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Echocardiography during cardiopulmonary arrest: Integrative review

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***Keywords*— Cardiopulmonary Resuscitation, Echocardiography, Heart Arrest, Heart Rate, Point of care.**

***Abstract*— *Introduction: The identification of the rhythm in the care of the patient with cardiopulmonary arrest (CA), (shockable and non-shockable) is fundamental for the reversal of the condition. In this context, echocardiography (ECHO) allows real-time recognition of myocardial movement and helps to identify the potential reversible cause of CA in non-shockable rhythms such as PEA and Asystole. Objective: to present an update of the scientific evidence about the use of ECHO during CA. Method: integrative literature review, in the Medical Literature Analysis and Retrieval System Online database, using the descriptors "Echocardiography" and "Cardiac Arrest", with original articles published between 2019 and 2021. Results: the use of ECHO during CRP allows visualizing the movement of heart chambers and valves, blood flow and myocardial contractility, helping to identify the cardiac rhythm and, in turn, the cause of the shock. The use of transthoracic echocardiography (TTE), a non-invasive method, requires pauses in chest compressions and is interfered with by external or patient-related conditions. Transesophageal echocardiography (TEE), in turn, does not require interruption of chest compressions and provides more reliable images, but it is a semi-invasive method. Conclusion: the use of ECHO during CA helps to identify the cause of shock, which provides adequate case management and predictive definition. Due to the non-interruption of chest compressions, the use of TEE proved to be an alternative to TTE, but with a longer learning curve and lack of studies with outcomes such as survival and prognosis.*

I. INTRODUCTION

Cardiopulmonary arrest (CA) is the cessation of cardiac mechanical activity as confirmed by the absence of signs of circulation [1].

It consists of a worldwide public health problem, with an incidence of 47.3/100,000 per year in the United States (USA), in Europe, on average 40.6/100,000 inhabitants, in Asia 45.9/100,000 inhabitants and in Australia 51.1/100,000 inhabitants per year. According to Kiguchi et al. (2020), the most affected age group is between 64 and 79 years old, most of them male [2-4].

The identification and early intervention of circulatory collapse are of fundamental importance in clinical practice, as they are directly related to increased patient survival. In this sense, the adoption of care protocols such as Basic Life Support (BLS) and Advanced Life Support (ALS), developed by the American Heart Association/International Liaison Committee on Ressuscitation (AHA/ILCOR) [5], make it possible not only to standardization of care and the improvement of CPR, but also the reduction of morbidity among these patients.

In the occurrence of CA, some factors are determinant in its evolution, namely: initial heart rate, location of the event (infirmary versus emergency unit), time of occurrence and absence of a witness. Among these factors, the assessment of the initial heart rhythm consists of an objective variable, which must be carefully identified by the professional who will conduct this service.

In order to identify the possible cause of CA and provide adequate management of the case, cardiac monitoring of the patient should be initiated. The electrocardiographic rhythms detected on cardiac monitors allow them to differentiate between ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electrical activity (PEA), also called electromechanical dissociation (EMD), and asystole. The rhythms of VF and pulseless VT are called shockable rhythms and their primary treatment is electrical defibrillation, whereas those of PEA and asystole are called non-shockable rhythms and the appropriate approach is based on reversing the underlying cause (Fig. 1) [5].

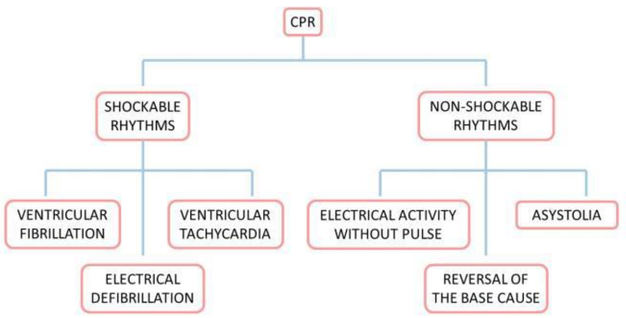

Fig. 1 – Classification of cardiorpulmonary arrest

CPR, Cardiopulmonary resuscitation.

