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Ultrasound in Emergency Medicine

FOCUSED TRANSESOPHAGEAL ECHOCARDIOGRAPHY BY EMERGENCY PHYSICIANS IS FEASIBLE AND CLINICALLY INFLUENTIAL: OBSERVATIONAL RESULTS FROM A NOVEL ULTRASOUND PROGRAM

Robert Arntfield, MD,*† Jacob Pace, MD,* Michael Hewak, BSC,‡ and Drew Thompson, MD*

*Division of Emergency Medicine, †Division of Critical Care Medicine, and ‡Faculty of Medicine and Dentistry, Western University, London, Ontario, Canada

Reprint Address: Robert Arntfield, MD, London Health Sciences Centre – Victoria Hospital, 800 Commissioners Road, East, London, ON N6A 5W9, Canada

☐ **Abstract—Background: Emergency physicians frequently employ transthoracic echocardiography (TTE) to assist in diagnosis and therapy for patients with circulatory failure or arrest. In critically ill patients, transesophageal echocardiography (TEE) offers several advantages over TTE, including reliable, continuous image acquisition and superior image quality. Despite these advantages, TEE is not widely used by emergency physicians. Objective: Report the feasibility, findings, and clinical influence observed from the first described TEE program implemented in an emergency department (ED) point-of-care ultrasound program. Methods: This was a retrospective review of all ED TEE examinations carried out between February 1, 2013 and January 30, 2015. TEE images and report details (including operator, indication, findings, and clinical recommendation[s]) were exported from the institutional ultrasound archive and analyzed. The electronic chart of each patient was subsequently reviewed for the presence of any complications related to the examination and their clinical course in the hospital. Results: A total of 54 TEE examinations were performed by 12 different emergency physicians. All patients were intubated, and 98% of the examinations were determinate. The most common indications for TEE were intracardiac arrest care in 23 (43%), postarrest management in 14 (26%), and undifferentiated hypotension in 16 (40%). Probe insertion was successful in all cases. TEE imparted a diagnostic influence in 78% of cases and impacted therapeutic decisions in 67% of cases. Conclusion: From our analysis of a single-center experience, ED-based TEE showed a high degree of feasibility and clinical utility, with a diagnostic and therapeutic influence seen in the majority of cases. Focused TEE demonstrated strongest uptake among intubated patients with either undifferentiated shock or cardiac arrest.** © 2016 Elsevier Inc.

☐ **Keywords—point-of-care ultrasound; echocardiography; resuscitation; imaging; ultrasound; transesophageal echocardiography; cardiac arrest; new technology; critical care**

INTRODUCTION

Cardiac ultrasound is a well-accepted component of contemporary emergency medicine practice. Effective applications of emergency department (ED)-based cardiac ultrasound include the identification of pericardial effusion (medical or traumatic), differentiation of shock, assessing left ventricular function, and guiding treatment and prognosis in cardiac arrest (1–7).

Ethics approval was completed. Dr. Robert Arntfield is an educational consultant for Sonosite. Dr. Jacob Pace, Mr. Michael Hewak, and Dr. Drew Thompson have no conflicts of interest.

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The transthoracic approach to echocardiography (TTE) is the preferred method of cardiac ultrasound in the ED. Despite its widespread use, TTE has important limitations. User factors (varying skill in image generation and level of experience), patient factors (obesity, mechanical ventilation, subcutaneous emphysema, ongoing cardiopulmonary resuscitation [CPR]), and logistical factors (interruptions of CPR to acquire images during cardiac arrest) may limit the acquisition of reliable, high-quality TTE images. These factors are often at play in critically ill patients, and may explain why TTE images are frequently poor or inadequate in this population (8).

In contrast, transesophageal echocardiography (TEE) offers a reliable acoustic window via the esophagus, lessening variability in image generation and generally assuring high-resolution images. TEE has been shown to outperform TTE in answering high-stakes, clinical questions in the critically ill, and demonstrated great promise in cardiac arrest for addressing reversible causes and guiding intra-arrest procedures (9–13). Further, TEE may be carried out during cardiac arrest without interrupting chest compressions.

