Transesophageal echocardiography during cardiopulmonary arrest in the emergency department

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Received 26 October 2007; received in revised form 10 February 2008; accepted 20 February 2008

Summary Management of patients in cardiopulmonary arrest is challenging and can be resource consuming. Outcomes continue to be poor and physicians may feel a sense of futility when running a resuscitation. Bedside ultrasound has been utilized to guide resuscitations, diagnose correctable cardiac pathology leading to an arrest and has proved to have a prognostic value when utilized in the initial stages of resuscitation. Bedside emergency ultrasound is limited by inability to scan during chest compression and poor image quality in obese patients and those with emphysema. During cardiopulmonary resuscitation pulse checks need to be rapid and leave little time for transducer manipulation during image acquisition. Recent American Heart Association guidelines further stress the need for quality chest compressions and minimizing intervals with no compressions. Transesophageal echocardiography offers high resolution and clarity of images in the vast majority of patients. It allows for constant visualization of the heart, even during chest compressions, cardioversion and other procedures. This case series describes the use of transesophageal echocardiography (TEE) during cardiac arrest by emergency physicians. The cases illustrate some of the potential benefits of TEE during cardiopulmonary arrest.

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Introduction

Patients in cardiopulmonary arrest present a special challenge to the clinician, regardless of setting. Whether being evaluated in the pre-hospital arena, emergency department or intensive care unit, the etiology of sudden cardiopulmonary arrest may not be evident in many cases. However, undetected pathology such as cardiac tamponade, myocardial rupture or pulmonary embolism may require specific and critical interventions that would not be otherwise undertaken in the majority of cardiopulmonary arrest patients.1–3

Focused bedside echocardiography is advocated more frequently for evaluation of critically ill patients.4–6 Previous studies have shown that non-imaging specialist physicians can accurately determine ejection fraction and
grade myocardial impairment. Focused echocardiography has also been shown to predict negative outcome in patients found to have true, echocardiographic, asystole upon presentation to the emergency department. In addition bedside echocardiography has been shown to accurately detect critical pathology and direct resuscitative efforts.

The majority of published case reports and studies on bedside echocardiography in patients suffering cardiopulmonary arrest describe the use of transthoracic echocardiography. Transthoracic echocardiography (TTE) may be limited by a number of factors that degrade image quality or even make image acquisition impossible. Transesophageal echocardiography (TEE) is not affected by body habitus, subcutaneous air, emphysema or many of the other factors limiting transthoracic scans and would seem an ideal choice in cardiopulmonary arrests. This series describes six illustrative cases where TEE offered distinct advantages over TTE scanning in patients suffering cardiopulmonary arrest and undergoing CPR. These cases were selected from among 15 TEE resuscitation cases occurring over a 6-month period at a large tertiary care emergency department. The emergency physician performing the TEE examinations met American College of Emergency Physicians training guidelines for emergency ultrasound as well as having additional experience and training in emergency echo. TEE training consisted of a commercially available 2 h instructional DVD.

**Case 1**

A 35-year-old patient with a history of hypertension, drug and alcohol abuse was brought in by EMS with CPR in progress. The patient’s family found him down at home and initiated bystander CPR. The patient had been intubated and received two rounds of epinephrine for pulseless electrical activity. On arrival he was transferred to the bed and pulses were checked. An attending physician noted no pulses at two locations and chest compressions were restarted. During the pause a focused echo revealed a highly limited view and no cardiac movement was discerned. Parasternal and apical views were attempted but also failed. Endotracheal tube placement was confirmed and a right femoral central line was placed.

One more epinephrine dose was administered but there was no return of pulses, and the senior resident decided to end the resuscitation. At this time a TEE transducer attached to a SonoSite MicroMaxx (Bothell, Washington, USA) ultrasound machine was introduced into the esophagus and a four-chamber view of the heart obtained. The TEE revealed myocardial contraction with an EF of 15%. A rapid check of the carotids revealed flow on color Doppler for pulseless electrical activity. On arrival he was transferred to the bed and pulses were checked. An attending physician noted no pulses at two locations and chest compressions were restarted. During the pause a focused echo revealed a highly limited view and no cardiac movement was discerned. Parasternal and apical views were attempted but also failed. Endotracheal tube placement was confirmed and a right femoral central line was placed.

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**Case 2**

A 73-year-old obese female with hypertension and bronchitis presented with increased difficulty breathing and a room air oxygen saturation of 92%. CXR was unremarkable and blood work was sent. Two hours later the patient was noted to have a decreased level of alertness and tachypnea. She was intubated and arrested shortly after. The monitor showed asystole and ACLS protocol was initiated with a right femoral line placed for epinephrine and atropine. Blood work analysis was still not completed and a call was placed to the laboratory.

