Review Article

My Approach to Perform Echocardiographic Assessment during Cardiopulmonary Arrest

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Abstract

Cardiopulmonary arrest (CPA) is one of the most common events encountered by health care professionals. Attempts to reverse it by performing cardiopulmonary resuscitation (CPR) maneuvers still have very low success rates. Pulseless electrical activity (PEA) and asystole are associated with the worst outcomes. Major CPR guidelines emphasize the importance of identifying potentially treatable causes of CPA. Point-of-care ultrasound (PoCUS), when performed in a systematic, orderly fashion (i.e., without delaying or interfering with other CPR maneuvers), may be important in this change in outcome because it is a diagnostic and prognostic tool used in a scenario where the physical examination is not always conclusive. In this context, the main applications of PoCUS include diagnosis of CPA, differential diagnosis between PEA and pseudo-PEA, and etiologic diagnosis. Several protocols have been developed to optimize the performance of cardiac PoCUS simultaneously with each central pulse check. Pulmonary, abdominal and vascular PoCUS should be performed during resuscitation maneuvers, as they do not interfere with these maneuvers. In addition, PoCUS should preferably be performed by a trained physician who is not actively involved in the resuscitation maneuvers so that the dynamics of CPR are maintained. PoCUS contributes to the diagnosis, prognosis, and therapeutic care of patients suffering from CPA, especially in cases of PEA and asystole; however, there is still no robust evidence that the use of PoCUS reduces mortality among these patients.

Introduction

Cardiopulmonary arrest (CPA) is a common event that health care professionals are constantly confronted with in both the pre-hospital and in-hospital settings. However, CPA is particularly common in emergency units and intensive care units. Unfortunately, attempts to reverse CPA with cardiopulmonary resuscitation (CPR) maneuvers in these two settings still have very low success rates. Even if the actual death is reversed, the degree of disability of the survivors remains high. Regarding the initial electrical rhythm, pulseless electrical activity (PEA) and asystole are associated with the worst outcomes.[1]

What can be done to reduce failure and facilitate return of spontaneous circulation with good cardiocerebral viability? Major guidelines, including Advanced Cardiac Life Support (ACLS),[2] stress the importance of identifying potentially treatable causes of CPA (e.g., pericardial tamponade, pneumothorax, and even pulmonary embolism [PE]).[2] In this context, echocardiography (ECO), when performed in a systematic, orderly fashion (i.e., without delaying or interfering with other CPR maneuvers), may be important to this change in outcomes,[2] as ECO is a diagnostic and prognostic tool used in a scenario where the physical examination may be inconclusive.[3] However, due to the need for agility in the diagnosis and management of acutely ill patients, ECO is typically performed by a non-specialist physician trained to perform it. Several international medical organizations recommend that physicians caring for critically ill patients acquire and develop the skills to perform bedside ultrasound examinations, including ECO.[4] However, point-of-care ultrasound (PoCUS) is an examination with different characteristics from that performed by the echocardiographer. PoCUS is used to answer a well-defined question relevant to immediate patient care: "Why did it stop?". PoCUS is not limited to evaluation of the heart, but also includes the lungs, abdomen, and vessels.

The use of PoCUS during CPR should always be for the benefit of the patient. PoCUS should never interfere with systematic care, especially chest compressions, or the delivery of electrical defibrillation if indicated.

Based on the chain of survival, PoCUS should be used at three moments: 1) prior to CPA, with the aim of preventing its occurrence; 2) during CPR, with the aim of elucidating its etiology and guiding its management; and 3) after the restoration of spontaneous circulation, with the aim of further detailing the patient's clinical condition and refining treatment (Figure 1). In this article, we will focus on PoCUS during CPR.

PoCUS during CPR

PoCUS during CPR should be performed quickly and objectively by a trained physician, preferably one who is not actively involved in resuscitation maneuvers or time counting. Thus, the main uses of PoCUS are during 1) diagnosis of CPA, 2) differential diagnosis between PEA and pseudo-pulseless electrical activity (hereinafter referred to as pseudo-PEA), and 3) etiologic diagnosis.

