

CONCEPTS

Imaging

Transesophageal echocardiography in the emergency department: A comprehensive guide for acquisition, implementation, and quality assurance

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Funding and support: By *JACEP Open* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see <https://www.icmje.org>). The authors have stated that no such relationships exist.

Abstract

Echocardiography is an essential tool in emergency medicine, yielding valuable information for physicians that directly affects diagnostic and management strategies. Emergency department (ED) transesophageal echocardiography (TEE) is an increasingly common procedure performed in a variety of institutions, allowing for ongoing cardiac imaging during cardiopulmonary resuscitation as well as providing high-resolution assessment of both cardiac and aortic anatomy. However, despite the numerous benefits of ED TEE, the process of implementing this modality within a department is difficult because of unique process and cost considerations. This paper serves to provide an updated and in-depth description of these processes to assist with the initiation of such a program, including a detailed discussion of budgetary considerations, physician credentialing, and device use and maintenance protocols.

KEYWORDS

credentialing, emergency medicine, quality assurance, resuscitation, transesophageal echocardiography, transthoracic echocardiography, ultrasound

1 | BACKGROUND

Echocardiography is an essential diagnostic and management tool in emergency medicine for critically ill patients.¹⁻³ Rapid bedside transesophageal echocardiography (TEE) can provide invaluable information to the physician during an acute emergency.¹⁻⁵ TEE allows for superior imaging of both cardiac and aortic anatomy.^{6,7} Additionally, TEE has numerous indications including cardiac arrest, resuscitation, and procedural guidance that prove useful in the care of emergency department patients.⁸

TEE has been used in the operative setting since 1976.⁹ However, implementation in the emergency department (ED) occurred much later. In 2008, a landmark case series in the journal *Resuscitation*

described the benefits of TEE during cardiac arrest and jumpstarted TEE use in the ED.¹⁰ Since then, several protocols regarding the application of TEE in the ED have been published and multiple training programs designed to educate and credential emergency physicians have been developed.^{6,11} Despite the numerous benefits of TEE in caring for critical ED patients, there are aspects of developing a TEE program that need consideration and planning before integration of TEE into the clinical setting. These intricacies include budgetary considerations, maintenance and usage protocols, physician credentialing, and information technology (IT) workflow solutions. As the acquisition, maintenance, and implementation of TEE into an ED is complex with unique challenges compared to other traditional point-of-care (POC) ultrasound applications, sustainability of this effort necessitates an in-depth knowledge of these components. This manuscript serves

Supervising Editor: Faheem Guirgis, MD

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as a guide to outline the pragmatic considerations that are required to develop and sustain a successful TEE program.

2 | OBJECTIVES

Previous publications have offered general guidelines regarding the implementation of an ED TEE program. The aim of this article is to provide an updated and in-depth description of this process in order to assist other departments with initiating such a curriculum, a process that is best accomplished with interdisciplinary collaboration.⁶ The purpose of this paper is to provide a stepwise roadmap to aid clinicians in establishing an ED-based TEE program based on the existing evidence and experience of the authors in initiating a TEE program at a large academic hospital in Michigan.

2.1 | Implementation checklist

Multiple factors related to both budget and infrastructure must be considered during the initial planning phase when implementing an ED TEE program (See Table 1 for Implementation Checklist). Likely the most important initial logistical consideration is interdepartmental coordination. Early involvement and possibly collaboration with other departments experienced in TEE within an institution, such as anesthesiology and cardiology, will help ensure compliance with all institutional guidelines. Further, these departments may be able to assist with other processes, such as probe disinfection and maintenance. Finally, early coordination with the IT department will ensure that all purchases and technologies are compatible with existing equipment and help avoid unnecessary delays and costs due to incompatible equipment. Once an intradepartmental collaborative team has been established, a project budget that encompasses several key components must be developed. Although some of these costs may overlap with the existing infrastructure of a POC ultrasound program, such as IT workflow, there are several new costs as well. These include TEE transducer equipment, transducer repair/replacement warranties, storage and transport equipment, and high-level disinfection. See summary of anticipated costs outlined in Table 2. Finally, a program for ongoing faculty credentialing and quality assurance (QA) must be established. All of these elements must be discussed to determine the overall feasibility of an ED TEE program at any institution and will help maximize the likelihood of operationalizing a sustainable and successful program. In each of the subsequent sections there is a more detailed discussion of key steps and considerations in implementing an ED TEE program.

