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HOW TO

How to perform focused transoesophageal echocardiography during extracorporeal cardiopulmonary resuscitation?

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Introduction

Focused cardiac ultrasound is an important aspect of the comprehensive management of patients with cardiac arrest, especially in patients selected for extracorporeal cardiopulmonary resuscitation (eCPR). It guides physician during this very urgent state on the quality of cardiopulmonary resuscitation (CPR), on assessing the correct position of both venous and arterial cannulas, on identifying possible (reversible) causes of the arrest and contributes to prognostication and thus directly influences the patient management. Transoesophageal echocardiography (TOE) offers a wide range of (practical) advantages over a transthoracic examination and is therefore the preferred imaging technique in this acute setting. In this article, we review a five-step practical TOE approach to an eCPR patient (*Figure 1*), used to optimize the efficiency, quality, and eventually outcome of eCPR. The feasible four-view protocol used during this approach consists of the midoesophageal four-chamber view (ME 4C), the midoesophageal long-axis view (ME LAX), the midoesophageal bicaval view (ME BC), and the transgastric short-axis view (TG SAX). After veno-arterial extracorporeal membrane oxygenation (V-A-ECMO) start-up, we also acquire the transgastric long-axis view (TG LAX) (*Figure 1*).

Imaging protocol

Image acquisition during eCPR should never be a reason for cessation or compromising the ongoing resuscitation. Ideally, the echocardiographer should be at the head of the patient to avoid interference with the resuscitation team. Therefore, TOE is preferred over transthoracic echocardiography and should be performed by an experienced operator.

Step 1: preparation

It is recommended to guide the introduction of the TOE probe by (direct) laryngoscopy to prevent mucosal or pharyngeal injuries, as systemic anticoagulation is necessary in case of V-A-ECMO. Transoesophageal echocardiography during resuscitation is performed in intubated patients, so care should be taken not to dislodge the endotracheal tube. If necessary, lifting the mandible anteriorly and caudally can help the smooth passage of the probe. Generally, imaging is started at the mid-oesophageal level that is found at ∼30 cm. From this point, the different other views can be obtained.

Step 2: CPR quality assessment

Providing efficient and uninterrupted chest compressions is the key component of CPR.[1] Long-term resuscitation, especially during transport, often requires the use of a mechanical chest compression device. The correct position and depth of the chest compressions impacts outcome and should therefore be ascertained with TOE.[2] Compression of the left ventricle (LV) should be maximal without obstruction on the LV outflow tract (LVOT) and the aortic valve should open and close. If one of these goals is not achieved, repositioning of the compression device is required. Efficiency of CPR should be verified before diagnostic evaluations are pursued with TOE. Therefore, at the start of image acquisition we only briefly orient ourselves at the ME 4C view at 0° before rotating the transducer plane 120–140° to find the ME LAX view and to evaluate the LV, outflow tract and aortic valve at the same time. Alternatively, the TG SAX at 0–20° view can be used. Appraisal of the CPR efficiency using TOE should be correlated with finding from waveform capnography. End-tidal CO_2 should be above 10 mmHg and ideally above 20 mmHg.[1]

Step 3: diagnostics

Once proper resuscitation has been confirmed, the next step will be to search for a potential underlying (reversible) aetiology of the cardiac arrest. Here, the goals are as follows:

- Evaluation of the biventricular dimensions and global cardiac function.
- Evaluation of the presence of a pericardial effusion or tamponade.
- Identification of any intra-cardiac thrombi.
- Assessment of intravascular volume.
- Assessment of aortic morphology.

