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Diagnostic Accuracy of Transesophageal Echocardiography During Cardiopulmonary Resuscitation

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Objectives. **We sought to establish the diagnostic accuracy of transesophageal echocardiography (TEE) during cardiopulmonary resuscitation.**

Background. **Because of its bedside diagnostic capabilities, excellent cardiac images and lack of interference with resuscitation efforts, TEE is ideally suited to determine the cause of a circulatory arrest that is not due to severe arrhythmia. However, the diagnostic accuracy of TEE during resuscitation is unknown.**

Methods. **TEE was performed in patients with prolonged circulatory arrest. The TEE diagnoses were compared with diagnoses from autopsy, surgery and clinical follow-up.**

Results. **Of the 48 study patients (29 male, 19 female, mean age ± SD 61 ± 20 years), 28 had an in-hospital cardiac arrest and 20 an out-of-hospital onset of arrest. Forty-four patients eventually died; four survived to discharge. The diagnoses made with TEE were cardiac tamponade (n = 6), myocardial infarction (n = 21), pulmonary embolism (n = 6), ruptured aorta (n = 1), aortic dissection (n = 4), papillary muscle rupture (n = 1), other diagnosis (n = 2) and absence of structural cardiac abnormalities (n = 7). A definite diagnosis from a reference standard was available in 31 patients. The TEE diagnosis was confirmed in 27 of the 31—by postmortem examination (n = 19), operation (n = 2), angiography (n = 2) or clinical course (n = 4). In the other four patients the TEE diagnosis proved incorrect by postmortem examination. The sensitivity, specificity and positive predictive value of TEE were 93%, 50% and 87%, respectively. In 15 patients (31%), major therapeutic decisions were based on TEE findings.**

Conclusions. **TEE can reliably establish the cause of a circulatory arrest during cardiopulmonary resuscitation.**

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Transesophageal echocardiography (TEE) facilitates the diagnosis in emergency situations like massive pulmonary embolism, papillary muscle rupture and dissection of the thoracic aorta (1–4). Because it can be done at the bedside within minutes after a cardiac arrest code call and does not interfere with ongoing resuscitation efforts, it is ideally suited to determine the cause of a circulatory arrest. However, its efficacy in determining the cause of a circulatory arrest is unknown. In this study we investigated the efficacy and accuracy of TEE in patients with circulatory arrest who were undergoing cardiopulmonary resuscitation after in-hospital or out-of-hospital onset of resuscitation. In addition, we examined the influence of TEE on therapeutic management.

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Methods

Patients were included in our study if they were resuscitated by the resuscitation team that is operational on all wards and all hospital and university facilities within the hospital building, including the emergency room but not the intensive care unit. The team is trained in advanced life support according to the guidelines of the American Heart Association and the European Resuscitation Council (5,6). The investigators were notified through the code call system and arrived with the echocardiographic equipment ~5 min after the call. Patients were included if they were >18 years old and were still in circulatory arrest after initial resuscitative measures and endotracheal intubation. Patients were excluded if they had known esophageal disease.

The study was approved by the hospital ethics committee, considering that no informed consent could be obtained from unconscious patients but that each patient had a potential benefit from inclusion in the study.

A 5-MHz transesophageal ultrasound probe was inserted into the esophagus, either with or without laryngoscopic guidance. An aortic valve view, a pulmonary artery view, a four-chamber view, a transgastric short-axis view and visualization of the descending aorta were obtained by using a multiplane probe with a Sonos 1500 echocardiographic unit (Hewlett-

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Abbreviations and Acronyms

TEE = transesophageal echocardiographic, transesophageal echocardiography
TTE = transthoracic echocardiography

Packard) or a monoplane probe with a 77020A echocardiographic unit (Hewlett-Packard).

Diagnostic criteria. Regional ischemia or myocardial infarction was suspected when there was a difference in contractility of parts of the myocardium during spontaneous contractions with or without effective cardiac output. Pulmonary embolism was suspected in the presence of dilation of the right ventricle and right atrium, together with poor filling of the left atrium and left ventricle. Pericardial tamponade was defined as pericardial effusion with collapse of one or more cardiac chambers. A free moving intimal flap in the ascending or descending aorta was indicative for an aortic dissection, with or without tamponade. A papillary muscle rupture was defined as a flail mitral valve leaflet with a part of the papillary muscle head swinging through the mitral ostium.