2.2 | TEE transducer acquisition

As of early 2022, there are a variety of TEE transducers on the market sold by many of the industry leaders. Pricing ranges from \$30,000 for some pediatric probes up to \$60,000 for adult TEE probes.^{12,13}

TABLE 1 TEE implementation checklist

Departmental considerations	
1	Determine feasibility Gather support of key emergency department and organizational stakeholders to determine feasibility of initiating and sustaining a TEE program.
2	Interdepartmental coordination Ensure anesthesiology, cardiology, biomedical, and IT support.
3	Physician credentialing Determine a plan for physician credentialing that includes both didactic and hands-on components.
4	Quality assurance Incorporate consistent review of TEE examinations using existing QA system or develop a QA program leveraging expertise from other departments.
Budgetary considerations	
5	Probe expenses Transducer acquisition, device storage and transportation.
6	Equipment maintenance and warranties Maintenance and warranty policies as well as replacement parts.
7	High-level disinfection Equipment, cleaning solution, personnel.
8	Image processing Ensure TEE image capture, storage, documentation, and transfer for QA review. This component can be readily added to existing infrastructure of a point-of-care ultrasound exam.
9	TEE course or simulator Provide opportunities for users to attend TEE courses and consider renting or purchasing a high-fidelity simulator.

Abbreviations: IT, information technology; QA, quality assurance; TEE, transesophageal echocardiography.

TABLE 2 Transesophageal echocardiography budgetary outline

Projected purchases	Anticipated costs
Probe acquisition	\$35,000–\$60,000
TEE transportation tray	
Reusable	\$1000
Disposable	\$10
TEE storage cabinet	\$3000–\$4000
High-level disinfection equipment	\$25,000–\$35,000
Product warranty	\$3000–\$5000/year
Physician credentialing	
Courses	\$1000–\$2000
High-fidelity simulator rental	\$2500/day
High-fidelity simulator purchase	\$65,000–\$70,000

Note: All monetary values in US dollars. Abbreviation: TEE: transesophageal echocardiography.

Consideration of which brand and model to purchase should occur among a multidisciplinary team consisting of the hospital ultrasound director, ED administration, biomedical engineering, IT, the purchasing department, as well as leaders in the cardiology and anesthesia departments.^{6,13,14}

Securing adequate funding for an ED-specific TEE will be a crucial step in the process, with the most common method being through the hospital's capital funding. Consider timing of the funding request; although discretionary capital is available as soon as the beginning of the year, organizations typically moderate spending early to account for unanticipated needs, which can leave additional monies available in the last quarter.

2.3 | Storage, maintenance, and warranties

Given that TEE probes are more delicate and susceptible to damage than other ultrasound transducers, discussions with vendors regarding their equipment warranties, repair policies, preventative maintenance, and probe life expectancy are highly recommended.^{13,14} Manufacturer policies will typically cost \$3000–\$10,000 per year and include unlimited replacements if a product failure or malfunction related to normal wear occurs. They may also periodically replace probes damaged due to accidents (eg, up to one replacement probe per year), oftentimes providing a loaner probe for use in the interim. The probe manufacturer will have standard operating procedures for proper storage and transportation of the TEE transducer. Depending on the hospital's current infrastructure, a storage cabinet and transportation case or cart designed specifically for endoscopic probes may need to be purchased and fit into the budget.

2.4 | Disinfection process

Because of the invasive nature of TEE examinations, the probe must undergo proper high-level disinfection after each use.^{13,14} Sterilization protocols and instructions for proper equipment maintenance and storage are required to ensure the longevity and safety of the transducer as damage can negatively affect the clarity and utility of images.^{13–16} Discussion should involve the hospital's infection control department to ensure all possible preventative infectious disease measures are taking place. If there are problems with any of these components, the user should forgo the attempted exam and contact their vendor or biomedical engineering.

