JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY VOL. 76, NO. 6, 2020
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PUBLISHED BY ELSEVIER

JACC REVIEW TOPIC OF THE WEEK

Focused Transesophageal Echocardiography During Cardiac Arrest Resuscitation

JACC Review Topic of the Week

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ABSTRACT

Focused transthoracic echocardiography (TTE) during cardiac arrest resuscitation can enable the characterization of myocardial activity, identify potentially treatable pathologies, assist with rhythm interpretation, and provide prognostic information. However, an important limitation of TTE is the difficulty obtaining interpretable images due to external and patient-related limiting factors. Over the last decade, focused transesophageal echocardiography (TEE) has been proposed as a tool that is ideally suited to image patients in extremis—those in cardiac arrest and periarrest states. In addition to the same diagnostic and prognostic role provided by TTE images, TEE provides unique advantages including the potential to optimize the quality of chest compressions, shorten cardiopulmonary resuscitation interruptions, guide resuscitative procedures, and provides a continuous image of myocardial activity. This review discusses the rationale, supporting evidence, opportunities, and challenges, and proposes a research agenda for the use of focused TEE in cardiac arrest with the goal to improve resuscitation outcomes. (J Am Coll Cardiol 2020;76:745–54)

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Manuscript received April 6, 2020; revised manuscript received May 5, 2020, accepted May 21, 2020.

ISSN 0735-1097/$36.00 https://doi.org/10.1016/j.jacc.2020.05.074

JACC VOL. 76, NO. 6, 2020
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ABBREVIATIONS AND ACRONYMS

AMC = area of maximal compression

CPR = cardiopulmonary resuscitation

ECLS = extracorporeal life support

LVOT = left ventricular outflow tract

OHCA = out-of-hospital cardiac arrest

ROSC = return to spontaneous circulation

TEE = transthoracic echocardiography

TTE = transesophageal echocardiography

The use of focused point-of-care echocardiography, diagnostic modality aimed to provide immediate and actionable information, is an integral component of emergency and critical care ultrasonography, and represents a core competency of emergency medicine (1) and intensive care (2) training. In contrast to comprehensive echocardiography, a focused examination provides a goal-directed framework that can be used by many acute care clinicians to guide clinical care in various disease processes and syndromes (3-6). One example of the evolving role of real-time echocardiography in acute care environments is its use during cardiac arrest.

Observational studies show that focused transthoracic echocardiography (TTE) during cardiac arrest resuscitation can help identify patients with poor prognosis (7,8), accurately detect reversible pathology, and guide ongoing resuscitation efforts (9). International resuscitation guidelines establish the use of TTE as a diagnostic tool to help identify treatable pathologies and provide prognostic information (10). Focused TTE can be critical for the identification of obstructive pathologies including tension pneumothorax, cardiac tamponade, deep vein thrombosis with RV dilation suggesting pulmonary embolism, as well as filling status suggesting hypovolemia as a potential cause of arrest (9,11,12). Despite this strong rationale and evidence of benefit, an important limitation of the use of TTE during cardiac arrest is the technical difficulty in obtaining adequate cardiac windows. Several factors, including the limited time available during chest compressions, may decrease the use and quality of TTE during resuscitation of cardiac arrest patients.

Focused transesophageal echocardiography (TEE) has been recognized as an alternative to TTE that can overcome these limitations and has been proposed as a well-suited imaging modality to enhance cardiac arrest care (**Figure 1, Table 1**). In addition to the similar diagnostic and prognostic roles provided by TTE, TEE provides unique imaging advantages. The potential for TEE to improve outcomes in resuscitation includes minimizing chest compression interruptions, providing real-time feedback on the location and quality of chest compressions, correct rhythm interpretation, and facilitating the initiation of extracorporeal life support (ECLS) (13-16). **Table 2** provides a summary of the major clinical studies on the use of TEE in cardiac arrest.

This paper reviews the rationale and supporting evidence for the usefulness of TEE during cardiac arrest resuscitation, and discusses opportunities, challenges, and potential research topics for the use of focused TEE in cardiac arrest with the goal to improve resuscitation outcomes.

HIGHLIGHTS

- Focused TEE overcomes some of the difficulties of performing surface echocardiography during cardiac arrest resuscitation.
- TEE can provide reliable, high-quality cardiac images regardless of any patient-related or external factors.
- Continuous TEE images during cardiac arrest allow feedback on the quality of CPR.
- Like TTE, TEE allows identification of reversible pathologies and can provide prognostic information.
- Future research should include larger and multicenter studies evaluating the diagnostic value, impact in survival, and neurological outcomes of TEE-guided CPR.