Outcome criteria. Return of spontaneous circulation was defined as spontaneous heart rhythm with a palpable pulse lasting ≥5 min and allowing transfer to the intensive care unit. Shorter periods of spontaneous circulation were considered as no return of spontaneous circulation for this study. Survival was defined as discharge from the hospital alive.

Reference standard. When available, autopsy was considered the reference standard for comparison of the echocardiographic diagnosis for patients who died. Otherwise, and for survivors, pertinent data from surgical reports, angiography, laboratory tests, echocardiography during stable rhythm and hemodynamic status and alternative imaging techniques were used as the reference standard.

Statistical analysis. For the calculation of sensitivity and specificity a true positive result was defined as a TEE diagnosis confirmed by a reference method and a false positive result as a diagnosis that could not be confirmed. A true negative result was defined as the absence of a TEE-detectable cause of the circulatory arrest, where the reference method confirmed the absence of structural changes to the heart and great vessels. When the TEE study failed to find a cause for the arrest, but the reference method revealed a diagnosis that could have been detected by TEE, the result was termed a false negative result. The relation between outcome and other variables was analyzed with a Kruskal-Wallis test.

Results

From December 1992 to February 1995, TEE was performed in 48 patients with a circulatory arrest lasting >5 min. Twenty of these patients had an out-of-hospital arrest and underwent resuscitation attempts before their arrival at the emergency room; in 28 patients cardiac arrest occurred in the hospital. The mean age ± SD was 61 ± 20 years (range 23 to 90). Nineteen patients were female, 29 were male. The mean time from code call to start of TEE was 16.9 ± 9.8 min. The initial rhythm on arrival of the resuscitation team was electromechanical dissociation in 11 patients, bradycardia in 14, asystole in 11, ventricular fibrillation in 9 and sinus rhythm with output in 2. The initial rhythm was not recorded in one patient. Adequate images were obtained in all 48 patients.

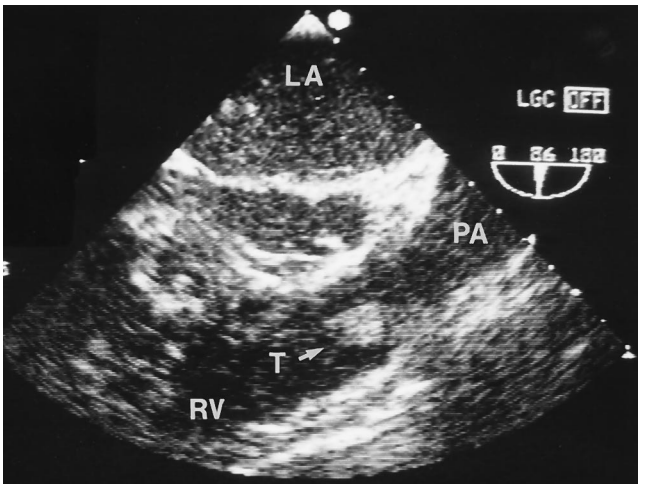

Figure 1. Transesophageal echocardiogram, long-axis view, from a patient with pulmonary embolism. The embolus (T) can be seen extending through the pulmonary valve in the right ventricle (RV). LA = left atrium; PA = pulmonary artery.

In 41 patients a diagnosis was established by TEE: myocardial infarction in 21; tamponade in 6; pulmonary embolism in 6 (of whom 2 had visible emboli in the right heart side) (Fig. 1); papillary muscle rupture in 1 (Fig. 2); dissected thoracic aorta in 4, including 1 with tamponade and 1 due to ruptured abdominal aortic aneurysm; traumatic rupture of the thoracic aorta with severe blood loss in 1; supraventricular tachycardia without other cardiac abnormalities in 1; and end-stage pulmonary hypertension in 1. The latter diagnosis was known to the resuscitation team and the investigator; the TEE findings did not differ from those of patients with acute pulmonary hypertension due to pulmonary embolism, although no emboli were found. In seven patients TEE found no structural cardiac abnormalities and could not establish the cause of the circulatory arrest. The TEE diagnosis had a major impact on treatment in 15 patients (31%).