Probe-specific disinfection procedures will be in the transducer operator's manual. Instructions will include how to perform electrical leakage testing as well as the length of time required to soak the probe in disinfectant. If you are considering handling probe sterilization in your department, there are Food and Drug Administration 510(k) approved disinfecting devices that can be purchased to aid in this process. Properly following these checklists will ensure that probes are inspected, tested, and cleaned consistently and adequately. Disinfection protocols generally include safety testing, such as electrical

leakage testing, which many probe manufacturers recommend before every clinical use.¹³ It is important to coordinate within the department who will be responsible for disinfecting and safety testing to ensure a system exists for tracking this patient information. If there is physical damage to the probe, patient bodily contents and sterilizing fluid can leak into the control housing and distal tip, increasing the likelihood of contamination, damage to the equipment, and ultimately harmful exposure for the patient.^{13,15–17} Because of this risk, it is also necessary to keep a log of patients on whom each probe was used in the event of a malfunction.

If the hospital's preexisting TEE cleaning equipment will be used, it is important to purchase a probe that is compatible with this equipment. This also means that sterilization will typically occur outside of the ED. If this is the case, a protocol (eg, checking the transducer in and out) should be developed to always track the probe's location. Therefore, coordination with cardiac anesthesia, biomedical engineering, and ED management is crucial to ensure that there is a plan for probe sterilization from both a logistic and budgetary perspective.^{13–15} For example, after the TEE probe has been sterilized by the cardiac anesthesia department, the ED management can maintain a log of patient names and medical record numbers along with results of leak testing to comply with hospital and national regulations.

2.5 | TEE use protocol

After deciding to purchase a TEE, it is essential to develop clinical use guidelines for physicians to follow that should include indications where the use of the TEE is warranted. Although the most common use of ED TEE is during cardiopulmonary arrest, other acute care indications for TEE should be considered. These include assessment of the thoracic aorta, procedural assistance, fluid resuscitation, and ongoing cardiac monitoring during resuscitation.⁸

It is also recommended to establish an image acquisition protocol for general TEE exams.⁷ TEE has several standard views that should be obtained in most ED scans. The four main views regularly used in resuscitative TEE include midesophageal 4 chamber (ME 4C), midesophageal long axis, transgastric short axis, and the midesophageal bicaval (ME Bicaval) views.^{6,18,19} These windows are similar to those seen in transthoracic echocardiography, with the exception of the ME Bicaval view. A standard progression and description of the utility of each view is available in Figure 1. Additional views can be obtained to better assess the aorta and pulmonary arteries; however, these should be used as adjuncts to the protocol described here based on guided resuscitation.^{18,20–23}

2.6 | Physician credentialing and quality assurance

When developing a simulation program for physicians, it is important to implement a combination of didactic and hands-on training. After clinicians familiarize themselves with the imaging protocol, use of the omniplane, probe rotation, and flexion will allow for visualization of

