILITY OF TRANSESOPHAGEAL ECHOCARDIOGRAPHY IN CARDIAC ARREST

For cardiac arrest patients, cardiac ultrasonography can provide potentially lifesaving information, but transthoracic echocardiography has a number of disadvantages. It may be limited by difficult image acquisition caused by air in the stomach, body habitus, and obstacles on the chest such as defibrillation pads, as well as CPR. Transthoracic echocardiography also risks interrupting chest compressions for longer than the 10 seconds recommended in the ACLS guidelines, and this risk is supported by recent literature showing delays in compressions with the use of

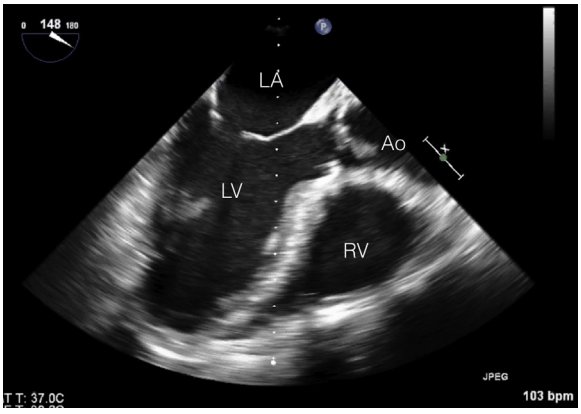

Figure 2. Midesophageal long-axis view. *Ao*, Aorta.

transthoracic echocardiography.[23] Transesophageal echocardiography provides a logical solution to these limitations, given its ability for continuous image acquisition both during compressions and during pulse checks, its reliably excellent image quality, and its lack of interference with chest compressions or other procedures needed during cardiac arrest.[16,18] The primary benefits of transesophageal echocardiography during cardiac arrest include the ability to determine the presence or absence of cardiac contractility, the diagnosis of reversible causes of arrest, the ability to monitor chest compressions, and the ability to monitor response to interventions.[16]

The American Heart Association's guidelines for treating cardiac arrest rely on information from the pulse check and rhythm analysis to guide treatment, both of which have been shown to be error prone. In some studies, the accuracy of the pulse check has been as low as 15% when limited to the 10 seconds permitted for a pulse check.[24,25] Multiple studies have shown discrepancy when comparing the rhythm observed by ECG with that observed by echocardiography, with one study finding that 35% of patients thought to be in asystole had coordinated cardiac contractility.[6-8,24] Transesophageal echocardiography can correct these errors by directly visualizing the presence or absence of cardiac contractility, which also provides valuable prognostic information, with cardiac motion visualized on ultrasonography being the best predictor of survival.[9,26]

The identification and treatment of reversible causes of arrest is a major goal of cardiac arrest resuscitation. Transesophageal echocardiography can be a helpful adjunct in diagnosing myocardial infarction, pulmonary embolism, pericardial tamponade, and hypovolemia as causes of arrest. Anesthesia literature has found transesophageal echocardiography to reliably identify the cause of arrest as much as 86% of the time.[27,28] The potential advantages of

being able to confidently guide treatment decisions such as thrombolysis, vasopressors, intravenous fluid or blood administration, or pericardiocentesis present an exciting area for further outcomes research. Providers can also obtain instant feedback to the response of any intervention, such as immediate visualization of the resumption of coordinated contractility after defibrillation, or improvement in contractility after administering epinephrine.

Another potential benefit to transesophageal echocardiography is immediate assessment of the quality of chest compressions. The 2015 ACLS guidelines recommend a specific compression depth of 5 to 6 cm during CPR.[3] Depth of compressions can be difficult to clinically evaluate during CPR; however, transesophageal echocardiography can be used to monitor compression depth by monitoring the excursion of the sternum during chest compressions.[16] This measurement can provide feedback to providers about the quality of the CPR.

FUTURE DIRECTIONS FOR TRANSESOPHAGEAL ECHOCARDIOGRAPHY USE BY EMERGENCY PROVIDERS

Although this article is focused on the limited indication of transesophageal echocardiography in cardiac arrest, there may be additional uses of it for which an emergency provider could potentially gain training and achieve competency through expanded protocols similar to those mentioned by the American Society of Echocardiography and critical care organizations. These additional indications could include the following:

Shock

Transthoracic echocardiography has been shown to be a valuable tool for the resuscitation of critically ill patients in the ED; however, not all patients have adequate transthoracic echocardiography views that will lead to a definitive diagnosis.[29-31] In these cases, transesophageal echocardiography would be an alternative to determine the cause of the shock, assess fluid responsiveness, and continuously monitor patients during resuscitation.[32]

Atrial Fibrillation

Symptomatic atrial fibrillation is a common presentation to the ED. When patients have been in atrial fibrillation for longer than 48 hours or when its duration is unclear, admission to the hospital is often required to evaluate for the presence of thrombus by transesophageal echocardiography.[33] ED-based transesophageal echocardiography interrogation of the left atrial appendage, followed by cardioversion if no thrombus is present, may be an alternative approach to inpatient admission.