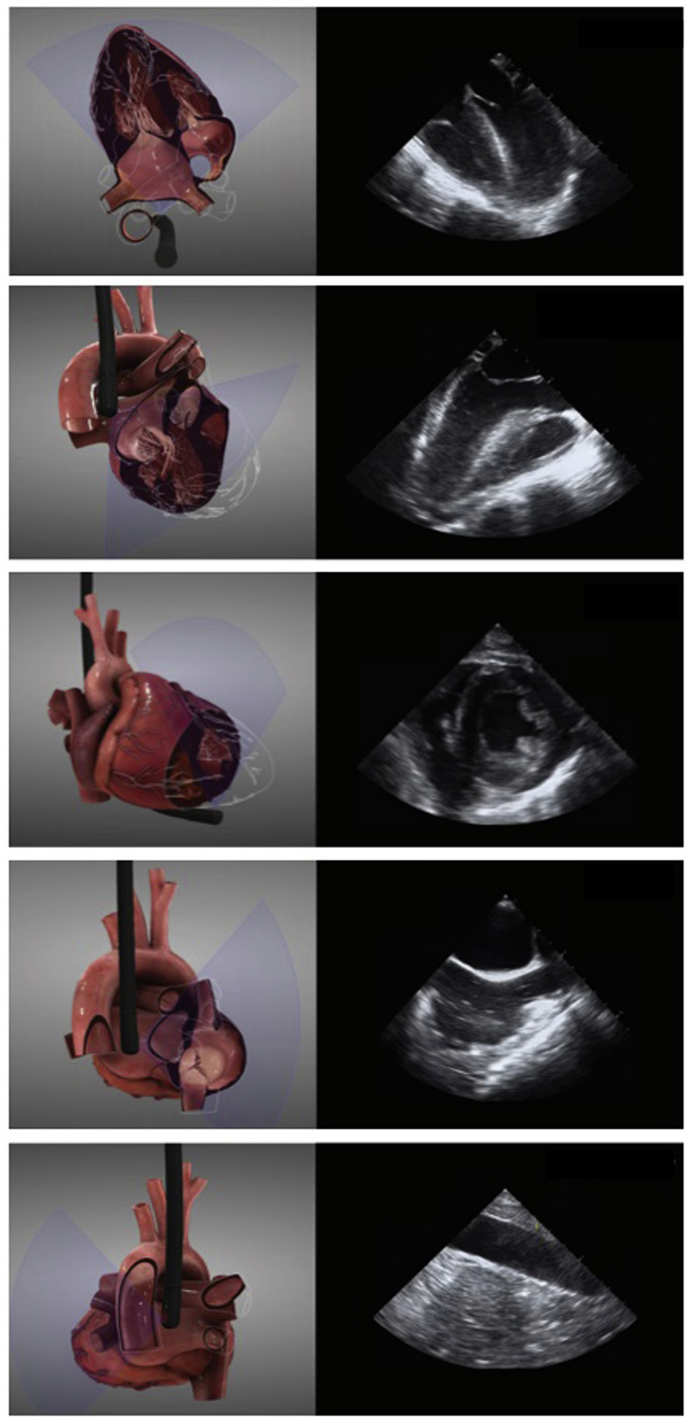
POTENTIAL TO ENHANCE QUALITY OF RESUSCITATION

Current resuscitation guidelines emphasize the importance of delivering high-quality compressions and minimizing interruptions to improve survival and neurological outcomes (10,17,18). Although it is recognized that TTE can provide valuable information in critically ill patients, relying on images generated through the skin surface of a patient in cardiac arrest poses limits. External factors such as defibrillation pads, ongoing chest compressions, automated compression devices, or positive pressure ventilation, as well as pathophysiological interference of patient-related factors such as obesity, an air-filled stomach, and subcutaneous emphysema can render the acquisition of interpretable images challenging. Nevertheless, in many cases of cardiac arrest, TTE can suffice as a diagnostic modality. Unfortunately, recent observational data demonstrating longer chest compression pauses, suggests that TTE may interfere with chest compression delivery during resuscitation (19,20). Alternatively, TEE allows for continuous visualization of the heart—an anatomic cardiac monitor—during cardiopulmonary resuscitation (CPR) without interfering with chest compressions or other resuscitation efforts. The reliable imaging of TEE may further serve to more readily identify treatable causes of cardiac arrest such as pericardial tamponade, intracardiac thrombus, fine ventricular fibrillation, and to characterize the type of cardiac activity such as cardiac standstill or pseudo-PEA (13). In a recent retrospective analysis of 25 patients during CPR, Fair et al. (16) compared duration of chest compression pauses between TEE, TTE, and manual pulse checks on recordings of cardiac arrest resuscitations. Their findings over the 139 CPR pauses demonstrated that TEE resulted in shorter interruptions of CPR than that of TTE (16). Although potentially biased by the smaller number of patients who received TEE and the expertise of those performing TEE, these data suggest that TEE can promote greater continuity in the provision of CPR compared with TTE.