Despite these advantages, uptake of TEE in the ED has been limited. Acceptance may be limited due to many potential factors, including transducer cost, invasiveness, and barriers to emergency physician training (lack of teachers and established ED curriculum), as well as hospital culture.

The purpose of this retrospective review is to describe the feasibility, findings, and clinical impact of TEE in the ED from the first 2 years of a novel ED TEE program.

METHODS

Design

This was a retrospective review of all ED TEE examinations performed between February 1, 2013 and January 30, 2015, after the introduction to a tertiary care ED. The study was approved by our institution's Research Ethics Board (REB #105354).

Setting

The setting for this study was an academic emergency medicine program comprising two EDs (one of which is a regional trauma center) with total annual visits of 140,000. At least one point-of-care ultrasound machine and an immediately accessible TEE probe are available at each site.

Data Acquisition

TEE examinations performed from February 1, 2013 until January 30, 2015 were reviewed in our ED ultrasound database (Qpath, Telexy Healthcare, Maple Ridge, BC, Canada). The relevant details of the examination (entered by the operator at the time of the examination) were retrieved from the Qpath archive and included: date of examination, operator, examination indication, probe insertion details, TEE views obtained, examination findings, recommended clinical actions, the utilization of additional ultrasound modalities for the same patient, ED discharge diagnosis, and disposition of the patient. Data were abstracted by author MH, who was trained by and underwent regular supervision by author RA. Data were populated into a preformed data abstraction tool (spreadsheet).

The electronic medical record of each patient was subsequently reviewed for the presence of any documented aerodigestive complications related to the examination.

DATA ANALYSIS

Data obtained from the TEE examination reports consisted of both categorical (through drop-down fields and check boxes) and free text (Figure 1). Free text data, such as indication, clinical background, and examination interpretation, were analyzed by the authors and categorized into predefined, discrete categories. Diagnostic and therapeutic decisions related to the examination were extracted from the "recommended clinical actions" section of the examination report.

To explore any incremental influence of TEE beyond what TTE might be able to provide, examination findings were further divided into "basic" echocardiographic findings and TEE-specific findings. Basic echo findings were derived from the scope defined by the American Society of Echocardiography/American College of Emergency Physicians consensus on ED echocardiography (14). TEE-specific findings included those findings made possible through the unique acoustic window of TEE (e.g., during CPR, visualization of the ascending aorta) or the enhanced structural resolution of the modality (e.g., fine ventricular fibrillation).

TEE Program Structure

Training. A group of 14 emergency physicians participated in a 4-h TEE workshop comprised of didactic teaching and simulator-enhanced hands-on training and led by an emergency physician (RA) with expertise in both TTE and TEE. The workshop featured both didactic (2 h) and simulation-based (2 h) training. The educational workshop emphasized the generation and interpretation of a focused protocol of four discrete TEE views: the mid-esophageal four-chamber, the transgastric short-axis, the mid-esophageal long-axis, and the mid-esophageal bicaval view. A full description of this training and results has recently been published (15).

POC Ultrasound

Exam Date
Patient ID
Patient Name
Accession #
Exam Type Emergency Dept TEE
Operator
Attending

ED - TEE

Indication and Clinical Details

Indication

Clinical Background

Probe Insertion

TEE Findings

Pericardium

Left Ventricle

Right Ventricle

SVC Size and Variation

Valves

Summary of Findings

Summary

**RECOMMENDED ACTION(S) BASED ON FINDINGS

- ☐ No action or change in management required at this time
- ☐ IV fluids
- ☐ Inotrope initiation or escalation
- ☐ Diuresis
- ☐ Surgical or procedural intervention
- ☐ Follow up point of care study (reason indicated below)
- ☐ Diagnostic echocardiogram when convenient (reason indicated below)
- ☐ Diagnostic echocardiogram urgently (reason indicated below)
- ☐ Referral to a consultant service
- ☐ Termination of Resuscitation
- ☐ Addtional lab or radiology study
- ☐ Other

Details

Figure 1. Typical (blank) emergency department (ED) transesophageal echocardiography (TEE) report sheet completed by operators upon completion of a TEE study. POC = point-of-care.