One patient had a late cardiac tamponade after coronary bypass surgery that was not visible on transthoracic echocardiography (TTE) owing to poor acoustic windows but was evident on TEE; surgical treatment was successful in this patient. Thrombolytic therapy was successful in one patient with myocardial infarction but failed in two patients with suspected pulmonary embolism. In one patient with an aortic dissection and one patient with a papillary muscle rupture the TEE diagnosis and the temporary return of spontaneous circulation led to arrangements for immediate surgery. However, resuscitation attempts were terminated in both patients

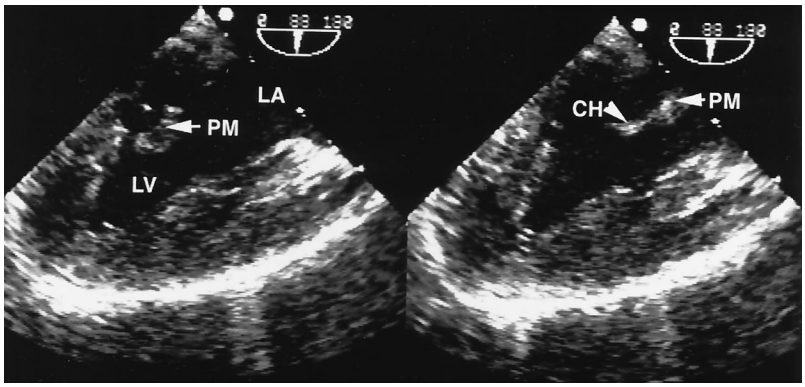

Figure 2. Transesophageal echocardiograms, long-axis view, from a patient with papillary muscle rupture. **Right panel,** The detached head of the papillary muscle (PM) is in the left ventricle (LV) during diastole. **Left panel,** The papillary muscle head is shown attached to its chordae (CH), swinging in the left atrium (LA) during systole.

after recurrence of circulatory arrest before the start of surgery. One patient with traumatic aortic rupture and one patient with a ruptured aneurysm of the abdominal aorta died during surgery. In six patients with cardiac tamponade due to myocardial rupture and one patient with tamponade due to aortic dissection the resuscitation attempts were discontinued after TEE. In all patients TEE was considered helpful in either excluding other life-threatening diseases, such as tamponade in patients with acute myocardial infarction and circulatory arrest, or confirming a strongly suspected clinical diagnosis. Ten patients (21%) had return of spontaneous circulation, 44 (92%) died in the hospital and 4 (8%) were discharged alive. The diagnosis in the four discharged patients was tamponade in 1, myocardial infarction in 2 and tachycardia without structural abnormalities in 1. There was no relation between outcome and the age of the patient ($p = 0.89$) or the delay from code call to the start of TEE ($p = 0.66$).

A postmortem examination was performed in 23 patients (48%). A definite diagnosis based on surgical or clinical data or coronary angiographic findings was available in eight patients (16%), including the four discharged patients. The diagnosis of myocardial infarction was confirmed by postmortem examination in 12 patients (8 with acute, 3 with recent and 1 with old myocardial infarction), by coronary angiography in 2 and by clinical course in 3. At autopsy, two patients were found to have myocardial infarction that had not been detected during TEE because of the absence of spontaneous rhythm. One patient in whom myocardial ischemia or infarction was suspected on TEE had no cardiac abnormalities at autopsy. Pulmonary embolism was confirmed by autopsy in two patients, but it was not found in one patient, who was treated with thrombolysis. Cardiac tamponade was confirmed in two patients by autopsy and in one patient by surgery. An aortic dissection was confirmed in one patient at autopsy. An aortic rupture and extensive abdominal trauma was confirmed by surgery in one patient. Autopsy confirmed the absence of structural abnormalities of the cardiovascular system in two patients. Clinical follow-up, enzymatic studies and repeated echocardiography during stable rhythm and hemodynamic status confirmed the absence of cardiac abnormalities other than supraventricular tachycardia in one patient.

Sensitivity and specificity. Definite diagnoses were available from a reference standard in 31 patients: from autopsy data in 23, clinical observations in 4, surgical findings in 2 and coronary angiographic findings in 2. Comparison of the diagnosis made by TEE with the results of autopsy, surgical and clinical data revealed that there were 25 patients whose TEE diagnosis was confirmed (for all diagnoses combined), 2 whose lack of structural abnormalities was confirmed (true negative result), 2 whose TEE diagnosis was not confirmed (false positive result) and 2 in whom TEE did not demonstrate the cause of the circulatory arrest (false negative result). The sensitivity of TEE was 93%, the specificity 50% and the positive predictive value 87%. At autopsy, two patients were found to have had myocardial infarction that could not be demonstrated with TEE owing to lack of spontaneous rhythm. Both patients were considered to have had false negative results. Of the two patients with false positive results, one had a TEE diagnosis of pulmonary embolism but no embolus was found during autopsy. The second patient was classified as having myocardial infarction or regional ischemia, but no infarction or any other reason for the circulatory arrest could be demonstrated by autopsy.