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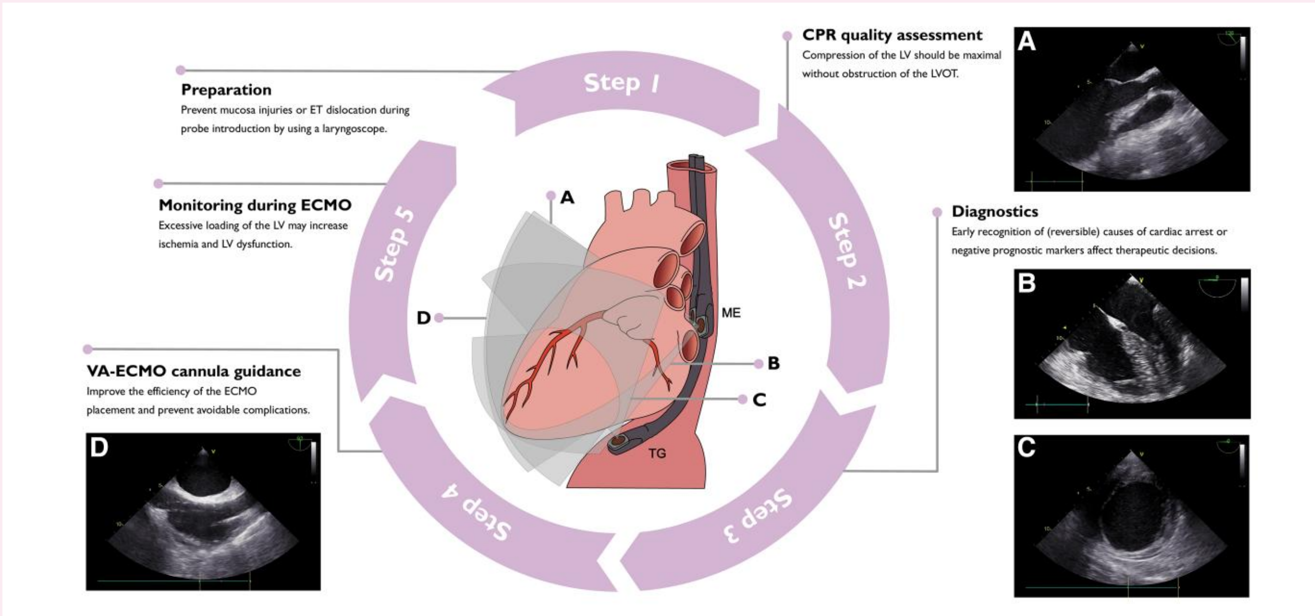

Figure 1 Overview of the five-step protocol and schematic representation of the four important TOE views during the protocol. (*A*) Midoesophageal long-axis view without obstruction of the LVOT during chest compressions. (*B*) Midoesophageal four-chamber view. (*C*) Transgastric short-axis view. (*D*) Midoesophageal bicaval view with a deep position of the venous ECMO cannula in the superior vena cava. TOE, transoesophageal echocardiography; VA-ECMO, veno-arterial extracorporeal membrane oxygenation; LV, left ventricle; LVOT, left ventricular outflow tract; ET, endotracheal tube.

A global functional analysis of both ventricles can be done during the repetitive rhythm checks while performing CPR. Determination of organized cardiac activity can distinguish pulseless electrical activity (PEA; organized electrical cardiac rhythm without cardiac contractility on TOE) from pseudo-PEA (organized electrical cardiac rhythm with presence of cardiac contractility on TOE but no pulse), which provides important prognostic information. Especially the absence of any cardiac contractility entails a poor prognosis.[3] Chest compressions, however, should never be halted in order to obtain better images.

The diagnostic validity of TOE during conventional CP has previously been demonstrated[4] and has shown to identify underlying aetiologies such as cardiac tamponade, aortic dissection and rupture, regional wall motion abnormalities, papillary muscle rupture, pulmonary embolism but also underlying (arrhythmogenic) cardiomyopathies. The presence of an aortic dissection or a severe aortic regurgitation are considered as contraindications for the placement of V-A-ECMO in eCPR-setting. Despite the proven accuracy of TOE, the operator must be aware of certain pitfalls inherent to the examination and the setting in which it is carried out. When determining the dimensions or function of both ventricles, there is often foreshortening. Also, during prolonged resuscitation, myocardial oedema can occur, which can mimic hypertrophy. A dilated right ventricle (RV) is not specific to pulmonary embolism and is frequently seen in other causes of cardiac arrest. Finally, it is important to note that even small amounts of pericardial fluid can cause a tamponade.