Keywords

Cardiorespiratory Arrest, Diagnosis, Echocardiography

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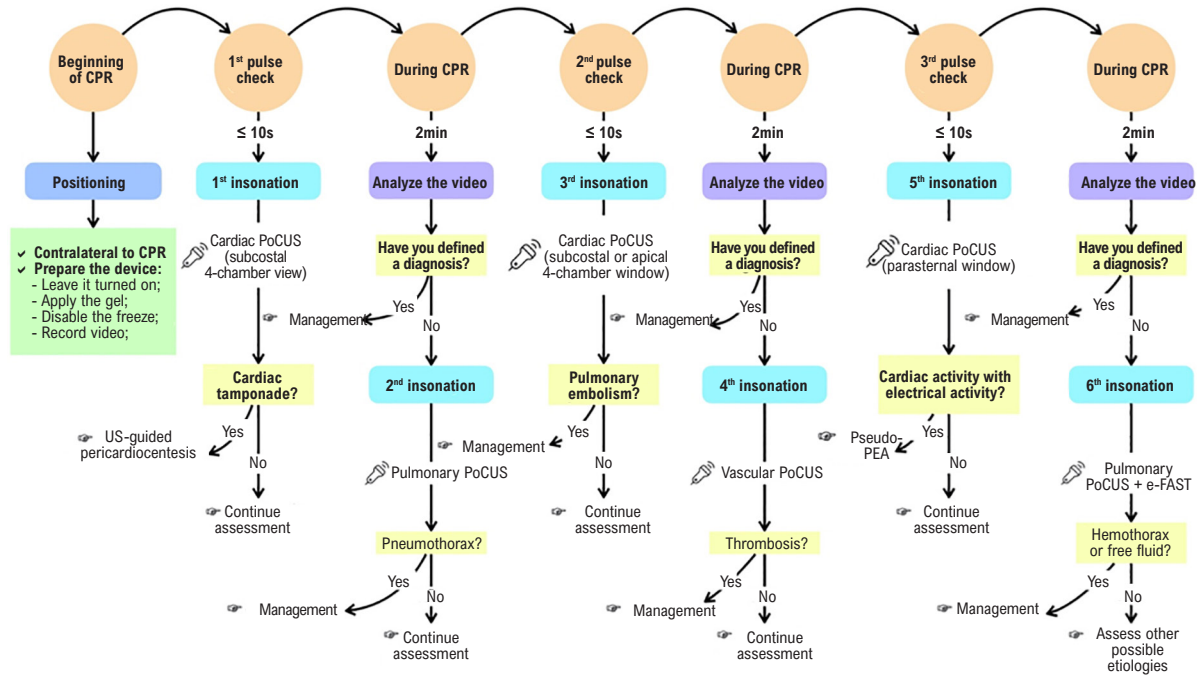
Central Illustration: My Approach to Perform Echocardiographic Assessment during Cardiopulmonary Arrest



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CPR: cardiopulmonary resuscitation; PEA: pulseless electrical activity; PoCUS: point-of-care ultrasound.

Diagnosis of CRP

The clinical diagnosis of CPA is the identification of an unconscious, apneic patient with no central pulse.[2] It is well known that in practice it can be difficult to detect the absence of a central pulse by palpation, even by trained physicians, delaying the diagnosis of CPA and/or prematurely interrupting resuscitation maneuvers.[1] PoCUS allows rapid, accurate diagnosis through the vascular compression maneuver of the transducer, which completely collapses the carotid artery and jugular vein during CPA.

Differential diagnosis between PEA and pseudo-PEA

One of the main goals of PoCUS during CPA is to improve resuscitation outcomes by identifying mechanical cardiac activity. In PEA, the patient presents with myocardial electrical activity without a palpable pulse and no identifiable mechanical cardiac activity by PoCUS. In pseudo-PEA, there is also myocardial electrical activity without a palpable pulse, but coordinated mechanical cardiac activity is visualized by performing PoCUS (Video 1). Distinguishing between these two diagnoses is not always easy without the aid of ultrasound.[3] This differential diagnosis is of utmost importance because the correct identification of pseudo-PEA leads to the adoption of the correct and specific treatment. The difference in prognosis between these two entities is very clear, as pseudo-PEA has a higher probability of return to spontaneous circulation than true PEA.[4-9]

Etiologic diagnosis of CRP and therapeutic management

Because of its systemic and integrative use, PoCUS can be used to identify reversible causes of PEA and asystole, such as PE, cardiac tamponade, pneumothorax, and hypovolemia.[3] Such identification is performed not only by cardiac evaluation, but also by pulmonary, abdominal, and vascular evaluation.

a. Pericardial tamponade: accounts for 4–15% of PEA cases. When pericardiocentesis is performed promptly, patients have a higher survival rate to hospital discharge (15.4%) compared to other causes of PEA (1.3%).[10] The presence of pericardial effusion associated with right ventricular (RV) collapse is indicative of cardiac tamponade as the cause of CPA; however, hemodynamic effects (e.g., diastolic compression of the ventricles and ventilatory changes in Doppler velocities and inferior vena cava [IVC] diameter) can only be visualized in the presence of spontaneous circulation.

