Transesophageal Echocardiography During Cardiopulmonary Resuscitation (CPR-TEE)

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Background: To take full advantage of transesophageal echocardiography (TEE) during cardiopulmonary resuscitation (CPR), we propose a flowchart derived from representative cases.

Methods and Results: TEE was used in patients requiring CPR to obtain information potentially helpful for rescue. TEE navigated the CPR procedures (navigation TEE), identified the possible cause of arrest (focus TEE), and optimized treatment while checking for pitfalls (secure TEE). In addition, TEE corrected prehospital misdiagnoses and detected new complications caused by CPR.

Conclusions: TEE provides valuable information without interrupting CPR procedures. It is hoped that our flowchart may facilitate goal-directed, efficient assessment.

Key Words: Cardiopulmonary resuscitation; Transesophageal echocardiography

Cardiopulmonary resuscitation (CPR) has been standardized and updated based on evidence derived from clinical trials and basic investigations. Although the rescue of patients with structural cardiovascular diseases could be inadequate without specific treatment, diagnostic measures available during CPR are limited. Percutaneous cardiopulmonary support (PCPS) is helpful for this purpose, but cannulation without fluoroscopic guidance has a risk of cannula misplacement or migration, or vascular damage. Although transthoracic echocardiography has been endorsed by guidelines as a potentially useful diagnostic modality for patients in cardiac arrest, assessment during CPR is limited and requires interruption of chest compression. Thus, transesophageal echocardiography (TEE) has been used. Although reviews and guidelines for CPR-TEE have been published, TEE is not yet commonly used in Japan, probably because of a lack of awareness of its benefits, concerns regarding potential complications, or the need for clinician expertise. Thus, the establishment of an education system and algorithm for TEE assessment has become important, because it may improve treatment as well as reduce the duration of treatment interruption, as is the case with transthoracic echocardiography. With the hope of promoting this approach, 4 representative cases are presented and a flowchart of CPR-TEE that visually summarizes what to examine is proposed.

Methods

The basic protocol for CPR-TEE is as follows. TEE is started as early as possible following tracheal intubation.
Case 3
A woman in her 60s with chest pain and dyspnea suddenly developed cardiac arrest. TEE was started immediately following tracheal intubation and detected PTE, although no apparent aortic or coronary disease was detected. Because the heart was in standstill and cardiac compression for longer than 30 min failed to restore contraction or even VF, endocardial pacing was attempted. When the pacing lead appeared in the right atrium as a linear, highly echogenic image with a narrow acoustic shadow (Figure 2B), the balloon was inflated, as identified by side lobes artifact with a wide acoustic shadow (Figure 2C), similar to the inflated balloon of a pulmonary artery catheter. As the
TEE in CPR

of cardiac arrest, such as myocardial infarction or PTE, which allows early diagnosis and decision making for initiating specific treatment. However, CPR-TEE is not adequately used in Japan, probably because of concerns about the risk of TEE probe manipulation during CPR procedures and the need for expertise in making a correct diagnosis in such an extraordinary situation. Thus, to facilitate the introduction of CPR-TEE, the proposed flowchart of CPR-TEE categorizes the assessments into 3 groups: (1) “navigation TEE” for efficiently navigating CPR procedures along the Adult Cardiac Arrest Algorithm; (2) “focus TEE” for identifying the cause of cardiac arrest while excluding other pathologies; and (3) “secure TEE” for assuring the efficacy and safety of the interventional procedures (Figure 4).

“Navigation TEE” is started as soon as the TEE probe is introduced to evaluate the CPR procedures. The efficacy of chest compression is evaluated, as it may be inadequate (case 2) or cause unexpected complications, such as pericardial hemorrhage (case 4), which potentially limits resuscitation efficacy. Although the latter can be detected easily by transthoracic echocardiography, TEE is capable of detecting its presence and monitoring progression without interrupting the CPR procedures. In addition, the heart rhythm is checked to determine whether it is shockable, as ECG monitoring can be misleading.10 Despite a flatline ECG, the heart may be fibrillating, which can be visually recognized by TEE (case 2). Defibrillation can be precisely applied based on navigation TEE. When the heart is in standstill, external or endocardial pacing should be used. If fluoroscopic guidance is not available in the emergency room, the placement of a pacing lead can be guided by TEE (case 3).

Figure 3. Sequential changes during resuscitation in case 4. (A) Severe hypovolemia with some pericardial fluid. (B) Recovery of the right atrium (RA) after infusion. (C) Progressive pericardial tamponade. (D) Large echo-free space in the abdomen (transgastric approach). LA, left atrium; RV, right ventricle.

CPR-TEE was first reported in 1997,8 and a prospective study, a literature review, and guidelines have been recently published.10–12 Although the AHA guidelines recommend CPR procedures guided by a pulse check and rhythm analysis,14 TEE is capable of identifying reversible causes of cardiac arrest, such as myocardial infarction or PTE, which allows early diagnosis and decision making for initiating specific treatment. However, CPR-TEE is not adequately used in Japan, probably because of concerns about the risk of TEE probe manipulation during CPR procedures and the need for expertise in making a correct diagnosis in such an extraordinary situation. Thus, to facilitate the introduction of CPR-TEE, the proposed flowchart of CPR-TEE categorizes the assessments into 3 groups: (1) “navigation TEE” for efficiently navigating CPR procedures along the Adult Cardiac Arrest Algorithm;14 (2) “focus TEE” for identifying the cause of cardiac arrest while excluding other pathologies; and (3) “secure TEE” for assuring the efficacy and safety of the interventional procedures (Figure 4).