TEE examination acquisition and oversight. Upon inception of the TEE program, emergency physicians were required to archive clips of relevant views obtained and complete a comprehensive typewritten report using the Qpath archiving database. All studies were reviewed and subject to mandatory quality assurance by the ED TEE curriculum director (RA).

RESULTS

During the study period, 54 TEE examinations were carried out. Examinations were performed by 12 different emergency physicians (10 attending physicians, two senior residents; average 4.9 examinations/physician, range 1–17). The majority of patients were male, and the most common indication for a TEE examination was cardiac arrest and its management (either intra-arrest or postarrest). All patients were intubated at the time of examination (Table 1).

Probe insertion was successful in all 54 examinations (100%), with first-pass success in 45 (83%), more than one attempt in six (11%), and inserted with the aid of a laryngoscope in three (6%) of the examinations. There were no documented aerodigestive injuries in the 39 patients who survived to hospital admission. None of the 15 patients who died had autopsies to assess for mechanical complications of the procedure.

Fifty-three (98%) examinations produced images that were interpretable by the operator. A single patient who presented in cardiac arrest after blunt chest trauma had no interpretable windows via TEE or TTE.

Table 1. Demographic Data of 54 ED Patients Undergoing Transesophageal Echocardiography

Age, y	60.1
Male	41 (76%)
Presenting problem	
Vital signs absent	35 (64%)
Blunt trauma	8 (15%)
Penetrating trauma	1 (2%)
Decreased LOC	4 (7%)
Sepsis	2 (4%)
Seizure	3 (6%)
Overdose	1 (2%)
Indication for TEE examination	
Cardiac arrest: Intra-arrest	23 (43%)
Cardiac arrest: Postarrest	14 (26%)
Medical hypotension	9 (17%)
Traumatic hypotension	7 (13%)
Rule-out aortic dissection	1 (2%)
Intubated	54 (100%)
Transthoracic echo attempted and documented	19 (35%)
Admitted to ICU	39 (72%)
Died in ED	15 (28%)
Aerodigestive injury	0

ED = emergency department; LOC = level of consciousness; TEE = transesophageal echocardiography; ICU = intensive care unit.

The most commonly acquired TEE views were those emphasized in the four-view training curriculum. The mid-esophageal four-chamber view was the most commonly achieved view in 52 (98%) cases, followed by the transgastric short-axis view in 43 (81%), mid-esophageal long-axis view in 42 (79%), and bicaval view in 25 (47%) cases (Figure 2). A summary of these and other views used by study physicians is found in Table 2.

The clinical impact of each TEE examination was divided into 1) its diagnostic influence on clinical decision-making and 2) its therapeutic influence on procedures, prescription of medication or fluids, or ceasing resuscitation based on findings (prognosis). Operators' reports confirmed that TEE was diagnostically influential in 78% of cases. The most common diagnostic contributions were exclusion of a cardiac cause of cardiac arrest (56%), identification of depressed left ventricular function (15%), hypovolemia (13%), regional wall motion abnormalities suggestive of coronary artery disease (6%), and aortic dissection (4%) (Table 3).

A therapeutic impact was present in 67% of cases, including changes to the quality, timing, or location of intra-arrest CPR (43%). Misplaced vector of force (in both manually and automated delivery of CPR), identification of chest compressor fatigue, shortened pulse-check duration, and identification of return cardiac activity during CPR were all described. TEE findings were additionally noted to influence prognosis and cessation of resuscitation (30%), and guide hemodynamic support either through volume (18%) or vasoactive drugs (8%) (Figure 3).

The findings of each TEE examination, divided into basic echo findings (those that are generally achievable with either TTE or TEE) and TEE-specific findings are summarized in Table 4.

