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EDITORIAL

How I use ultrasound in cardiac arrest

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Advanced Cardiac Life Support (ACLS) guidelines recommend a standardized approach to manage cardiac arrest, including cardiopulmonary resuscitation (CPR), defibrillation, and administration of drugs such as epinephrine [1]. Ultrasound (US) should be performed by a dedicated operator in parallel to the resuscitative process without interfering with CPR [2]. It can also help in the post-resuscitation phase to optimize hemodynamic function and assess for multiorgan complications, such as pneumothorax, lung contusions, and peripheral organ dysfunctions [2].

We illustrate how head-to-toe US can be advantageously used during CPR and immediately after return of spontaneous circulation (ROSC). We aim to provide a practical approach and mainly focus on the use of transthoracic echocardiography (TTE) although transesophageal echocardiography (TEE) may have its advantages and uses in this context [3]. Whilst various protocols have been described, their core principles are identical and none has been demonstrated as superior to others (electronic supplementary material, ESM, Top tips).

Ultrasound to confirm cardiac arrest and guide management during cardiopulmonary resuscitation

Given the time critical context of cardiac arrest, appropriate leadership and coordination with the US operator is crucial. US assessment must be rapidly performed by a trained operator to obtain all relevant information during chest compressions and pauses for pulse and rhythm evaluation [4]. Recommendations suggest that the individual performing the scan is not the team leader.

During chest compression, the subxiphoid window offers the easiest visualization of the heart whilst avoiding interruptions of chest compressions. US can be used to evaluate the effectiveness of chest compressions by providing direct, real-time observation of compression/relaxation of the cardiac chambers during cardiac massage. Despite adequate hands positioning on the chest, the area of maximal compression may involve the aortic root or the left ventricular outflow tract rather than the left ventricle, resulting in impeded forward flow. In this case, US may aid adjusting hands location for optimization of chest compressions [5].

During the usual 10 s of pulse and rhythm evaluation as per resuscitation guidelines [1], virtually all TTE views can be used (although the subcostal view is recommended to minimise interruptions in chest compression), and two-dimensional imaging is stable and accessible to accurate interpretation. Although the decision process between shockable and non-shockable rhythms relies on electrocardiography, US may detect false cardiac standstill. Studies have shown that 10% to 35% of patients with asystole have a demonstrable cardiac contraction [6]. Nevertheless, 'cardiac motion' is not unanimously defined, hence inter-observer agreement for diagnosis of cardiac standstill is only moderate [5]. Although the presence of cardiac activity has been suggested to be associated with better outcome, the evidence for using US as a prognostic tool during CPR is of very low certainty emanating from studies with multiple biases [7].

In addition, US is a useful approach to promptly identify rapidly reversible causes of cardiac arrest (Fig. 1) [8]. Examination of the heart, lungs and proximal veins of lower limbs can be used to rule in or out cardiac tamponade, profound hypovolemia, pulmonary embolism and tension pneumothoraces (ESM, Table S1). For time constraint, US assessment must be extremely focused and guided by clinical presentation. In trauma patients, US primarily search for tension pneumothorax and profound hypovolaemia. In a hypertensive patient presenting with migrating chest pain, a tamponade revealing an acute aortic syndrome must be ruled out. In post-operative or