Faced with a situation of shock with reduced cardiac output associated with a reduction or absence of central arterial pulse, there may be an erroneous classification of the cause of CA and consequent inadequate pharmacological and/or mechanical intervention, with an unfavorable outcome for the patient. In addition, a lot of time can be wasted in evaluating the pulse in a patient on PEA, delaying chest compressions and reversal of the underlying cause.

In this scenario, echocardiography (ECHO) allows real-time recognition of myocardial movement, classifying this situation as PEA or pseudo-PEA. Both situations evolve with absence of pulse, but while myocardial contractility is absent in PEA even in the face of coordinated electrical impulse, pseudo-PEA can lead to ventricular myocardial contraction or detectable pressure in the aorta [6].

The early distinction between PEA and pseudo-PEA is necessary, as they have different management and prognosis. This is because pseudo-PEA, if not treated immediately, can progress to PEA, with total cessation of mechanical activity associated with more severe electrolyte and metabolic disturbances. This fact becomes especially relevant due to the increase in CA due to non-shockable causes and, also, the higher incidence of pseudo-PEA (Fig. 2) [7].

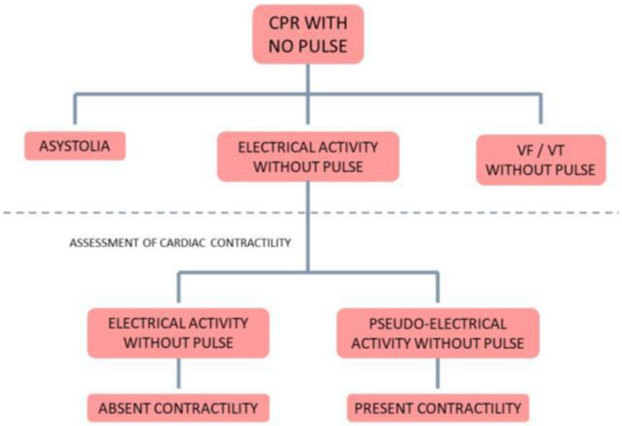

Fig. 2 – Dichotomization of pulseless electrical activity

CPR, Cardiopulmonary resuscitation; VF/VT, ventricular fibrillation/ventricular tachycardia.

As for the possible causes or aggravating factors of CA, they can be divided into cardiac and non-cardiac. Cardiac ones are more common (50-60%) [2], such as arrhythmia, myocardial infarction, heart failure. Among the non-cardiac causes, the most prevalent cause is respiratory failure (15-40%) [2], but, in general, they are synthesized in the 5Hs (Hypovolemia, Hypoxia, Hypothermia, Hydrogen ion – metabolic acidosis and hypo/hyperkalemia) and 5Ts (Cardiac tamponade, pulmonary thromboembolism, coronary thrombosis, tension – hypertensive and toxic pneumothorax) [2,5], with adequate treatment for each cause (Table 1). Early identification of the cause can improve the patient's prognosis.

Table 1 – Main causes of cardiopulmonary arrest and its treatments

Cause		Treatment
5 Hs		
	Hypovolemia	Volume replacement, blood products, stop bleeding
	Hypoxia	Oxygen supply
	Hypothermia	Rewarming
	(acidosis)	Sodium bicarbonate
	H's	Hypokalemia: intravenous potassium chloride Hyperkalemia: intravenous calcium gluconate, sodium bicarbonate and/or polarizing solution
5 Ts		
	Tamponade (cardiac)	Pericardiocentesis
	Thrombosis (pulmonary)	Fibrinolytic
	Thrombosis (coronary)	Primary angioplasty
	Tension (pneumothorax)	Thoracic drainage
	Toxins	Specific antagonist

The use of echocardiography as a diagnostic tool in the world of emergency and intensive care has been developing over the last 10 years, with a growing number of publications. The relevance of the theme is related to the improvement in the care of critically ill patients and aid in decision-making by the health professional, considering the trinomial: problem, critically ill patient and echocardiography. These aspects resulted in the expression "ultrasound at the point of care" (Point of Care Ultrasound - POCUS) (Fig. 3) [8].