b. Pulmonary embolism: accounts for 4–7.6% of CPA cases. Survival to hospital discharge is 6.7%.[10] In this scenario, two findings can be quickly visualized by using PoCUS: a change in ventricular volume with a dilated right ventricle (RV) and a comparatively small left ventricle (LV) (Video 2). Upon return of spontaneous circulation, the presence of paradoxical movement of the interventricular septum is also observed.

c. Hypertensive pneumothorax: an extremely rare cause of nontraumatic CPA.[10-12] Hypertensive pneumothorax can be diagnosed by performing bilateral pulmonary PoCUS,

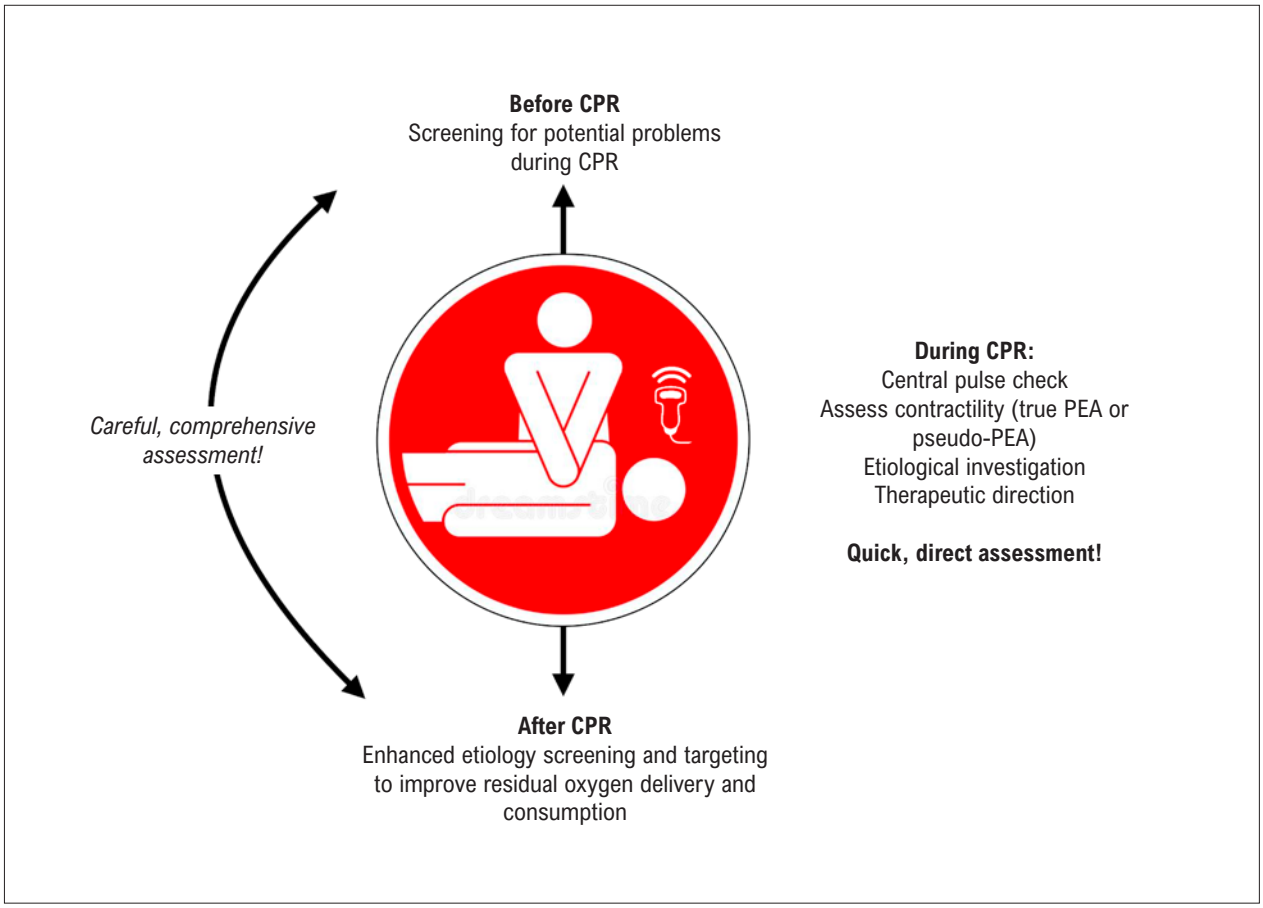
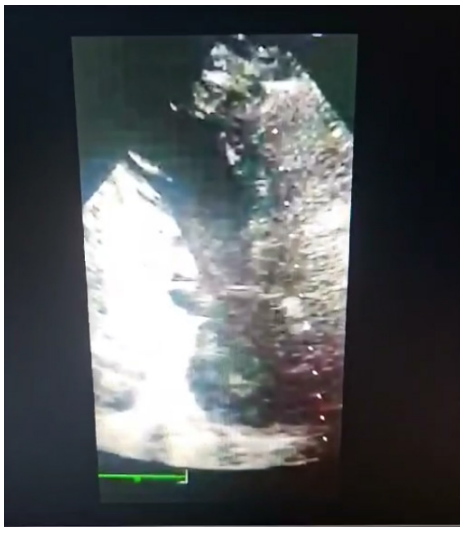