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cannulation was made without hesitation based on TEE findings. In case 4, TEE clarified the reason for difficult cannulation prior to PCPS and optimized the CPR procedure by stepwise confirmation, leading to a good outcome. In patients with disappointing outcomes, the treatment process and/or strategies must be reviewed; information on what took place in the body makes discussion fruitful. Although necropsy and autopsy imaging provide morphological information, CPR-TEE may function as “pre-autopsy imaging”, because it provides both structural and hemodynamic information at the bedside repeatedly or even continuously. The exclusion of several diseases allows for a more focused discussion.

Concern about potential complications and the expertise needed for CPR-TEE may be reasons why TEE is not commonly used in Japan. The risk of complications, such as esophageal perforation or mucosal damage, should be kept in mind, although there is no literature on the safety of CPR-TEE. TEE should not be used in cases of potential injury in the upper gastrointestinal tract or when unusual resistance is encountered while advancing the probe.

The time needed for TEE assessment is a concern. Even for experienced examiners, it can be difficult and time-consuming to diagnose unexpected events. This is exactly the reason why a flowchart for CPR-TEE is presented here: when and what to check during CPR.

“Focus TEE” is diagnostic imaging to be done at the earliest opportunity. Identification of etiology early during CPR is important, because it allows for selection of subsequent treatment as well as for assembly of the necessary staff. TEE can be useful because it is capable of visualizing almost the entire region of the heart and great vessels, and identifying the main causative diseases at the bedside, including (1) extreme hypovolemia; (2) acute myocardial infarction; (3) aortic dissection or ruptured aneurysm; and (4) PTE, as well as related pathologies such as pericardial tamponade, hemоторax, hemomediatinum, or malperfusion of vital organs (heart, brain, and visceral organs), which can be shared with surgeons because these conditions will affect the treatment strategy.

“Secure TEE” is interactive imaging to assure the safety and certainty of the treatment procedures: (1) interventions are visually guided; (2) results are immediately evaluated; and (3) occurrence of unintended complications is checked. Real-time imaging allows for monitoring the adequacy of infusion/transfusion (case 4) or efficacy of pericardial or pleural drainage. When PCPS is used, blind cannulation may lead to cannula misplacement (case 1). Although echo-guided cannulation is desirable, it is not easy to distinguish between an artery and vein. It is recommended that the appearance of a guidewire in the aorta or inferior vena cava should be confirmed by TEE. If PCPS has already been started, potential catheter misplacement can be checked by the direction of aortic blood flow and drainage of the cardiac chambers. In case 1, the decision for cannulation was made without hesitation based on TEE findings. In case 4, TEE clarified the reason for difficult cannulation prior to PCPS and optimized the CPR procedure by stepwise confirmation, leading to a good outcome. In patients with disappointing outcomes, the treatment process and/or strategies must be reviewed; information on what took place in the body makes discussion fruitful. Although necropsy and autopsy imaging provide morphological information, CPR-TEE may function as “pre-autopsy imaging”, because it provides both structural and hemodynamic information at the bedside repeatedly or even continuously. The exclusion of several diseases allows for a more focused discussion.

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The time needed for TEE assessment is a concern. Even for experienced examiners, it can be difficult and time-consuming to diagnose unexpected events. This is exactly the reason why a flowchart for CPR-TEE is presented here: when and what to check during CPR. Although undetected events may be present, such as thrombus formation in the arch branches in a patient with PTE, because cardiac arrest per se is an unforeseen event, further exploration for

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**Figure 4.** Flowchart of transesophageal echocardiography in cardiopulmonary resuscitation (CPR-TEE) in 3 categories of assessment. AMI, acute myocardial infarction; ECG, electrocardiography; IV, intravenous; LV, left ventricle; OR, operating room; PCPS, percutaneous cardiopulmonary support; PEA, pulseless electrical activity; PTE, pulmonary thromboembolism; pVT, pulseless ventricular tachycardia; ROSC, recovery of spontaneous contraction; TEE, transesophageal echocardiography; VF, ventricular fibrillation.
such events is not always needed unless hemodynamics or other findings are accounted for with the known data. Nonetheless, the time needed for assessment depends on the experience of the examiner, and thus education is important. A number of teaching materials that are currently available would be helpful for learning assessment in the above 3 categories, as the number of pathologies to be checked is limited. If emergency physicians are unfamiliar with TEE, experienced cardiologists or anesthesiologists can cooperate as a team because they may be involved in subsequent treatment.

It should be stressed that CPR-TEE does not obscure the standard CPR procedures, but potentially optimizes them by providing information that would not be obtained otherwise, as shown in the representative cases. The author hopes that the flowchart of CPR-TEE will be helpful for this purpose.

COI

Nothing to declare.

IRB Information

Granted an exemption from requiring ethics approval by institutional ethics committee of Kochi Medical School.

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