In addition to positively influencing the cumulative dose of CPR, TEE has the unique potential to enhance its quality. Due to the indwelling nature of the transducer, the real-time, precise location of chest compressions with respect to cardiac anatomy can be observed and manipulated to optimize circulatory flow. Although the current recommended location for chest compressions during CPR is on "the center of the victim's chest," human radiologic studies of chest computed tomography and cardiac magnetic resonance imaging have found that the left ventricle (LV) is not always located beneath the center of the sternum, whereas the left ventricular outflow tract (LVOT), aortic valve, or aortic root are located in that position in 50% to 80% of patients (21,22). In 2009, a prospective observational study of 34 patients in cardiac arrest used TEE to confirm that the area of maximal compression (AMC) was found at the aorta in 59% of patients and at the LVOT in 41% of patients, with a significant narrowing of the LVOT or the aorta noted in all patients (23). In agreement with those findings, a recent prospective study of patients with out-of-hospital cardiac arrest (OHCA) showed that the AMC was located over the LVOT or aortic root in 53% of patients (13). These findings suggest that some patients in cardiac arrest may be receiving compressions that fall short of the goal to provide optimal coronary and cerebral perfusion, and that via TEE, a more personalized approach may be possible.

Anderson et al. (24) conducted a prospective, randomized trial to evaluate the difference in hemodynamic variables and return to spontaneous circulation (ROSC) when chest compressions over the LV were compared to compressions over the aortic root. Using a swine model of ventricular fibrillation, TEE was used intra-arrest to record the

FIGURE 1 **Selected TEE Views Used in Cardiac Arrest Resuscitation**



Five views of focused transesophageal echocardiography (TEE) commonly used during cardiac arrest resuscitation: **(top to bottom)** midesophageal 4 chamber (ME4C); midesophageal long axis (MELAX); transgastric short axis (TGSAX); bicaval; and descending thoracic aorta long axis (DTA LAX). 3-dimensional graphics provided with permission for use by HeartWorks by Intelligent Ultrasound (Alpharetta, Georgia).

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TABLE 1 Clinical Applications of Focused TEE Views in Cardiac Arrest

Focused TEE View	Cardiac Structures	Applications
ME4C	All cardiac chambers Pericardium LV/RV walls Mitral and tricuspid valves	Rule out tamponade Assess cardiac activity Identify intracardiac thrombus Assess LV/RV size and function Detect fine VF
MELAX	LV, LA, and RV chambers LV outflow tract Aortic root Mitral and aortic valves	Assess ascending aorta for dissection/injury Determine AMC during CPR
TGSAX	All LV walls and septum	Assess cardiac activity LV/RV size and function, cardiac filling status, presence of tamponade
Bicaval	IVC, RA, and SVC	Procedural guidance (ECMO, CVC) Volume responsiveness in post-arrest, intracardiac thrombus
DTA LAX	Descending aorta	Procedural guidance (ECMO)

AMC = area of maximal compression; CPR = cardiopulmonary resuscitation; CVC = central venous catheter; DTA LAX = descending thoracic aorta long axis; ECMO = extracorporeal membrane oxygenation; IVC = inferior vena cava; LA = left atrium; LV = left ventricle; ME4C = midesophageal 4 chamber; MELAX = midesophageal long axis; RA = right atrium; RV = right ventricle; SVC = superior vena cava; TGSAX = transgastric short axis; VF = ventricular fibrillation.

TABLE 2 Summary of Clinical Studies on the Use of TEE in Cardiac Arrest

First Author, Year (Ref. #)	N, Setting, Study Design	Key Findings
Redberg et al., 1993 (32)	20 ED Prospective observational	Feasibility and usefulness of intra-arrest TEE. Established cardiac pump theory as predominant physiological mechanism in CPR.
Van Der Wouw et al., 1997 (30)	48 ED, wards Prospective observational	Diagnostic accuracy of TEE during resuscitation. TEE can reliably establish cause of circulatory arrest during resuscitation.
Lin et al., 2006 (33)	10 OR Prospective observational	TEE found impactful identifying or excluding cause of arrest and guiding management during noncardiac surgery.
Memtsoudis et al., 2006 (29)	22 OR Retrospective observational	TEE found useful providing diagnostic information and guiding resuscitation therapies during noncardiac surgery.
Arntfield et al., 2016 (14)	37 ED Retrospective observational	TEE found clinically impactful to establish etiology of arrest and guiding therapy during resuscitation in the ED.
Teran et al., 2019 (13)	33 ED Prospective observational	TEE found feasible and clinically impactful identifying treatable pathologies and optimizing quality of CPR.
Fair et al., 2019 (16)	12 ED Retrospective observational	TEE-guided pulse checks found to be shorter compared to TTE-guided pulse checks.
Catena et al., 2019 (25)	19 ED Retrospective observational	Association between LVOT opening during intra-arrest TEE and successful resuscitation (ROSC).
Fair et al., 2019 (39)	25 ED Retrospective observational	Intra-arrest TEE feasible and useful for guidance of vascular cannula placement during ECLS.