In 19 patients, a TTE was also carried out, but abandoned in favor of TEE. Comparisons between TTE and TEE image quality in three of these cases are shown in Figure 4.

DISCUSSION

The 2008 American College of Emergency Physician guidelines on the use of ED ultrasound lists TEE as one of a set of seven "emerging applications" in emergency ultrasound (16). Although 7 years have passed since publication, there has been little evidence of TEE adoption by emergency physicians.

Our report of 54 TEE examinations is the largest series of emergency physician TEE examinations yet reported. It is also the first known ED TEE program to be described, and the first description of in vivo use of a four-view, focused TEE protocol.

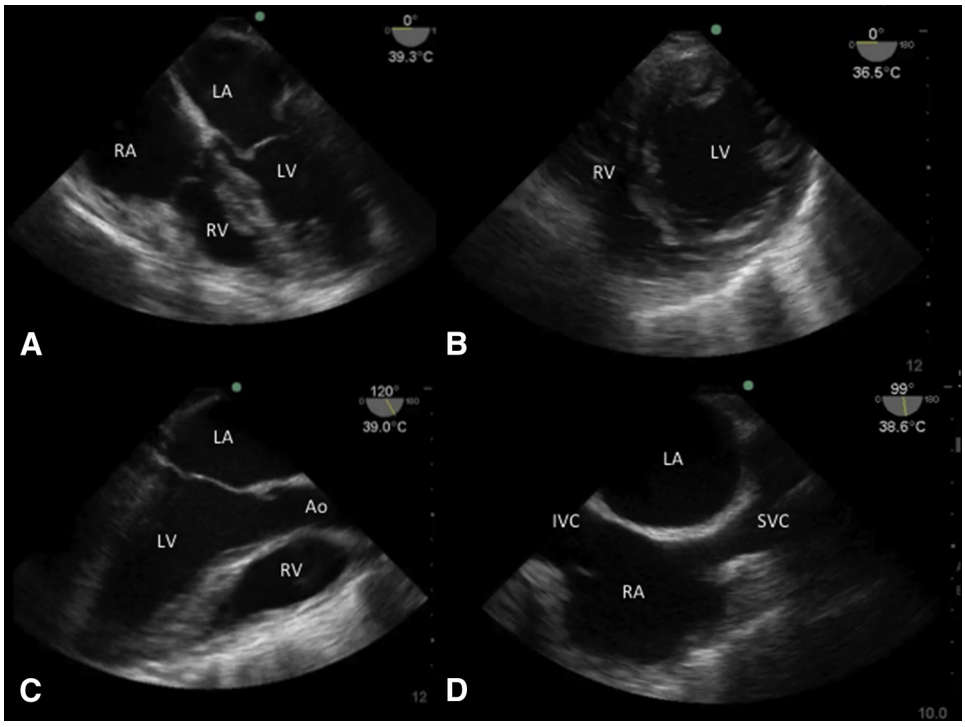

Figure 2. Representative 4 views of our focused emergency department transesophageal echocardiography protocol obtained from a patient with undifferentiated hypotension. (A) mid-esophageal 4 chamber view; (B) transgastric short axis; (C) mid-esophageal long axis; (D) bicaval view. Ao = aorta; IVC = inferior vena cava; LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle; SVC = superior vena cava.

Despite prolific advancement of ED ultrasound in both academic and clinical domains, TEE has remained relatively unused and unstudied. With obvious advantages over TTE, especially for the critically ill, notable obstacles to implementation include the cost of the TEE transducer (~$40,000 USD), lack of established ED training models or curricula, and in some centers, interdepartmental politics.