A bedside echo, first using the subxiphoid, then parasternal and finally apical views yielded poor quality images that showed myocardial standstill. A TEE transducer was then inserted and while the monitor indicated asystole, clearly

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**Figure 1** Color Doppler flow image of the carotid artery (CA) and internal jugular vein (IJ) during the arrest is shown. This image captures flow in both the carotid and jugular. There was no time to optimize color Doppler flow parameters during this evaluation.

**Figure 2** Pulse wave Doppler shows flow in the carotid artery, where its gate is located. In this image flow up to 60 cm/s is noted. There was not time during the arrest to optimize pulse wave Doppler flow parameters.
showed ventricular fibrillation. The patient was shocked with real time monitoring with TEE and given amiodarone. She then appeared to be largely asystolic, but had an occasional electrical beat on the monitor. The TEE however showed good contractility with each rare beat. Transcutaneous pacing failed to capture and a transvenous pacer was placed but also failed to capture. CPR continued for approximately 30 min with real time monitoring on TEE. As the code was drawing to an end, the laboratory called with potassium of 9.4.

Kayexalate was administered orally and rectally and the patient was then given bicarbonate, calcium, insulin and glucose at total of three times while CPR continued with ongoing TEE monitoring. Several persons delivering chest compressions were changed out due to obvious inadequate force based on TEE. On one pulse check 30 min after the potassium report, TEE revealed good contractions with estimated ejection fraction of 50%. No peripheral pulses were noted and CPR was automatically restarted but the physician ordered a halt to the compressions. Ultimately the patient was determined to have a urinary tract infection leading to urine retention, acute renal failure, hyperkalemia and cardiac arrest. She was released from the ICU, at her baseline mental state, after 8 days never requiring dialysis.

Case 3

A 73-year-old female with a history of hypertension complained of sudden onset shortness of breath at home and collapsed in her chair at dinner. She was intubated in route by EMS and received two rounds of epinephrine and atropine for asystole. Just prior to arrival she had spontaneous return of circulation with a pulse and blood pressure of 88 mmHg systolic. Pulses were confirmed by nursing staff on arrival but a bedside echo from the subxiphoid approach but appeared to show no cardiac activity. The parasternal and apical views were unobtainable. A resident physician confirmed femoral pulses and the monitor showed a heart rate of 60 beats/min. However, the attending EP introduced a TEE probe and visualized myocardial standstill.

CPR was restarted and the patient given epinephrine through a femoral central line. TEE showed good compressions and blood flow through mitral and tricuspid valves. On pulse check the patient was noted to be asystolic on monitor and without a pulse. TEE showed ventricular fibrillation and the patient was shocked. The TEE showed the shock and immediate cessation of ventricular fibrillation followed by return of spontaneous circulation and good myocardial contractility on TEE. After several minutes the patient’s heart rate slowed on TEE, which was being used for continuous resuscitation monitoring. Dopamine was started and CPR resumed. A check three minutes later revealed good myocardial contractility and CPR halted, but pulses were not found for another minute. After several minutes the patient again became asystolic on TEE, but continued to have bradycardic rhythm on monitor. TEE also showed a thrombus leaving the right atrium and entering the right ventricle, which was not noted before, Figure 1. The patient was given an 80 mg bolus of TPA and started on heparin. Despite several more episodes of asystole and ventricular fibrillation the patient made it to the ICU on a dopamine drip. Dopamine was slowly weaned off but the patient suffered multiple complications including pneumonia and line infection and expired in the hospital 3 weeks later secondary to a brain hemorrhage while on warfarin.

Case 4

A 45-year-old male with a history of hypertension and osteomyelitis who was being treated with home intravenous antibiotic infusion through a PICC line collapsed at home shortly after infusion began. On arrival EMS found the patient to be in ventricular fibrillation with CPR ongoing. They administered amiodarone and several shocks in route to the ED. No pulse was regained despite transient return of sinus rhythm on the monitor, and the patient would quickly go into ventricular fibrillation.