CPR = cardiopulmonary resuscitation; ECLS = extracorporeal life support; ED = emergency department; LVOT = left ventricular outflow; OR = operating room; ROSC = return of spontaneous circulation; TEE = transesophageal echocardiography.

AMC. This study demonstrated that compressions directed over the LV resulted in improved hemodynamics and a higher rate of ROSC and survival to 60 min compared with chest compressions over the aortic root. Providing consistent findings in humans, a recent retrospective study of 19 witnessed refractory OHCA patients with criteria for ECLS found that LVOT opening as identified by TEE during CPR was associated with successful resuscitation (25). This is the first study in humans showing that information obtained by TEE during cardiac arrest may have prognostic value regarding resuscitation outcomes. Although this evidence suggests that TEE has potential to improve resuscitation outcomes, several important questions remain. It is unclear if these findings are due to associated pathophysiological changes or inaccurate surface anatomical landmarks. Although it seems clear that the optimal location to produce the most effective chest compressions may be variable across patients, the effect of factors such as timing and chest compression method (i.e., manual vs. mechanical), as well as physiological determinants including volume status and lung-heart interactions associated with ventilation methods during CPR, are yet to be determined. Based on the authors' own experience, all of these factors seem to have some impact in the intra-arrest findings seen on TEE.

DIAGNOSTIC ROLE OF TEE IN CARDIAC ARREST

It has been well-established that focused TTE can accurately diagnose life-threatening pathologies in critically ill patients (11,12,26,27). These findings may include cardiac tamponade, right ventricular strain indicative of pulmonary embolism, hypovolemia, ventricular arrhythmia, and aortic emergencies. Multiple studies have shown that these findings on TTE can guide management and may result in improved survival (9,28). The 2015 American Heart Association/International Liaison Committee on Resuscitation guidelines for cardiopulmonary resuscitation recognized the benefits of performing ultrasound in cardiac arrest and recommended that it "may be considered to diagnose treatable causes of cardiac arrest and guide treatment decisions" (10,17). Similarly, a statement from the American Society of Echocardiography recommends focused echocardiography in nonshockable arrest for guidance of diagnosis, prognosis, and procedures (11).

Although TTE can provide these diagnostic benefits in cardiac arrest, there are many situations in which it is not feasible. As discussed previously, many factors can make consistently obtaining interpretable surface echocardiography images challenging. For this reason, the reliable sonographic windows of TEE are increasingly being sought in cardiac arrest. The use of TEE has been described as a useful tool in cardiac arrest in both the anesthesiology and cardiology published data (29–33). More recently, with the increased use of point-of-care ultrasound (POCUS), focused TEE is being performed in critical care settings such as the emergency department (ED) and intensive care unit (ICU). This was first described in 2008 as a novel use of POCUS (34). Subsequent studies have established that emergency physicians can obtain focused TEE images after a brief structured simulation-based training (6,35). In 2016, Arntfield et al. (14) reported the successful implementation of a focused TEE program in an ED. In this retrospective observational study, TEE was found to be feasible, safe, and clinically influential. In 78% of the examinations performed, there was a diagnostic impact on case management, which was commonly cited as excluding etiologies of cardiac arrest. An analysis based on the TEE diagnoses concluded that 55.6% of these examinations had findings that could not be easily visualized on TTE. In a study by the same group, point-of-care TEE was seen to exert considerable influence on diagnosis and hemodynamic management decisions in the ICU setting (36). These TEEs were appraised for their accuracy and found to compare favorably to comprehensive cardiologist-performed echocardiograms in this environment (37). Another recent prospective observational study, focusing specifically on ED cardiac arrest TEE, found that it was feasible to perform a focused TEE early in the resuscitation. These authors reported TEE to be a valuable diagnostic tool, with a therapeutic or prognostic impact in 97% of cases. The diagnoses included fine ventricular fibrillation, right ventricular dilation, and the presence of intracardiac thrombus. Aside from diagnosing pathology during an arrest, TEE can also be used for procedural guidance, including the placement of an intravenous temporary pacemaker and extracorporeal life support cannulae (38,39).