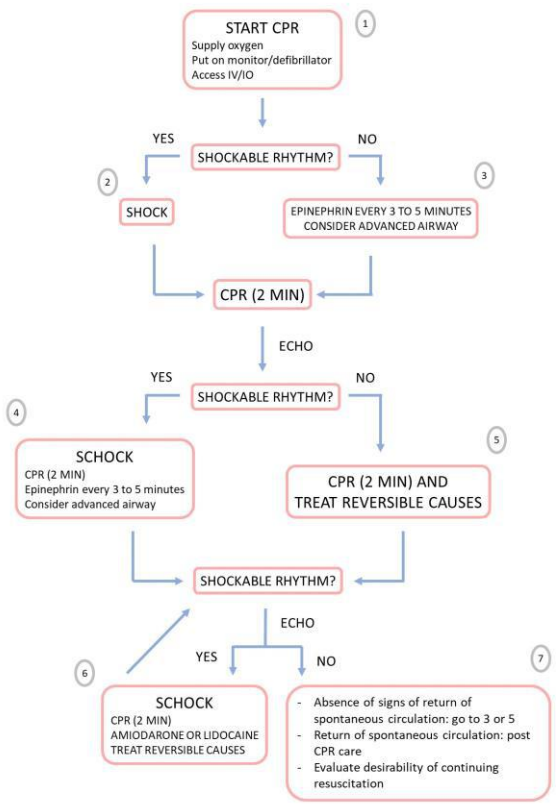

Fig. 3 – Insertion of the ECHO in the CA

CPR, Cardiopulmonary resuscitation; IV/IO, intravenous vascular access/intraosseous vascular access; ECHO, Echocardiography.

POCUS is an imaging diagnostic modality used for a wide range of purposes, both in the emergency room, as well as in intensive care units and perioperative environments. This tool has defined, in recent years, a paradigm shift in the provision of care and management of critically ill patients, as it allows for an accessible, quick and targeted assessment of the patient. In addition, it allows for a patient-centered approach, as it is performed at the bedside (at the point of care), adding physical examination to real-time technology, and, in the case of patients undergoing CA, ECHO can be performed in the transthoracic (TTE) or transesophageal (TEE) modalities [8,9].

The short and long parasternal axis, apical 4-chamber and subxiphoid views are visible at TTE. In turn, TEE is performed in intubated patients, by inserting a probe into the esophagus, and allows the visualization of the 4-chamber mid-esophageal region, mid-esophageal axis and transgastric vision [8].

Although the latest American Heart Association guideline invalidates POCUS as a prognostic tool (Class 3: No Benefit), it points to the use of echocardiography in identifying the potential reversible cause of CA or detection of return of spontaneous circulation (Class 2b: Weak). However, this aspect was not reassessed for 2020, with the latest evidence compiled in 2015 [5,10]. In contrast, the latest CPR guide from the European Resuscitation Council supports the idea that the use of the POCUS helps to identify reversible causes, with reservations about the pauses in chest compressions, indicating the use of TEE, which allows continuous imaging without interfering with resuscitation movements [11].

Thus, given the importance of correctly identifying the cause of CA to promote adequate treatment for the patient and increase their survival and how ECHO can help in this critical moment, this article aims to present an update of the scientific evidence about the use of ECHO during the CA.

II. METHOD

Integrative literature review, which covered theoretical and practical concepts of the use of ECHO during CA. This approach allows researchers to gather scientific evidence and contextualize it, in order to elucidate their respective applicability. It can be carried out from experimental and non-experimental studies, in addition to theoretical and empirical literature, in order to support the reader in understanding the phenomenon studied. [12].

The six steps suggested by Souza et al. [12] were followed in this research: 1) elaboration of the guiding question; 2) search or sampling in the literature; 3) data collection; 4) critical analysis of the included studies; 5) discussion of results and 6) presentation of the integrative review.