Figure 1 – *Main indications of USIE in Peri-resuscitation.*
CPA: cardiopulmonary arrest; CPR: cardiopulmonary resuscitation; PEA: pulseless electrical activity.



Video 1 – *Two-chamber apical view of a patient in cardiac arrest due to PEA caused by a mechanical complication of non-ST-elevation acute myocardial infarction occurring 24 hours after angioplasty. A mid-basal akinesia of the inferior wall is observed, associated with a rupture of the posteroinferior papillary muscle and weak cardiac motion, leading to the diagnosis of pseudo-PEA. Source: Case provided by Dr. Marcelo Dantas Tavares de Melo.*
Link: http://abcimaging.org/supplementary-material/2024/3702/2024-0035_video_01.mp4

Video 2 – *Apical 4-chamber view of a patient in cardiac arrest receiving chest compressions, considered to be of good quality. Right-sided chamber overload is observed, suggesting PE as the etiologic factor. The presence of an image suggestive of contrast is due to the injection of drugs through the central catheter. Source: Personal collection of the authors.*
Link http://abcimaging.org/supplementary-material/2024/3702/2024-0035_video_02.mp4

anterior to the chest, or by observing the absence of pleural slippage during CPR. The use of M-mode may be critical in identifying the stratosphere sign or barcode sign. In this case, needle decompression or thoracostomy may be considered. Small, clinically insignificant pneumothoraces may result from rib fractures during CPR and do not necessarily require immediate intervention.

d. Hypovolemia: suggested by the appearance of flattened right and LVs in the subcostal or parasternal windows in addition to the presence of a virtually collapsed IVC and no ventilatory variability in its diameter upon return to spontaneous circulation.

PoCUS can also be useful for:

a) identifying other mechanical cardiac complications, such as obstructive transvalvular flow due to tumors, thrombi, or vegetations;

b) assessing the quality of chest compressions;

c) identifying the presence or absence of cardiac kinetics during CPR; and

d) setting a prognosis.

Protocols

The use of PoCUS in the care of a patient with CPA should be systematic, so that there is no delay in chest compressions or electrical defibrillation in cases where the baseline electrocardiographic rhythm is shockable. Several protocols have been developed to optimize the performance of cardiac PoCUS simultaneously with each central pulse check. Pulmonary, abdominal, and vascular PoCUSs should be performed during resuscitation maneuvers, as they do not interfere with these maneuvers.

Protocols such as Focused Echocardiographic Evaluation in Resuscitation (FEER)[11] and Focused Echocardiographic Evaluation in Life Support (FEEL)[9] focus solely on the heart. The Cardiac Arrest Ultra-Sound Exam (CAUSE)[13] protocol adds pulmonary PoCUS to the initial echocardiographic assessment during CPR. The Cardiac Arrest Sonographic Assessment (CASA)[10] protocol adds abdominal PoCUS to the heart and lungs, if clinically indicated, by using the Focused Assessment with Sonography in Trauma (FAST)[14] protocol to look for evidence of free fluid in the abdominal cavity, such as from abdominal aortic aneurysm rupture or ectopic pregnancy.

The Sequential Echographic Scanning Assessing Mechanism (SESAME)[15] protocol, originally developed for patients with severe shock or imminent CPA, was quickly expanded to include established CPA situations. SESAME is a multiorgan protocol that examines the heart, lungs, abdomen, and deep proximal veins of the lower extremities by using a single transducer (microconvex) to acquire all images, optimizing examination and diagnostic time. The Global Ultrasound Check for the Critically Ill (GUCCI)[16] protocol was developed for the use of ultrasound in acute respiratory failure, circulatory shock, and CPA and includes ultrasound-guided procedures. Similar to the SESAME protocol, GUCCI proposes a stepwise holistic approach by integrating cardiac, pulmonary, vascular, and abdominal PoCUSs.