Guidelines for point-of-care applications of TEE in cardiac arrest support the use of focused TEE in a diagnostic capacity (16). Similarly, a policy statement from the American College of Emergency Physicians lists the identification of cardiac activity, identification of cardiac rhythm, evaluation of the left and right ventricular function, and identification of pericardial effusion/tamponade as the objectives of the focused TEE examination (40).

In the peri-operative setting, several studies have demonstrated the diagnostic impact of focused TEE during acute circulatory collapse (41,42) and cardiac arrest (29,42).

PROGNOSTIC ROLE OF TEE IN CARDIAC ARREST

Although early cardiac arrest management can focus on identifying and reversing suspected etiologies, it is likewise important to attempt prognostication regarding likelihood of survival and good neurological outcome. It has been shown that the patients with reversible causes of cardiac arrest such as pericardial tamponade carry the best prognosis, whereas patients with myocardial standstill have the lowest chances of survival (9).

The echocardiographic finding of myocardial standstill upon arrival to the ED was shown in a large multicenter prospective study to be predictive of poor outcome, whereas patients with presence of myocardial activity were more likely to be successfully resuscitated (9). In one of the largest focused TEE studies to date, Canadian authors reported on 274 consecutive TEE examinations in the ICU that were performed by a diverse group of physicians (36). Of these ICU patients, 20.1% of patients were in cardiac arrest at the time of TEE examination, and overall mortality was 43%. The focused TEE led to a change in management in 81% of the cases, including 3.7% in whom resuscitation was terminated. Furthermore, in nearly one-half of patients with a TTE performed in the prior 24 h, the indication for TEE was "inconclusive TTE," illustrating the earlier point that TTE can be technically limited in this population. Overall, this observational data shows that management decisions based on TEE findings can provide valuable prognostic information.

Last, the recognition of certain structural pathologies such aortic root dissection with pericardial involvement, aortic rupture, or cardiac chamber rupture as the etiology of the arrest may indicate very poor survival odds and lead to de-escalation of efforts (**Central Illustration**).

SAFETY AND COMPETENCY FOR THE PRACTICE OF FOCUSED TEE IN CARDIAC ARREST

The safety of TEE has been extensively studied across clinical settings including peri-operative, ambulatory, and intensive care environments. Focused TEE is a resuscitative procedure performed in critically ill patients who will routinely have a protected airway

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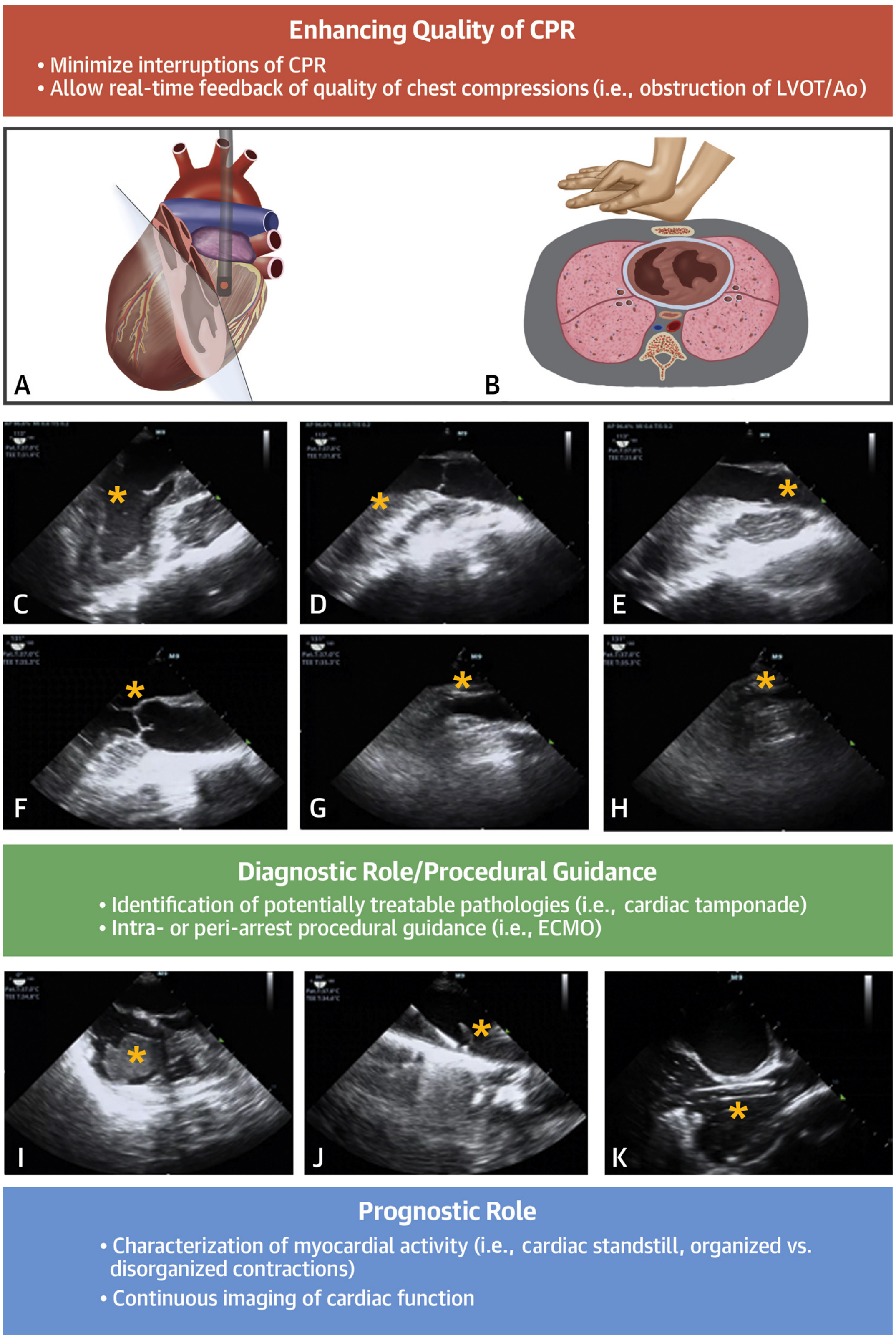
CENTRAL ILLUSTRATION Use of Focused Transesophageal Echocardiography During Cardiac Arrest Resuscitation