Table 2. TEE Views Employed Across 54 TEE Examinations

TEE View	Frequency (%)
ME4C	52 (96)
MELAX	42 (78)
TGSAX	43 (80)
BC	25 (46)
DTA (one or more views)	8 (15)
AV SAX	3 (6)
Deep TG	2 (4)
TG LAX	1 (2)
ME2C	1 (2)
RV I/O	1 (2)

TEE = transesophageal echocardiography; ME4C = mid-esophageal 4-chamber; MELAX = mid-esophageal long-axis; TGSAX = trans-gastric short axis; BC = bicaval; DTA = descending thoracic aorta; AV SAX = aortic valve short-axis; Deep TG = deep transgastric; TG LAX = trans-gastric long-axis; ME2C = mid-esophageal 2-chamber; RV I/O = right ventricular inflow-outflow.

In this series of 54 cases, 53 studies (98%) were determinate–supporting the reliability of this tool for cardiac imaging in emergency physicians' hands. In reviewing the TEE examinations, we found that three of the four views were routinely acquired (Figure 2). The near-universal use of the mid-esophageal four-chamber (96% of cases) is felt to relate to the ease with which this view is acquired, with little probe manipulation required upon insertion in the mid-esophagus. Frequent, successful image generation of two additional views, transgastric short-axis (80% of cases) and mid-esophageal long-axis (78% of cases), supports facility with probe manipulations by our emergency physicians after limited training.

Table 3. Breakdown of Operator-identified, Influential Diagnostic Findings from 54 Focused TEE Examinations

Diagnostic Finding	Number of Occurrences
Ruled out cardiac cause of arrest	27 (43%)
Ascertaining etiology of arrest	9 (14%)
LV dysfunction	5 (8%)
Hypovolemic shock	4 (6%)
Aortic dissection	2 (3%)
Identification of different underlying rhythm	1 (2%)
No influence	15 (24%)

TEE = transesophageal echocardiography; LV = left ventricular.

Table 4. Frequency of 57 Basic and 29 TEE-specific/ Advanced Findings Across a Sample of 53 Determinate TEE Examinations

Echocardiographic Findings	Frequency (%)
Basic echo findings	
Cardiac standstill	10 (19%)
LV dysfunction	15 (28%)
RV dysfunction	2 (4%)
Pseudo-PEA	2 (4%)
Pericardial effusion	4 (8%)
Normal examination	15 (28%)
Hypovolemia	10 (19%)
TEE-specific findings	
CPR quality	23 (43%)
Fine ventricular fibrillation	2 (4%)
External CPR device malpositioning	1 (2%)
Aortic dissection	2 (4%)
Mediastinal hematoma	1 (2%)
Procedural guidance (pacemaker insertion)	1 (2%)

TEE = transesophageal echocardiography; LV = left ventricular; RV = right ventricular; PEA = pulseless electrical activity; CPR = cardiopulmonary resuscitation.

Visualization of the superior vena cava (and its respiratory variation) afforded by the bicaval view, though useful in guiding volume resuscitation, was relatively uncommonly used (46% of cases) in our series (17). This may reflect the inability to gauge respiratory variation during cardiac arrest due to movement caused by chest compressions. Additional views to these four were generated rarely–typically only by an advanced user or after progressive comfort among those with the repeated TEE use.

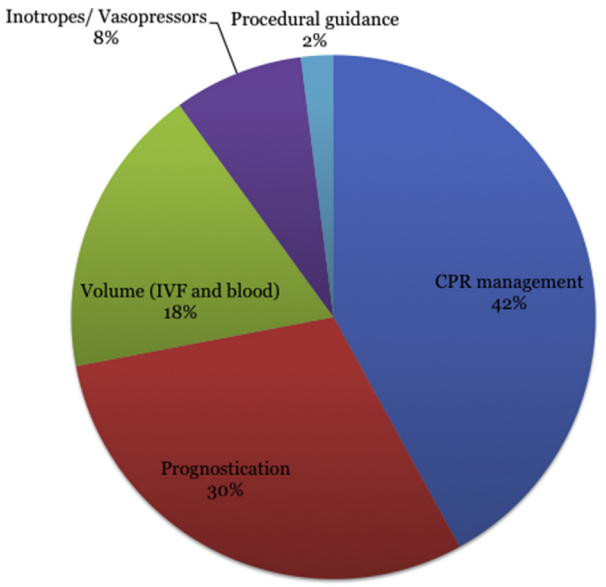

Figure 3. Breakdown of the management changes made in 67% of cases in response to transesophageal echocardiography findings. CPR = cardiopulmonary resuscitation; IVF = intravenous fluids.