The guiding question adopted for this study was elaborated based on the PICO strategy — an acronym in English for Population (P), Intervention (I), Comparison (C) and Outcome (O). Thus, in the present study, it was established: P – patients in CA; I – use of ECHO; C – use of ECHO with or without comparison; and O – advantages and disadvantages. The guiding question adopted was: What is the current scientific evidence on the advantages and disadvantages of using ECHO in patients during CA?

The search in the literature was performed using the descriptors "Echocardiography" and "Cardiac Arrest", according to the Medical Subject Headings (MeSH), together with the database with the greatest possibility of containing scientific material, relevance and level of worldwide evidence, on the information required, namely, Medical Literature Analysis and Retrieval System Online (Medline). Studies were considered eligible if: original and available in full, answered the study question, had an adult population sample (> 18 years old) and published between 2019 and 2021, with a view to including more contemporary articles. Theoretical reflection articles, reviews and editorials were excluded, as well as those dealing with traumatic CA.

Initially, 253 articles were identified. After screening the authors, by reading the title and abstract, and, confirming the inclusion, read it in full. Subsequently, from the full analysis, the final sample consists of 8 articles (Fig. 4).

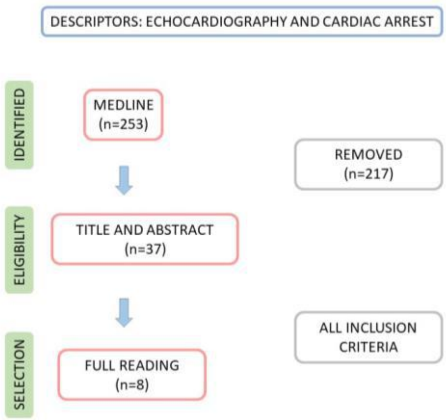

Fig. 4 – Article selection flowchart for review

The search in the database was performed by one of the authors and the critical analysis of titles and abstracts, separately by three of the authors, who later met and compared their impressions. In cases of disagreement, a fourth reviewer was consulted, until consensus was reached, considering the purpose of this review.

For data collection, the authors performed the full reading of the eligible articles and, from a script containing the article title, journal, year of publication, authors, country of origin, objective, study design, number of participants, average age, ECHO positioning, operator, training, initial rhythm and main results, carried out their critical analysis. Next, a consensus was reached, leading to the definition of the articles to be analyzed in this review.

The categorization of data extracted from selected articles into thematic areas was then carried out, through the identification of common variables, and the presentation of results and discussion in a descriptive manner.

III. RESULS AND DISCUSSION

Use of TTE during CA

A prospective observational OH [13], with 32 patients, and a cross-sectional IH and OH study [14], with 9, reported the use of TTE during CA. Both performed the procedure in adults with PEA and the rescuer was a medical professional.

In addition to enabling the visualization of moving heart chambers and valves, synchronized with CPR, the use of TTE was strongly correlated with the level of end-tidal carbon dioxide ($EtCO_2$) induced by resuscitation maneuvers [13]. According to the study authors, the relevance of this finding lies in the fact that, when analyzing this non-invasive measure (lateral flow technique), hemodynamic-guided CPR can be performed, since the $EtCO_2$ levels during CPR reflect pulmonary blood flow and cardiac output. Such parameters can even guide the positioning of the rescuer's hands, which are placed in the lower half of the sternum, without considering individual morphophysiopathological changes, which can potentially affect the hemodynamic effect of CPR [15] (Table 2).

In this sense, it is noted that the personalization of CPR through TTE can increase the hemodynamic efficacy of CPR, the rate of return of spontaneous circulation and survival, in addition to having been considered a promising non-invasive tool for patients undergoing CA. However, as the study itself suggests, it is necessary to verify whether this parameter is applicable to all resuscitated patients [13].

Studies have associated the $EtCO_2$ value above 25 mmHg with the return of spontaneous circulation and, consequently, with survival. Thus, its use could help predict the patient's prognosis as well as decision-making regarding the continuation of resuscitation efforts [16,17].

Through TTE, Miyazaki et al. [14] identified that it is possible to detect right ventricular overload, indicative of pulmonary embolism. From that, it was possible to institute the required treatment, which gave rise to ECMO CPR (extracorporeal veno-arterial membrane oxygenation).