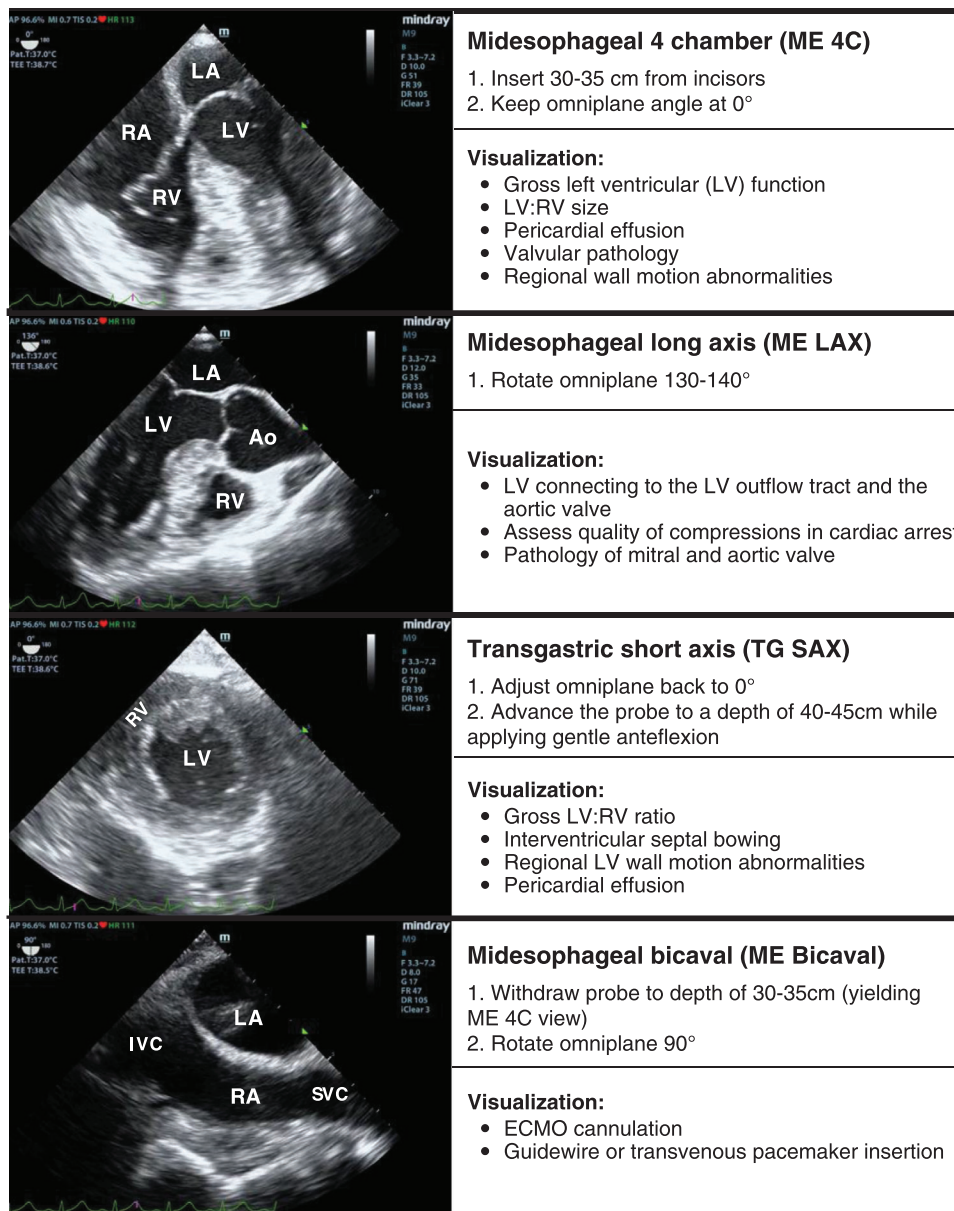


FIGURE 1 Four standard resuscitative TEE views. Abbreviations: Ao, aorta; ECMO, extracorporeal membrane oxygenation; IVC, inferior vena cava; LA, left atrium. RA, right atrium, LV, left ventricle, RV, right ventricle; SVC, superior vena cava; TEE, transesophageal echocardiography

structures along any potential axis.¹⁹ Obtaining this skill for use in clinical practice occurs through the review of still images, video clips, and the purchase or rental of commercially available high-fidelity simulators (Appendix A). If there are no physicians experienced in TEE in the ED, there are several multidisciplinary courses that provide hands-on training (Appendix B).

The requirements for user credentialing will vary for every ED. The following requirements are likely sufficient for developing proficiency with the procedure: a minimum of 5 hours of TEE didactic education, 10 supervised exams on either live patients or high-fidelity simulation models, and a proctored assessment completed by a credentialed physician. These criteria are consistent with the American College of Emergency Physicians guidelines for the use of TEE in the ED, as well

as the format of established international TEE workshops available to clinicians.^{20,24} Additionally, given that TEE has been used by anesthesiologists and cardiologists for over 40 years, it is important to have input from these departments when developing a credentialing program for emergency physicians.^{6,9} Because resuscitative TEE is primarily a diagnostic tool, the majority of pathology that TEE can diagnose will require definitive management outside of the ED. Therefore, consultants need to trust the emergency physicians' capability to obtain and accurately interpret TEE findings. Early involvement in conversations regarding the credentialing process will allow for a more widespread acceptance of ED TEEs within the hospital system and therefore a higher level of both diagnostic and postresuscitation care for critically ill ED patients. A recent publication by Reardon et al. provides a detailed description

of the successful credentialing of an entire emergency physician group using a 4-hour instructional session, demonstrating the feasibility of this process and clinical impact that it can have on an ED.²⁵