Teran, F. et al. J Am Coll Cardiol. 2020;76(6):745-54.

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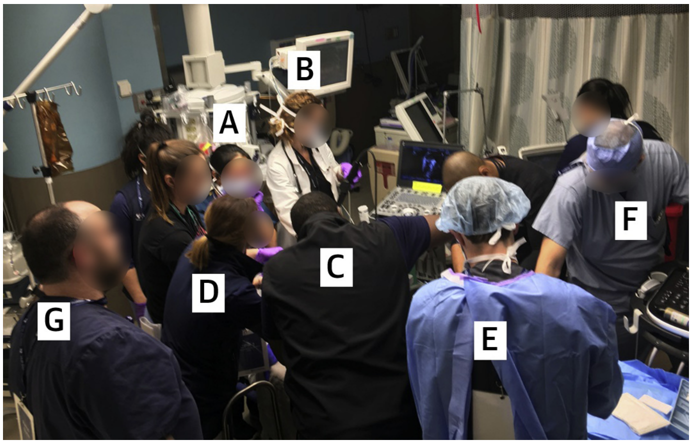
(with an endotracheal tube or tracheostomy). Respiratory consequences of the procedure, including aspiration and sedation, are therefore obviated. Further, deep anesthesia and/or neuromuscular blockade is typical for those not in cardiac arrest; this eliminates bucking and swings in intrathoracic pressure, which may confer additional safety advantages. The safety profile of focused TEE has not been studied directly and can only be inferred from the serious complications observed in larger case series composed primarily of ambulatory TEE examinations. Major complications such as serious oropharyngeal trauma, esophageal perforation, and major bleeding are overall quite rare with incidence rates between 0.01% and 0.08% (43-46). In addition to the sedation and airway distinctions, the context of the focused TEE examination alters the way any risk is perceived. Given the emergent nature of this resuscitative procedure, clinicians often have no information regarding patient's medical history including the possibility of contraindications (i.e., esophageal stricture). Nevertheless, the opportunity to obtain time-sensitive, lifesaving information, as is often the case in these resuscitative settings, has a powerful influence on the perception of risk. Some groups regard this as a sufficiently derisked, benefit-weighted procedure such that consent is not routinely sought out (36).

Despite the intuitively favorable risk-benefit ratio in cardiac arrest, practitioners should have knowledge and careful consideration of the potential negative effects of implementing TEE in this population. As is the case in adopting any advancement in medicine, providers necessarily take on risk whenever practicing beyond the local standard-of-care. In all cases, TEE in cardiac arrest should not be performed without the multidisciplinary collaborative approval of hospital leadership and all involved specialties. Given the relatively recent adoption of this practice, many unknowns remain. It is unclear if placement of the TEE in an emergent scenario or use during electrical defibrillations and chest compressions increase risk of damage to the transducer. Anecdotal evidence suggests that TEE transducers can withstand these forces without damage; however, the manufacturer's recommendations and warranty should be consulted. Last, there are recognized limitations of TEE in the setting of cardiac arrest such as observed findings related to the pathophysiology of the cardiac arrest, the chest compressions, and inotropic medications commonly used. Familiarity with these findings on TTE and having a pre-specified TEE protocol can avoid misdiagnosis (Table 1).