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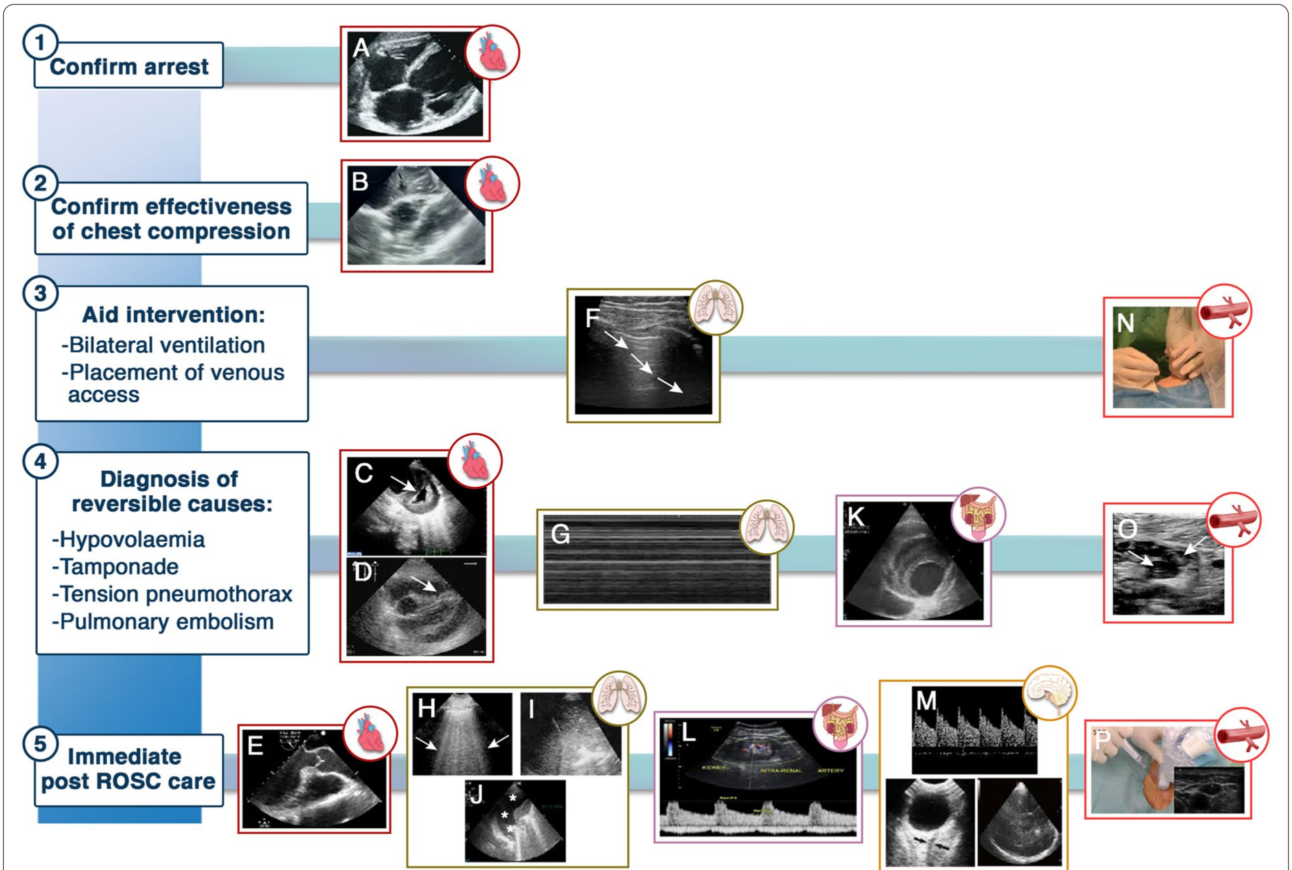

Fig. 1 Illustration of the temporal sequence of use of critical care ultrasonography to help guiding acute management of patient during cardiac arrest and after return of spontaneous circulation (ROSC) (see text for details). Echocardiography: during cardiac arrest, the subcostal view offers the easiest visualization of the heart whilst minimising interruptions of chest compressions. It allows immediate confirmation of 'standstill' heart vs. cardiac contraction, and of shockable vs. non-shockable rhythm (panel **A**). It also allows confirming the effectiveness of chest compressions with facilitated left ventricle ejection (panel **B**). Echocardiography can also promptly identify reversible causes of cardiac arrest, such as acute cor pulmonale associated with a massive pulmonary embolism (panel **C**: subcostal short-axis view depicting inversed end-systolic bulging of interventricular septum towards left ventricular cavity; white arrow), or tamponade physiology (panel **D**: subcostal long-axis view disclosing a compressive pericardial effusion with collapsed right ventricular cavity; white arrow). Finally, in the post-ROSC phase, echocardiography provides a comprehensive hemodynamic assessment to best guide therapy, including with the use of the transesophageal approach if indicated (panel **E**). Lung ultrasonography: can help in confirming bilateral ventilation and identifying reversible causes of anoxic cardiac arrest. Aerated lung is characterized by the presence of a lung sliding in real time associated with A lines (panel **F**, white arrows). In contrast, the absence of both the lung sliding and the presence of a lung point is consistent with an underlying pneumothorax (panel **G**, M-mode). In the post-ROSC phase, lung ultrasound can allow a more specific assessment of pulmonary function and aeration: B lines associated with unspecific interstitial edema (panel **H**, white arrows); extensive lung consolidation indicating de-aeration of lung territories (panel **I**); pleural effusion which can be semi-quantitatively assessed (panel **J**, asterisks). Abdominal ultrasound: can provide prompt diagnosis of reversible causes (panel **K**: large aortic aneurysm with unstable intraluminal thrombus formation), and can help in the assessment of organ perfusion in the post ROSC phase (panel **L**). Brain ultrasound: can help identifying cerebral edema and intracranial hypertension (panel **M**: pulse wave-Doppler guided by color Doppler mapping depicting blood flow velocity in the middle cerebral artery with increased pulsatility index; measurement of optic nerve sheath diameter (black arrows); cerebral ultrasound used to assess the presence of intracranial hemorrhage and midline shift). Vascular ultrasound: best guides the insertion of peripheral and central venous catheter (panel **N** and **P**). In addition, ultrasound of proximal lower limb veins can expeditiously depict thrombus formation responsible for lethal pulmonary embolism (panel **O**, white arrows)