Despite the limited number of views applied in our series, it is evident that TEE offered important diagnostic information in three-quarters of patients. These interpretations most frequently related to exclusion of cardiac causes of cardiac arrest or hypotension. Such peri-arrest questions have long been shown to be possible to address through a transthoracic approach to echo (5). With excellent structural resolution, expanded anatomic scope (e.g., ascending aorta), and capacity to be performed without interrupting CPR, we submit that TEE should be considered the tool of choice for this indication in centers with access to TEE.

In 21 patients, important pathology was identified. Though prior intensive care unit-based studies show a strong diagnostic advantage of TEE over TTE, the retrospective nature of our study did not allow us to compare the two modalities head to head in our severely ill ED sample.

ED TEE contributed to a therapeutic intervention in a majority of patients. Twenty-one cases of intra-arrest TEE were reported by operators to prompt changes in CPR delivery. Other therapeutic changes resulting from TEE related to differentiation of shock and corresponding prescription of intravenous fluids and vasoactive medications. Though cardiac arrest outcome is influenced by CPR quality and minimizing CPR interruptions, and echocardiography-guided management of shock has shown patient benefit, our small, retrospective sample does not allow us to generalize the benefit of these findings to our patients (18,19).

The 4% aortic dissection prevalence in our small sample was not anticipated, but highlights the advanced diagnostic potential of TEE in the resuscitative setting (Figure 5; online e-supplement Videos 1 and 2). Though the scope of our program was intended to address limitations, rather than supersede TTE, it is plausible that with program maturation and appropriate training, advanced indications for TEE (such as assessment for aortic dissection) may develop.

The feasibility of TEE in the ED was described by a single operator in 2008 (11). Our work is different, as it draws on a much larger sample. Further, 12 different ultrasound-credentialed emergency physicians carried out the TEE studies in our study. We propose that our integration of TEE across a point-of-care ultrasound program in the ED is a milestone that supports the generalizability of this tool for emergency physicians.

Limitations

Our study has several limitations. It is limited by its retrospective methodology and small sample size. Also, relative to the number of total visits to our ED, the number of examinations performed is comparatively small. As well,