Table 2 – Use of transthoracic echocardiography during cardiopulmonary arrest

Study	**Design**	**No.**	**Initial rhythm**	**Main results**
Skulec et al. [13]	Prospective observational	32	PEA	Positive relationship between compression and expired CO_2 levels (non-invasive measure)
Miyazaki et al. [14]	Cross-sectional	9	PEA	The discovery of right ventricular overload by TTE led to the suspicion of pulmonary embolism, influencing the decision to use extracorporeal veno-arterial membrane oxygenation

TTE, transthoracic echocardiography; PEA, pulseless electrical activity.

Cardiac tamponade, right ventricular distension indicative of pulmonary embolism, hypovolemia, ventricular arrhythmia, and aortic emergencies are examples of accurate diagnoses possible with the use of TTE. When it allows for adequate visualization of the heart, it directs the position of the rescuer's hands over the left ventricle (hemodynamic improvement and higher rate of circulation return and survival) [18,19].

However, Teran et al. [20] carried out a review on the use of TTE during CPR and found the difficulty to obtain interpretable images as a limitation of its use. To this, they linked external and patient-related factors, such as continuous chest compression, positive pressure ventilation, obesity and stomach air, which contribute to challenging images to interpret. For this reason, the use of TTE is being increasingly sought after.

Use of TEE during CA

Of the selected articles, four dealt with the use of TEE during CA: two observational OH studies, one with 33 patients [21], and the other with 22 [22], and two control cases: one with 22 patients, which included events of CA IH and OH [23], and another with 25, performed in the IH environment [24]. In these articles, CPR was performed by emergency physicians and only one specified the heart rate (not shockable) [21].

The studies showed that, by using TEE, it was possible to explore the blood flow mechanism through the opening and closing of the mitral valve and the tricuspid, to identify the type of myocardial activity as well as the reversible causes during CPR compressions [21,22]. Through TEE, for example, ventricular fibrillation was identified, which resulted in defibrillation, ventricular dysfunction [21], and aortic dissection [23], conducted with specific management, but which is associated with unsatisfactory outcome CPR.

In addition, TEE allowed for optimal CPR placement of the hands or mechanical device during ventricular compression. Despite being invasive, the adoption of this practice was evaluated as useful to optimize compressions and guide invasive and homodynamic treatments [21]. It was also identified that the pause of compressions during CA is smaller with the use of TEE compared to TTE [24] (Table 3).

Table 3 – Use of transesophageal echocardiography during cardiopulmonary arrest

Study	Design	No.	Initial rhythm	Main results
Fair et al. [24]	Case-control	25	Not specified	The pause of compressions during cardiopulmonary arrest is smaller with the use of the TEE compared to the TTE
Kim et al. [22]	Prospective observational	22	Not specified	The dynamics of heart compression can be measured by analyzing TEE images of the right ventricle
Teran et al. [21]	Prospective observational	33	Not specified	Characterization of cardiac activity
Kim et al. [23]	Case-control	45	Not specified	TEE is a useful tool for diagnosing aortic dissection as a cause of cardiac arrest during CPR. This condition is associated with poor resuscitation results.

TEE, transesophageal echocardiography; TTE, transthoracic echocardiography; CPR, cardiopulmonary resuscitation.

A prospective cohort study [25], carried out with 40 emergency medical residents, evaluated their ability to learn and practice, in a simulated environment, TEE image acquisition techniques to identify common pathological causes of cardiac arrest as highly precise and accurate. Regardless of external or patient-related factors, TEE is capable of providing continuous, reliable and high-quality myocardial images, which allow for feedback and, in turn, immediate adjustments, aiming at the quality of CPR. Thus, it has a diagnostic and prognostic role similar to TTE, but it does not interrupt chest compressions and provides imaging advantages [20,26].