On arrival in the ED the obese male was transferred to the bed and CPR continued. No pulses were palpable and a focused emergency echocardiogram from the subxiphoid window indicated cardiac standstill. The parasternal and apical views were unobtainable. A TEE probe was inserted while CPR continued. At a pulse check no pulse was detected and the monitor showed either asystole with poor baseline or possible ventricular fibrillation. The TEE however showed clear ventricular fibrillation but also revealed a catheter tip moving in the entrance to the right atrium periodically striking the wall, Figure 2. A decision was made to pull back the PICC line several centimeters. The PICC line was pulled back and CPR continued but the PICC line was accidentally pulled out completely. After another shock the patient regained sinus rhythm on the monitor and although no pulses were detected the TEE showed myocardial contractions with a moderately depressed ejection fraction of about 30%. Chest compression was discontinued and an arterial line placed under ultrasound guidance revealed a blood pressure of 83/44 mmHg. The patient was started on a dopamine drip, which had to be weaned off after 30 min due to hypertension. He was admitted to the cardiology service and catheterization showed normal coronaries but the patient went into ventricular tachycardia and then fibrillation easily from the catheterization. He was discharged on amiodarone (Figures 3 and 4).

Case 5

A 37-year-old male with a history of DVT and PE secondary to a hypercoagulability disorder, who had recently stopped taking coumadin, was brought in after complaining of chest pain and shortness of breath. On arrival into the ED he arrested, was intubated and a central line was placed and ACLS protocol initiated. A subxiphoid echo was performed and showed asystole with no pulses felt. Another pulse check was performed and echo showed bradycardia with a markedly depressed EF of approximately 5%. Although the right ventricle and septum were difficult to visualize a presumptive diagnosis of PE was made and TPA was called for as CPR continued. A TEE probe was introduced during chest compressions and revealed no RV or ventricular septal movement abnormalities and showed a proximal aortic dissection. TPA administration was cancelled and thoracic surgery emer-
Figure 3  This TEE image shows a thrombus (arrows) traversing from the right atrium (RA) into the right ventricle (RV). The left ventricle (LV) and aortic outflow tract (AO) are labeled for reference.

gently consulted. The patient was taken to the operating room emergently without a CT angiogram due to low blood pressures. The dissection was confirmed at surgery and the patient survived synthetic aortic graft placement but had a prolonged postoperative course that included pneumonia, renal failure and a mild CVA. He was released after 2 months to rehabilitation but was expected to make a near complete recovery.

Case 6

A 61-year-old female with a history of HTN, COPD and breast cancer collapsed at home after complaining of shortness of breath. The patient was given two rounds of ACLS medications in route by EMS. Pulses were transiently regained and then lost during the 15-min transport time. The patient experienced ventricular fibrillation once and was shocked out of it to PEA. On arrival the patient had no pulses, a junctional rhythm, was being bagged and had a left tibial interosceous needle in place. The patient was intubated and a femoral central line was placed. After one more dose of epinephrine a focused echo was performed and showed myocardial contractions with severely depressed function. The right atria and ventricles appeared dilated, but the images were limited due to body habitus and emphysema. Both lungs had a normal sliding lung sign on ultrasound and TPA was readied for possible pulmonary embolism.

CPR was paused and the patient’s rhythm was ventricular fibrillation, the patient was given amiodarone and shocked. Asystole appeared on the monitor and CPR continued. TEE revealed greatly improved images and showed little right heart strain and no paradoxical movement of the ventricular into the left ventricle and was consistent with chronic right atrial and ventricular dilation. No thrombus was seen in the right atria or ventricle and was TPA held. While the monitor showed asystole again, TEE revealed fine ventricular fibrillation and the patient was shocked. She regained a bradycardic rhythm with a weak pulse and an estimated ejection fraction of 10%. The patient was started on Dopamine at 20 mcg/(kg min) and slowly increased her rate to 100 beats/min and systolic blood pressure to 125 mmHg.

A CT angiogram was negative for PE but a head CT revealed a small traumatic subdural. Twenty-four hours after admission to the ICU her condition suddenly declined and she expired after a prolonged code in the ICU.

Discussion

Resuscitation of patients in cardiopulmonary arrest has always been a difficult task. Despite the introduction of ACLS training and public emergency medical systems, outcome is still dismal with less than 11% surviving to hospital discharge in most studies. One of the primary difficulties is that physicians are typically working blind. Electrocardiogram monitoring during a cardiac arrest provides some information about cardiac electrical activity, but fails to define myocardial status to any great extent. Bradycardia for instance in no way determines whether the ejection fraction is good or poor. Similarly, in a patient with tachycardia and hypotension or lack of pulses the heart may have essentially no contractions or be working vigorously and the physician could be non-the wiser. What appears to

Figure 4  (A) PICC line tip in the right atria (RA) in short axis. (B) an oblique view focusing on the superior vena cava (SVC) inlet shows the catheter in long axis. (LA, left atrium; LV, left ventricle; RV, right ventricle; OA, aortic outflow tract.)
be electromechanical dissociation may actually represent myocardial contractions without pulses.