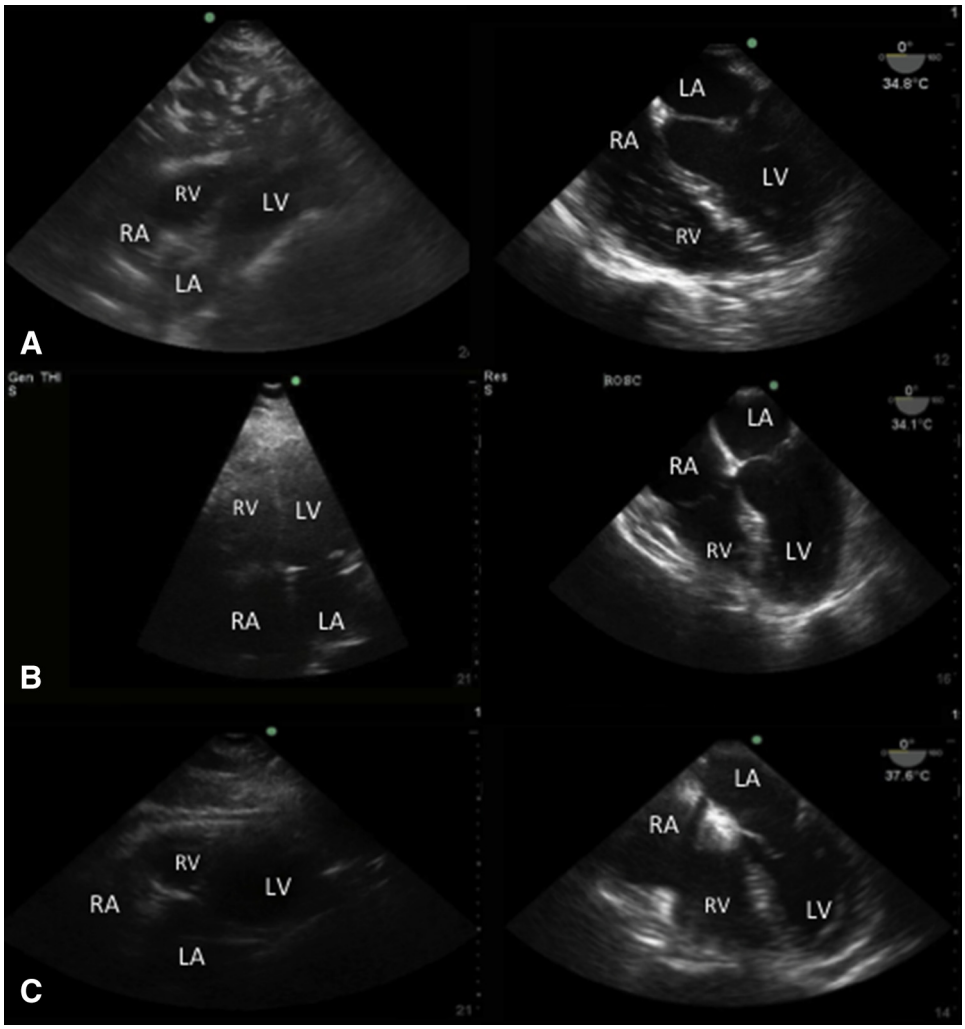

Figure 4. Transthoracic echocardiography (left-hand column) and transesophageal echocardiography (right-hand column) images from the same patient on the same encounter. (A) Subcostal 4-chamber view and a corresponding mid-esophageal 4-chamber view. (B) Apical 4-chamber view and corresponding mid-esophageal 4-chamber view and (C) subcostal 4-chamber view and a mid-esophageal 4-chamber view. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

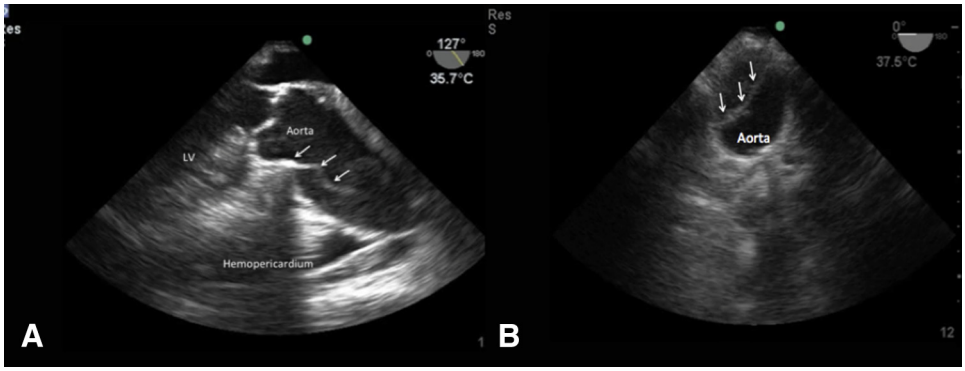

Figure 5. Representative images from 2 separate cases of cardiac arrest determined by transesophageal echocardiography to be due to aortic dissection. (A) Mid-esophageal long-axis view and (B) short-axis view of the descending thoracic aorta. Arrows: dissection flap; LV = left ventricle.

our study methodology did not allow us to address the influence of TEE on patient-centered outcomes. These limitations may be addressed through future prospective, multi-center studies of TEE in the ED.