The Core Ultrasound in Resuscitation (CURE)[17] protocol combines cardiac PoCUS with transesophageal echocardiography (TEE) after a definitive airway has been established. CURE aims to reduce the interval between compressions by providing dynamic and continuous visualization of CPR, thereby guiding

rescuers to improve chest compressions. CURE also provides better cardiac visualization, including assessment of the aorta. TEE appears to be superior in CPA because it does not interfere with CPR maneuvers; however, transthoracic echocardiography is most used due to its difficulty of access.

Our approach

In our practice, we base our approach to performing PoCUS during CPR on the CASA[10] and GUCCI[16] protocols with some adaptations (Central Illustration). First of all, we emphasize that the whole team should be aware that PoCUS will be used. PoCUS is mainly indicated in cases of PEA or asystole CPA and should preferably be performed by a trained physician who is not actively involved in performing resuscitation maneuvers, thus maintaining the dynamics of CPR.

The PoCUS device should preferably be positioned next to the bed contralateral to the bed of the professionals performing chest compressions, so as not to interfere with the dynamics of their rotation. We emphasize that in all cases, cardiac PoCUS should be performed during the interval when chest compressions are paused to check the central pulse and should last 5–10 seconds to avoid delaying the resumption of chest compressions, whereas pulmonary, abdominal, and vascular PoCUSs should be performed during chest compressions and ventilation.

All efforts should be focused on determining the cause of the CPA. The PoCUS algorithm in CPR (Central Illustration) systematizes the steps required to determine the cause of CPA:

1. Position and turn on the ultrasound machine and have the transducer(s) ready to use (apply gel and deactivate freeze) while performing chest compressions. Position the transducer in the selected window. In the absence of gel, distilled water, saline, nonalcoholic chlorhexidine, or other noncorrosive solutions can be used, always following the technical guidelines of each equipment manufacturer. Remember to always activate the video recording function.

2. Within a timeframe of 10 seconds or less, during the interval when chest compressions are paused to check the central pulse, obtain the subcostal 4-chamber view to diagnose cardiac tamponade, which is suggested by the presence of pericardial effusion associated with RV collapse. If these changes are present, ultrasound-guided pericardiocentesis should be performed. If this is not the diagnosis, the evaluation should continue.

3. During the next 2 minutes, while performing CPR maneuvers, analyze the video obtained in the previous step (if the diagnosis has not been made) and perform pulmonary PoCUS to evaluate for pneumothorax; if pneumothorax is present, needle decompression or thoracostomy may be considered. Pulmonary PoCUS may also be used to evaluate bilateral lung ventilation. The absence of pleural slippage in only one hemithorax may be due to selective intubation of the contralateral lung.

4. After 2 minutes of CPR, during the pulse check interval, if the cause of CPA has not yet been identified, place the transducer again in the subcostal or apical window, aiming to obtain the 4-chamber view, in which a dilated RV and a relatively smaller LV suggest the diagnosis of PE and allow for thrombolysis.

5. During the next 2 minutes, while CPR maneuvers are being performed, the video obtained in the previous step should be analyzed (if the diagnosis has not yet been made). If PE is suspected, vascular PoCUS may be performed at this time to look for thrombosis to confirm the diagnosis.

6. After 2 minutes of CPR, during the pulse check interval, if the cause of CPA has not yet been determined, repeat cardiac PoCUS through the parasternal window to look for any cardiac motion, which, if present and associated with electrical activity, will confirm the diagnosis of pseudo-PEA. If the patient has regained spontaneous circulation and the heart is hyperdynamic, the cause of CPA may have been hypovolemia.

7. During the next 2 minutes, while CPR maneuvers are being performed, analyze the video obtained in the previous step and perform pulmonary PoCUS and the e-FAST protocol to diagnose hemothorax and/or look for free fluid in the abdominal cavity that would suggest hypovolemia as the cause of CPA.

8. If none of these findings are present, look for other possible causes of CPA: hypovolemia, hypoxia, acidosis, hypokalemia, hyperkalemia, hypothermia, coronary thrombosis, and toxins.

Conclusion

PoCUS plays an important role in the diagnosis, prognosis, and appropriate therapeutic management of patients in CPA, especially in cases of asystole and PEA. However, it should be noted that the use of PoCUS should not compromise the provision of systematic care, especially chest compressions, or the administration of electrical defibrillation when indicated. Therefore, the use of PoCUS in CPR is already recommended. However, it has not yet been conclusively proven that the use of PoCUS reduces mortality in patients in CPA.

Author Contributions

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Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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