oncology patients, a massive pulmonary embolism is first sought. Although RV dilation has been advocated as a sign of acute obstructive cause, RV acutely dilates after a few minutes of cardiac arrest as blood is shifted from vena cava to right cardiac cavities along its pressure gradient. Accordingly, the diagnosis of massive pulmonary embolism should not solely rely on RV dilatation in patients with prolonged CPR [9].

Focused TEE can advantageously be used during CPR since it does not interfere with chest compressions and provides high-quality images and additional windows to the heart and great vessels [3]. In addition to the diagnostic yield of TTE, TEE may provide valuable diagnostic information (e.g., entrapped thrombus within proximal pulmonary artery, compressive mediastinal hematoma, ruptured lesion of the thoracic aorta) and guide placement of temporary pacemaker or extracorporeal life support (ECLS) cannulae [10].

When feasible, US may also be helpful during CPR to confirm adequate endotracheal tube position [11], and to provide information on the presence of cerebral edema and perfusion (brain US). Finally, US can be used to aid placement of peripheral or central venous access (Fig. 1).

General assessment immediately after ROSC

Once ROSC has been achieved, US allows more comprehensive assessment to further guide therapy (Fig. 1).

Assessment of hemodynamics and circulatory support

In this phase, a more comprehensive assessment of the heart (e.g., new regional wall motion abnormalities, acute valvular disease), hemodynamic profiling of shock, assessment of fluid responsiveness and inotropes titration, and management of ECLS can be performed.

Non-cardiac ultrasound

The placement of venous/arterial lines is facilitated by US guidance, including larger bore cannulas for extracorporeal life support (ECLS) [10].

Following placement of the endotracheal tube, lung US is a reliable tool for the assessment of global and regional lung aeration. Collapsed lung or pneumothoraces secondary to the resuscitation process can be identified and treated [12].

Future perspective

After ROSC, the optimal target for organs perfusion remains a subject of debate and research. There is a growing body of literature studying the evaluation of regional intra-abdominal hemodynamics by color Doppler resistive index (e.g., kidneys), where abnormalities precede overt organ dysfunction and biochemical changes [13].

Finally, cerebral hemodynamics after resuscitation can be determined using the pattern of Doppler spectral waveform, pulsatility index and mean flow velocity of the main cerebral arteries. Serial transcranial Doppler examinations, and optic nerve sheath diameter evaluations using US can help in the non-invasive assessment of cerebral edema secondary to the ischemia–reperfusion syndrome, and other complications [14, 15].

Take-home message

During cardiac arrest, the main goal of US is to confirm the efficacy of chest compression, identify cardiac activity in uncertainties, and promptly identify a reversible cause. US should be performed alongside cardiopulmonary resuscitation, but with minimal interference with chest compression. Since data on US diagnostic accuracy and impact on outcome is lacking, large-scale studies are warranted to standardize US assessment during CPR, validate criteria of CPR efficacy, improve prognostication, and target regional/organ flow improvement during and after CPR.

Supplementary Information

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Data availability

These are all from the authors own library and have no identifiable patient details.

Declarations

Conflicts of interest

The authors confirm that they have no conflicts of interest to declare.

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