CONCLUSION

From our analysis of a single-center experience, ED-based TEE showed a high degree of feasibility (98% determinate rate) and clinical utility, with a diagnostic and therapeutic influence seen in the majority of cases. Focused TEE demonstrates the most promise in patients who are intubated and have either undifferentiated shock or cardiac arrest.

REFERENCES

1. Blaivas M. Incidence of pericardial effusion in patients presenting to the emergency department with unexplained dyspnea. Acad Emerg Med 2001;8:1143–6.
2. Plummer D, Brunette D, Asinger R, et al. Emergency department echocardiography improves outcome in penetrating cardiac injury. Ann Emerg Med 1992;21:709–12.
3. 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.
4. Moore C, Rose G, Tayal V, et al. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. Acad Emerg Med 2002;9:186–93.
5. Tayal VS, Kline J. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. Resuscitation 2003;59:315–8.
6. 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.
7. Cohn B. Does the absence of cardiac activity on ultrasonography predict failed resuscitation in cardiac arrest? Ann Emerg Med 2013;62:180–1.
8. Cook CH, Praba AC, Beery PR, et al. Transthoracic echocardiography is not cost-effective in critically ill surgical patients. J Trauma 2002;52:280–4.
9. Vignon P, Mentec H, Terre S, et al. Diagnostic accuracy and therapeutic impact of transthoracic and transesophageal echocardiography in mechanically ventilated patients in the ICU. Chest 1994;106:1829–34.
10. Font VE, Obarski TP, Klein AL, et al. Transesophageal echocardiography in the critical care unit. Cleve Clin J Med 1991;58:315–22.
11. Blaivas M. Transesophageal echocardiography during cardiopulmonary arrest in the emergency department. Resuscitation 2008;78:135–40.
12. Memtsoudis SG, Rosenberger P, Loffler M, et al. The usefulness of transesophageal echocardiography during intraoperative cardiac arrest in noncardiac surgery. Anesth Analg 2006;102:1653–7.
13. Arntfield RT, Millington SJ, Wu E. An elderly woman that presents with absent vital signs. Chest 2014;146:e156–9.
14. 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;23:1225–30.
15. Arntfield RT, Pace J, McLeod SL, Granton J, Hegazy A, Lingard L. Focused transesophageal echocardiography for emergency physicians – description and results from simulation training of a structured 4-view examination. Crit Ultrasound J 2015;7:27.
16. American College of Emergency Physicians. Emergency ultrasound guidelines. Ann Emerg Med 2009;53:550–70.
17. Vieillard-Baron A, Chergui K, Rabiller A, et al. Superior vena caval collapsibility as a gauge of volume status in ventilated septic patients. Intensive Care Med 2004;30:1734–9.
18. Hazinski MF, Nolan JP, Billi JE, et al. Part 1: executive summary: 2010 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation 2010;122(16 Suppl 2):S250–75.
19. Kanji HD, McCallum J, Sirounis D, MacRedmond R, Moss R, Boyd JH. Limited echocardiography-guided therapy in subacute shock is associated with change in management and improved outcomes. J Crit Care 2014;29:700–5.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jemermed.2015.09.018.

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ARTICLE SUMMARY

1. Why is this topic important?

Transesophageal echocardiography (TEE) in the emergency department (ED) is an emerging application for point-of-care ultrasound. TEE has many advantages over transthoracic echocardiography (TTE) and is of particular value in those with critical illness or cardiac arrest where TTE may be technically difficult.

2. What does this study attempt to show?

This study offers the first description of a point-of-care TEE program in the ED, including likely indications, findings, and impact on diagnosis and therapy.

3. What are the key findings?

Our review demonstrates that TEE in the ED is used most commonly in those with hypotension or cardiac arrest, and that it imparts an impact on therapy and diagnosis in the majority of cases.

4. How is patient care impacted?

Patient care may be influenced by establishing the feasibility of a point-of-care TEE program by emergency physicians that could promote increased uptake and, based on results of this small review, provide meaningful therapeutic and diagnostic information for critically ill patients presenting to the ED.