Procedural Guidance

Transesophageal echocardiography can be a helpful adjunct in extracorporeal membrane oxygenation, which requires the appropriate placement of large arterial and venous cannulae within the inferior vena cava, the superior vena cava, and aorta.[19,34] Transesophageal echocardiography can also help with the proper placement of intra-aortic balloon pumps, transvenous pacemakers, and, potentially, with newer resuscitative intravascular devices such as resuscitative endovascular balloon occlusion of the aorta.[35]

TRAINING AND CREDENTIALING FOR POINT-OF-CARE TRANSESOPHAGEAL ECHOCARDIOGRAPHY

Since 2001, clear and succinct ultrasonographic credentialing recommendations in emergency medicine have been specifically established by the American College of Emergency Physicians' ultrasonographic guidelines and recommend a benchmark minimum of 25 to 50 quality-reviewed scans per modality to demonstrate technical and interpretive ability.[36] Conversely, for ultrasonographically guided procedures, 10 quality-reviewed procedures with ultrasonographic guidance are recommended. Along the same lines, the guidelines recommend a similar pathway for "different techniques" (such as performing transvaginal ultrasonography once competency with transabdominal ultrasonography has been achieved). Just as with procedures, if a different technique is performed for image acquisition, 10 quality-reviewed examinations using that technique are required to establish competency.

Transesophageal echocardiography credentialing is unique in this regard, such that image interpretation will have already been achieved through credentialing in transthoracic echocardiography. In this respect, transesophageal echocardiography credentialing is more a question of technical ability and image acquisition. Moreover, the data that a minimum number of scans is sufficient for competency assessment are poor.[37] Standardized assessments may be more important compared with documented number of scans.[38] Standardized direct observational tools are protocolized methods of evaluating competency and are used in medical education (Figure 4). Transesophageal echocardiography is highly dependent on hand-eye coordination and reliant on image acquisition, making proctoring and standardized direct observational tools

Procedure Competency Form:
Transesophageal Echocardiography

Resident:
Faculty Observing:
Date:

- ❑ Enters patient identifying information into ultrasound machine
- ❑ Chooses appropriate ultrasound transducer
- ❑ Places bite block
- ❑ Applies gel to probe
- ❑ Inserts probe with correct orientation
- ❑ Obtains mid-esophageal 4-chamber view with appropriate depth and gain and identifies all 4 chambers correctly
- ❑ Obtains mid-esophageal long-axis view and with appropriate depth and gain and identifies left atrium, mitral valve, left ventricle, and aortic valve
- ❑ Obtains trans-gastric short-axis view with appropriate depth and gain and identifies left ventricle, right ventricle, and interventricular septum
- ❑ Removes probe and sends for cleaning
- ❑ Procedure note written correctly

Assessment:

- ❑ Unsatisfactory
- ❑ Proficient
- ❑ Mastered

Comments:

Faculty Signature:

Figure 4. Standardized direct observational tool example.

ideal for this modality. For this reason, providers seeking credentialing in transesophageal echocardiography of cardiac arrest and periarrest applications should have completed training and met competency standards in transthoracic echocardiography and should complete a minimum of 2 to 4 hours of continuing medical education, perform a minimum of 10 proctored transesophageal echocardiography examinations (including probe insertion) on live patients and simulation models, and complete a standardized assessment by a credentialed transesophageal echocardiography provider. These standards are compatible with the American College of Emergency Physicians' ultrasonographic guidelines for the performance of new procedures, and we have added the additional criterion of a standardized assessment by a credentialed provider.

These minimum standards are lower than those of other organizations because of our limited indication and scope of cardiac arrest patients. For example, the critical care echocardiography training guidelines have adopted 35 scans as the benchmark for critical care physicians performing transesophageal echocardiography with the indication of hemodynamic assessment in patients receiving ventilation.[39,40] The National Board of Echocardiography requires a total of 150 examinations for their limited 14-view transesophageal echocardiography examination for perioperative echocardiography, which, although not specifically designed for critical care, is the closest certification they offer.[41] However, there is evidence from critical care literature that performing as few as 10 examinations is adequate to establish competency for a limited examination.[42] We also recommended a 3-view assessment, below the recommendations of the National Board of Echocardiography and advanced critical care echocardiography.

There is clearly a delicate balance between establishing benchmarks to ensure safe transesophageal echocardiography evaluation and yet not developing insurmountable roadblocks to learning potentially lifesaving diagnostic techniques. Our goal with these criteria is to ensure proficient providers through a multimodal system of competency-based assessment.

CONCLUSION

Cardiac arrest is an extremely difficult clinical scenario in which point-of-care echocardiography can influence important changes in management. Transesophageal echocardiography has advantages over transthoracic echocardiography in this setting, and as transesophageal echocardiography is implemented more widely in cardiac arrest resuscitations, these guidelines should assist emergency providers in acquiring the equipment and skills necessary to successfully incorporate transesophageal echocardiography into the management of cardiac arrest patients.

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