Discussion

Broad range of cardiovascular abnormalities. With TEE a broad range of cardiac and circulatory abnormalities can be accurately defined. TEE has therefore become the diagnostic tool of choice in many emergency situations (1–4). An electrocardiographic monitor is at present the only instrument that is available to resuscitation teams to establish the cause of a circulatory arrest. When no arrhythmia is present, the resuscitator must rely on physical examination and anamnestic information to form a hypothesis until more advanced diagnostic instruments are available. TEE is a diagnostic tool that can be helpful both in defining and excluding cardiac causes of circulatory arrest. However, its diagnostic accuracy during cardiopulmonary arrest and resuscitation has not been extensively studied.

In this study a wide range of cardiovascular abnormalities causing circulatory arrest was encountered. The TEE images

obtained during cardiopulmonary resuscitation were excellent and were as good as images obtained in patients with spontaneous circulation. Although the diagnoses made by TEE in this investigation were life-threatening diseases, it was not always clear that these diseases were the primary or only cause of the circulatory arrest. Especially in the large group of patients in our study with signs of myocardial ischemia or infarction, the question remains whether the cardiac arrest was caused by regional ischemia and infarction or whether the regional ischemia was caused by the circulatory arrest.

Myocardial infarction. Almost 50% of the patients in our study group had a myocardial infarction. With the classical criteria for the echocardiographic diagnosis of myocardial infarction it was not always possible to distinguish between old and acute myocardial infarction. However, most of the patients with an old myocardial infarction also demonstrated signs of recent infarction at autopsy. The TEE criteria used to define the presence of myocardial ischaemia or infarction are based on regional wall motion abnormalities. To be able to detect wall motion differences, some kind of organized rhythm is necessary. During resuscitation, spontaneous organized rhythm might recur, although often without effective circulation (electromechanical dissociation). These bouts of spontaneous rhythm were enough to reliably diagnose the presence of myocardial infarction in this study. In only two patients who proved to have myocardial infarction was the infarction not detected because of the absence of spontaneous rhythm.

Pulmonary embolism. Pulmonary embolism can be detected with echocardiography (7–9). Pulmonary embolism was defined in this study as the combination of an enlarged right side of the heart combined with a nearly empty left side of the heart. An embolus was only seen twice. Wittlich et al. (8) reported the detection of an embolus in the pulmonary artery with TEE in 35 (58%) of 60 patients with pulmonary embolism who were in circulatory shock. It is possible that during cardiopulmonary resuscitation pulmonary emboli, completely obstructing the pulmonary artery, are more difficult to visualize. The detection of an embolus in the pulmonary artery improves the diagnostic accuracy of TEE in defining pulmonary embolism, especially as primary pulmonary hypertension has the same echocardiographic characteristics.

Aortic dissection. The high diagnostic yield of TEE in patients with aortic disease is consistent with previous reports (10,11) in patients not in circulatory arrest.

Cardiac tamponade. Cardiac tamponade leading to circulatory arrest is easily detected by TTE. Depending on the aggressiveness of treatment protocols for cardiac tamponade, it might be necessary to define the cause of the tamponade, and TEE may be helpful in defining causes like aortic dissection, endocarditis or myocardial free wall rupture.

Limitations of TEE in resuscitation. Introduction of a transesophageal probe during resuscitation after endotracheal intubation is unproblematic for experienced workers. TEE was not limited by time delay or age constraints. In this small sample no relation between age of the patient or time delay between code call and start of TEE and outcome could be found. Whenever there is sufficient clinical reason to start and continue resuscitation efforts, the use of TEE could be beneficial for the patient.

Conclusions. Diagnosing the cause of a circulatory arrest should lead to better treatment and better outcome for the patient. In a substantial number of cases (31%) the treatment was changed after the TEE diagnosis was obtained. Because there was no control group, no effect on mortality could be demonstrated. Although a diagnosis made by TEE is helpful in considering both continuation and discontinuation of resuscitation attempts, it remains to be established whether this diagnosis leads to an improvement in survival. Studies comparing the combination of TEE early during resuscitation with aggressive treatment schemes with other diagnostic modalities are necessary to assess whether TEE during resuscitation increases survival. Until the results of such studies are available, performing TEE during resuscitation should be considered whenever possible.

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