As TEE—focused TEE in particular—uptake continues to grow across many disciplines, we are arriving at an improved understanding of requirements for

FIGURE 2 Incorporation of Focused TEE During Cardiac Arrest Resuscitation Care



This figure depicts the use of focused transesophageal echocardiography (TEE) during the resuscitation of a patient with out-of-hospital cardiac arrest in the emergency department (ED). Emergency physician **(A)** has performed endotracheal intubation while a second physician **(B)** is performing TEE at the left side of the head of the bed. Other members in this team are performing placement of mechanical cardiopulmonary resuscitation (CPR) device **(C)**, administration of medications **(D)**, and venoarterial extracorporeal membrane oxygenation (ECMO) cannulation **(E and F)**, while the team leader **(G)** stands on the right side of the bed behind the other providers.

CENTRAL ILLUSTRATION Continued

During cardiopulmonary resuscitation (CPR), transesophageal echocardiography (TEE) allows the evaluation of chest compressions in real time. **(A)** The anterior-posterior plane of the heart visualized with mid-esophageal long axis view (ME LAX), corresponds to the same plane in which chest compressions are delivered during CPR **(B)**. **(C to H)** Intra-arrest ME LAX views during CPR. **(C)** The left ventricle (LV) is seen during the decompression phase with the mitral valve open **(asterisk)**. **(D)** Appropriate early LV compression **(asterisk)** with no obstruction of the left ventricular outflow (LVOT) or aortic root. **(E)** The aortic valve is open **(asterisk)** during the remaining compression phase, allowing stroke volume to be ejected. **(F to H)** Depiction of an example of complete obstruction of the aortic root during the compression phase of CPR, effectively impeding forward blood flow (**asterisks** show the location of the aortic root as it is progressively obstructed during the compression phase). **(I)** A large occlusive thrombus **(asterisk)** located in the right atrium seen in midesophageal 4-chamber view. **(J, K)** Use of TEE during cannulation for veno-arterial extra-corporeal membrane oxygenation (ECMO) during ongoing CPR. **(J)** An arterial guidewire **(asterisk)** is visualized in the descending thoracic aorta before dilation. **(K)** The position of a venous cannula **(asterisk)** is confirmed in bicaval view. Ao = aorta.

training and competency. Several acute care fields, including anesthesia, emergency medicine, and intensive care, have studied feasibility, training, and education for the practice of focused point-of-care ultrasound, including the use of focused TEE. Such efforts have shown that clinicians who have prior competence in focused TTE are quite capable at crossing over to TEE and are able to rapidly acquire the cognitive and motor skills necessary to perform and interpret TEE images (6,35,47,48).

For emergency physicians, a 4-view protocol designed to mimic the scope of 2-dimensional TTE endorsed as the standard of care has been taught durably (with 6-week retention evaluation) in a workshop using high-fidelity simulators (35). For an examination in the ICU setting, with higher sophistication including additional views and quantitative hemodynamic measurements, a mean number of 31 studies was shown to be necessary before competence was achieved (49). This same study, repeated with a simulation pre-training intervention, demonstrated a reduction in required in vivo examinations to achieve competence to an average of 14 examinations (49). These results, showing accelerated learning curves when high-fidelity TEE simulators are used as training aids, have also been demonstrated in more conventional training models, including cardiac anesthesiology and cardiology fellowships (50,51).

Although the exact scope and complexity of the TEE examination called for will vary by specialty and call for different intensities of training, it appears evident that simulation should be featured in the pedagogical designs across all specialties.