In order to obtain more information about their patient’s myocardial status, emergency physicians began to adopt bedside echocardiography almost 20 years ago. Initial indications focused on identification of pericardial effusion and cardiac tamponade as the cause of cardiopulmonary arrest. In the last decade emergency physicians have also shown the utility of evaluating cardiac contractility, detecting lack of cardiac activity and utilizing it as a predictor of bad outcome. A number of studies have described other applications of bedside ultrasound in the evaluation of patients in cardiopulmonary arrest. These include detection of ventricular fibrillation not otherwise evident on electrocardiogram and discovery of unsuspected causes of arrest such as free wall rupture or pulmonary embolism.

Recent cardiac arrest guidelines specify limiting breaks from quality chest compression and do suggest the utility of focused echo during resuscitation. However, transthoracic echo can encounter obstacles ranging from suboptimal images limiting interpretation to inability to obtain any useful image. Transesophageal echocardiography is not typically utilized by emergency physicians. TEE is thought of as a more advanced application of cardiac ultrasound and the transducers are considerably more expensive than phased array transthoracic cardiac probes. The price difference is typically threefold. Limitations to TEE imaging come from the introduction of air between the probe and stomach if gastric decompression has not been completed. Mechanical and prosthetic valves will cause shadowing and create interference similar to TTE imaging. All of the typical ultrasound artifacts that plague abdominal, soft tissue and TTE imaging can also be encountered with TEE and require general ultrasound experience in order to improve image quality and avoid misinterpretation. Use of TEE will require additional training that can vary depending on degree of previous experience and the individuals use requirements.

TEE does offer several advantages over the standard transthoracic approach. The TEE probe is placed into the esophagus, giving it optimal distance and acoustic window to visualizing the heart. Neither the enlarged lungs of chronic obstructive pulmonary disease patients nor additional adipose tissue of the many patients interfere to a significant degree with TEE imaging. The chambers are seen with greater detail, enough that cardiologists comfortably rule out the presence of thrombus in the atria prior to cardioversion of patients in atrial fibrillation. Valves and wall motion can be seen with great detail and allow for a close assessment of vegetations and valve failure. TEE also allows for excellent evaluation of diastolic function, adult congenital heart disease, intracardiac masses and other pathologic states that will typically be less critical to the clinician running a cardiopulmonary resuscitation.

As indicated in the cases presented, TEE offers some very specific advantages in the cardiopulmonary arrest patient in the emergency setting. Once placed, the TEE probe may be left in during the entire resuscitation and may require little to no manipulation. Much like an overhead cardiac monitor, it allows all members of the resuscitation team to monitor progress. It can even be left in place during cardioversion as it is electrically isolated. The quality of chest compressions can be assessed by directly watching the heart during the compressions. Blood flow across valves may be measured with color Doppler. Further, it is typically obvious on visual inspection if the walls of the chambers are moving inward with compressions and if the chambers are changing in size to suggest filling and emptying during CPR. Most importantly, in accordance with recent guidelines, is that any break for a pulse or cardiac activity checking can be shorter than when relying on a transthoracic probe. In fact, the physician can leave the transducer in place and watch the heart on the ultrasound machine’s screen while he or she performs other vital functions such as placement of central lines and management of the resuscitation process.

Perhaps most helpful is the ability of identify pathology with higher certainty than that allowed by most TTE scans. For instance, the differentiation of PE versus dissection in case 5 and identification of an unsuspected PE in case 3 led to a change in management that may not have been possible otherwise. TEE may have additional utility in the emergency setting such as trauma patients with potential thoracic aorta injuries who are not stable enough for transfer for computed tomography. The learning curve with TEE use after attaining competency with TTE does not appear to be significant, but has not been well studied. The anatomy seen on TEE is much more clearly defined and one of the most difficult aspects is mastering manipulation of the simple controls present on a TEE transducer. Anatomy is seen so much more clearly that it is somewhat akin to the anatomical drawings most physicians are used to from anatomy courses and textbooks.

In summary, these cases illustrate potential advantages of TEE use in the emergency department for patients presenting in cardiopulmonary arrest. Further work will need to be performed to delineate cost effectiveness and impact on outcome as well as training requirements for focused applications.

Conflict of interest

None declared.

Appendix A. Supplementary data


References

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