Once credentialed physicians have begun performing TEE exams within the department, there should be a mechanism for image storage, transfer, interpretation, and timely QA review. Although some departments may already have a robust ultrasound QA program that could seamlessly incorporate TEE, many others do not. For those programs that currently do not have a QA process for ultrasound images, it is recommended to take an interdisciplinary approach with the anesthesiology and cardiology during the early stages of the project. The eventual goal would be to have an independent ED TEE QA process; however, this will take time to establish multiple credentialed and experienced faculty that are capable to reviewing these exams. The cost of both the collaborative and independent ED QA processes must be considered in the long-term budgeting for the program.

2.7 | Barriers to implementation

There are multiple barriers to implementation of a successful ED TEE program, the most significant of which is likely to be cost. The average reimbursement for ED resuscitative TEE exams (using Current Procedural Terminology code 93312 for non-contrasted studies) ranges from \$300 to \$320 US dollars. This accounts for the various components of a TEE examination including probe insertion, image acquisition, as well as study interpretation.²⁶ Although there is a substantial upfront cost for the acquisition of TEE probes, over time the collective reimbursement for exams will prove lucrative for the medical group and healthcare system. In one publication, the revenue generated from billing for TEE examinations over a 42-month period paid for an additional 10 TEE transducers in their ED, reinforcing the financial benefits that can be gained from incorporating this modality into ED resuscitation efforts.²⁵

Given the limited clinical scope of TEE and the added planning and preparation for each use, underuse of this modality is a valid concern. Because insertion of the TEE probe requires similar equipment and physician positioning as intubation, it is recommended that these two procedures occur in series. Once inserted, the process of acquiring and interpreting the four resuscitative TEE views is rapid. During resuscitation, the midesophageal long axis view is ideal for ongoing monitoring of resuscitative efforts including the position of chest compressions, cardiac activity during pulse checks, and gross chamber size. Once this view is obtained, the probe can be left in place, allowing the physician to assume a different role in the resuscitation. This is especially important in ED settings where the number of physicians is limited or in non-academic departments without residents or fellow coverage.

3 | CONCLUSION

ED bedside TEE evaluation of patients can provide high-yield information aiding in rapid diagnostic and management strategies. However,

successful implementation of a TEE program requires consideration of many logistical factors before use in the ED. Key elements to consider include budgetary implications, equipment acquisition, device maintenance, credentialing and use protocols, and image quality assurance. Adequate planning and preparation are essential to ensure long-term success of an ED-based TEE program.

CONFLICT OF INTEREST

There are no financial or other conflicts of interest for any of the authors involved in the development and submission of this manuscript.

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How to cite this article: McGuire D, Johnson S, Mielke N, Bahl A. Transesophageal echocardiography in the emergency department: A comprehensive guide for acquisition, implementation, and quality assurance. *JACEP Open.* 2022;3:e12758. <https://doi.org/10.1002/emp2.12758>

APPENDIX A

High-fidelity Transesophageal echoardiography (TEE) simulators

Heartworks

(<https://www.intelligentultrasound.com/heartworks/>)

Symbionics

(<https://symbionix.com/simulators/us-mentor/us-library-of-modules/us-tee/>)

APPENDIX B

Multidisciplinary courses that provide hands-on training (United States and worldwide)

The Resuscitative TEE Workshop

(<https://www.resuscitativetee.com/workshop>)

UCLA Advanced Transesophageal Echocardiography Training Program

(<https://www.uclahealth.org/anes/ucla-advanced-transesophageal-echocardiography-training-program>)

Basic Perioperative TEE education program; collaboration between Society of Cardiovascular Anesthesiologists & the American Society of Anesthesiologists

(<https://scahq.org/education/online-cme/asa-sca-basic-perioperative-tee-program/>)

Toronto General Hospital Department of Anesthesia and Pain Management Virtual Transesophageal Echocardiography

(<http://pie.med.utoronto.ca/tee/>)

European Association of Cardiovascular Imaging (EACVI) Teaching Course on Transoesophageal 2D and 3D Echocardiography

(<https://www.escardio.org/Education/Courses/Organised/EACVI-Organised-Courses>)

EM TEE

(<https://emteecourses.com/>)