PRACTICAL ASPECTS OF PERFORMING TEE DURING CARDIAC ARREST

Cardiac arrests represent important logistic challenges for clinicians. Due to the need to perform multiple time-dependent interventions within minutes, a well-defined strategy to safely and efficiently incorporate cardiopulmonary ultrasound into the workflow of resuscitation is critical, particularly to minimize chest compression interruptions. Studies demonstrating the feasibility of focused TEE in perioperative, ED, and ICU settings describe specific protocols. In most peri-operative descriptions, TEE has been performed by the anesthesiologist in the case, or by an anesthesiologist trained in echocardiography who is called in to assist (29,33,41,42). In ED and ICU settings, TEE probe is inserted and operated by the emergency physician or intensivist respectively, usually as an additional provider that informs the team and code leader about the findings of the goal-directed examination (13,35,36,38,39). In all resuscitative settings, TEE takes place following endotracheal intubation, which can be performed by the same clinician or another member of the team. Studies using TEE during intra-arrest portion for the resuscitation (i.e., before ROSC), have reported the average time to first TEE image between 7 and 12 min from patient arrival (13,25,32). In all studies describing focused TEE in resuscitation, patients were intubated prior to TEE. In the case of ICU and peri-operative studies, patients were already intubated at the time of cardiac arrest. In ED studies, patients who had not been intubated during prehospital care were intubated at arrival and TEE was performed following intubation. Additionally, similar to the organization of trauma teams, most emergency medicine teams have pre-defined roles for each task that include a designated person to perform POCUS as well as focused TEE. This role-driven choreography is not specific to the performance of TEE but is rather the preferred approach employed by high-performing resuscitation teams to provide optimal care. The specific location of the ultrasound machine as the position of the providers varies depending on a number of factors, including the number of providers, specific roles defined, and the physical space in which resuscitations take place. The ultrasound machines used for focused TEE during resuscitations are the same machines used for other common emergency POCUS applications. Given that TEE transducers require specific storage and cannot remain with the machine, it is recommended that this storage location be easily accessible and close to the operating rooms, ICUs, or the high-acuity resuscitations rooms of the ED in which it will be most used. **Figure 2** depicts an example of the team organization during the use of focused TEE during the resuscitation of a patient with OHCA in the ED.

DEFINING PRIORITIES TO ADVANCE KNOWLEDGE ON THE USE OF TEE IN CARDIAC ARREST RESUSCITATION: A RESEARCH AGENDA

To date, only relatively small single-center observational studies have been published on the use of TEE in cardiac arrest. To further advance the knowledge regarding the potential of this modality as a tool during cardiac arrest, we believe there are several important areas of research.

1. Larger observational studies describing the diagnostic impact of TEE in cardiac arrest resuscitation (i.e., multicenter studies). Larger studies will

generate important information regarding the prevalence of specific diagnosis that can be made using TEE during cardiac arrest. Of particular importance is the identification of potentially treatable pathologies, such as pericardial tamponade, pulmonary embolism, myocardial infarction and aortic dissection.

2. Clinical studies evaluating the hemodynamic impact of real-time feedback provided by TEE in the delivery of chest compressions. As described in the previous text, several studies have shown the problem of LVOT compression during standard CPR, its hemodynamic implications, and its potential impact on survival outcomes. Studies designed to establish the hemodynamic impact of TEE-guided CPR optimization will be of great importance in the field of resuscitation science. These studies involving patient centered outcomes will need to carefully evaluate potential confounders such as increased physician presence and monitoring as well as biases toward the success of an innovative program.
3. Studies aimed at the development and validation of a standardized protocol for the use of TEE in cardiac arrest that maximizes diagnostic and prognostic value with a feasible and efficient set of views. A useful next step would be multidisciplinary expert consensus (i.e., Modified Delphi consensus) guidelines incorporating the best available evidence of TEE in resuscitation, including the description of a protocol that incorporates the prevalence of treatable pathologies.
4. Studies aimed to further characterize the learning curve in focused TEE for clinicians in acute care settings. Characterizing competency, defining number of studies needed to achieve a level of proficiency required to use TEE in cardiac arrest, and establishing differences between simulator-based training and live scanning (particularly in the setting cardiac arrest) will be key to further expand this modality.
5. Creation of a national or international registry for focused TEE.

CONCLUSIONS

The use of focused TEE during the resuscitation of patients in cardiac arrest and periarrest states has shown to be feasible and clinically impactful in the peri-operative, intensive care, and emergency settings. Although focused transthoracic cardiopulmonary ultrasound remains a critical tool in cardiac arrest allowing the identification of tension pneumothorax, cardiac tamponade, deep vein thrombosis or hypovolemia, its use during cardiac arrest can be limited by external and patient-related limiting factors. Providing continuous, high-quality images of the heart, TEE allows real-time feedback on the delivery of chest compressions, identification of reversible pathologies, and guidance of resuscitative procedures. These unique qualities make TEE ideally suited during resuscitation and has potential to improve cardiac arrest outcomes. Future research should include larger studies evaluating the diagnostic value and hemodynamic and clinical impact of TEE-guided resuscitation.

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KEY WORDS cardiac arrest, focused cardiac ultrasound, point-of-care ultrasound, resuscitation, transesophageal echocardiography