Step 4: V-A-ECMO cannula guidance

Transoesophageal echocardiography is an important aid during V-A-ECMO placement. Confirming the position of the wires and cannulas is important to avoid complications and ECMO malfunction. The detection of a prominent Chiari network, mobile/aneurysmal interatrial septum, atrial septal defect, pacing/ICD-leads or thrombus material in the right atrium (RA) could cause placement or functional ECMO problems. As the arterial blood is often as dark as venous blood during resuscitation, errors between arterial and venous side are frequent during a stressful cannulation and TOE can quickly provide confirmation of the correct access in this regard. We mostly use the ME BC view whilst a better view of the inferior vena cava (IVC) can sometimes be obtained when the probe is introduced a bit deeper but remaining at the same angle. The venous wire should be seen in both the inferior and superior vena cava during sequential dilatation and cannula advancement to avoid migration to the RV through the tricuspid valve, to the left atrium (LA) through a potential atrial septal defect or to the coronary sinus. The ideal position of the venous cannula is just beyond the IVC-RA junction. The correct position of the arterial wire should be confirmed in the descending aorta. The echocardiographic guidance of V-A-ECMO instalment as described above improves the efficiency of the eCPR protocol and prevents unnecessary time loss or avoidable complications.

Step 5: monitoring during ECMO

After the placement and start-up of V-A-ECMO support, the morphology and function of the cardiac chambers and valves are re-evaluated. The presence of regional wall motion abnormalities, which may imply acute myocardial infarction (AMI), RV dilatation, aortic morphology, etc. can be assessed more easily at this time when compared with the earlier phases of CPR.

Transoesophageal echocardiography may provide additional information in assessing the need for LV venting during V-A-ECMO support. The aortic retrograde flow of femoral V-A-ECMO may strongly increase the LV afterload. No or minimal opening of the aortic valve, the presence of significant spontaneous echo contrast or thrombus in the LA, LV or aortic root and dilatation of the LV or LA are all signs of excessive afterload and/or insufficient stroke volume. Here, TOE can provide additional information in assessing the need for LV unloading (called venting) during V-A-ECMO support. Increased LV loading and distention may induce acute pulmonary oedema, thrombo-embolic phenomena and myocardial ischaemia, compromising myocardial recovery and maintaining a pro-arrhythmogenic substrate. Venting can be performed by adding a LV micro-axial flow device (ECMELLA configuration) or by various surgical unloading techniques.[5] The best way to determine the LV stroke volume is to measure the LVOT VTI (velocity time integral) on the TG LAX view at 120–140°.

Clinical perspective

Since January 2019, performing TOE has been a standard procedure in (witnessed) refractory cardiac arrest at our tertiary care institution. All cardiologists in training are instructed in our TOE-guided eCPR protocol through both theoretical and bedside teaching moments. Additionally, a permanent on-call function for supervisors specialized in TOE is active for back-up. During the peak of the COVID crisis, the programme was temporarily put on-hold due to a reallocation of resources. Nevertheless, since initiation, 19 patients have been evaluated according to our protocol. In all of these patients, an examination following the five-step approach protocol as described above was feasible and could provide the team with useful, real-time information that had an impact on further treatment. In nine (47%) cases, the suspected cause of the arrest could be diagnosed with TOE. Previously unknown hypertrophic cardiomyopathy was seen in three patients. The diagnosis of AMI could be made on the basis of regional wall abnormalities in two patients. Other diagnoses made on TOE were chordal rupture resulting in a flail posterior mitral leaflet and severe mitral regurgitation, Stanford Type A aortic dissection, massive right ventricular air embolism and severe paravalvular aortic regurgitation due to prosthetic valve dehiscence. Therapy was discontinued based on the negative prognostic findings (absence of any cardiac contractility during resuscitation) on echocardiography in three patients (16%). Thrombus in the RA with obstruction of the drainage cannula as a cause of low ECMO flow could be identified in one patient.

Conclusion

Transoesophageal echocardiography in the acute setting of eCPR initiation provides very useful information on CPR quality, cannula position, arrest-aetiology, and need for venting after V-A-ECMO start-up. Therefore, a standardized TOE-eCPR protocol should be available 24/7 in centres providing eCPR.

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Conflict of interest: None declared.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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