Recognizing that high-quality cardiac compressions and less interruption in CPR corroborate with increased survival and better neurological outcomes, TEE has been used in environments such as the emergency room and intensive care units (ICU). However, it should be noted that it consists of a semi-invasive procedure, contraindicated for patients with oroesophageal lesions (such as trauma or tumor), recent gastrointestinal (GI) surgery, active GI bleeding, severe coagulopathy, for example [27]. Furthermore, a prospective study carried out in 28 medical centers [28] identified a risk of complications (upper gastrointestinal or pharyngeal bleeding; gastroesophageal laceration or esophageal perforation) of 0.08%, that is, 1:1300 examination, followed by death in 0.03%, equivalent to 1:3000, most in patients without risk factors for gastroesophageal injury. Minor complications such as lip, dental and oral lesions; oral bleeding; odynophagia and swallowing dysfunction may also occur. Thus, although safe, there is a low morbidity and mortality rate associated with TEE that should be considered and support the training of emergency physicians.

The use of POCUS during CA

Finally, the remaining two articles did not specify the position of ECHO (TTE or TEE), approaching the subject in general (POCUS). One of the articles was carried out in the IH environment and consists of a cross-sectional study with 180 patients with non-shockable rhythm CA [29]. The other was a prospective observational study, carried out in the OH, with eight patients in asystole [30].

Greater speed in obtaining diagnoses and therapeutic decisions was observed with the use of POCUS [30], but further studies are needed due to possible risk of bias in the results and the scarcity of literary evidence. In addition, it is not yet proven that the use of this tool increases patient survival [29].

As seen in other articles, Beckett et al. [29] identified that it is possible to detect cardiac activity using POCUS and, in these cases, obtaining a better prognosis is more likely, as pre-hospital teams can look for reversible causes before arriving at the hospital service. [30].

When combined with the electrocardiogram (ECG), it has a sensitivity of 96.2% to identify failure to achieve spontaneous venous return, being more effective in predicting negative CPR results than the ECG alone [29] (Table 4).

Table 4 – Use of FOCUS during cardiopulmonary arrest

Study	Design	No.	Initial rhythm	Main results
Javaudin et al. [30]	Prospective observational	8	Asystole	POCUS can reveal reversible CA conditions, allowing adjustment of clinical management
Beckett et al. [29]	Cross-sectional	180	Non shockable rhythm	The use of POCUS, with or without ECG, better predicts negative outcomes in cardiac arrest than ECG alone.

ECG, electrocardiogram; CA, cardiopulmonary arrest; POCUS, point of care ultrasound.

When it comes to POCUS during CA, studies show that its use has expanded, with applications that include valve assessment, diastolic dysfunction and wall motion abnormalities, in addition to helping in the diagnosis of cardiovascular conditions that can cooperate with shock, such as left ventricular failure and right ventricular dilatation [31].

However, handling this tool has been associated with a significant increase in the time of pulse checks during CA, nearly doubling the maximum 10-second duration recommended in current guidelines. In this sense, it is essential that health professionals are aware of this factor and are trained to apply the POCUS with a view to improving CPR, since the time factor is non-negotiable for these patients [32,33].

IV. FINAL CONSIDERATIONS

The cardiac images provided by POCUS make it possible to assess the movement of cardiac chambers and valves, blood flow and myocardial contractility. From this, the rhythm can be classified as shockable, where the main treatment is electrical defibrillation, or non-shockable, in which the treatment consists of reversing the underlying cause, with ECHO helping to identify many of these causes. That is, you can start the appropriate treatment for the patient more quickly and enable a better prognosis.

According to the data, in addition to visualization of the heart, TTe associated with other monitoring methods, such as $EtCO_2$ (expiratory carbon dioxide levels), corroborate the efficiency of chest compressions and positioning (hemodynamic effectiveness of CPR) the rescuer's hands. However, it interrupts the CPR process and can be limited by conditions related to the patient, such as obesity, for example.

TEE, in turn, allows the visualization of more accurate cardiac images, contributing to more assertive diagnoses. It also helps with hand positioning during CPR, but although it does not interfere with chest compressions, it is an invasive measure. This tool has contraindications and there is a morbidity and mortality rate that, despite being low, should be considered by emergency physicians.

Comparing both, the superiority of TEE over TTE was noted due to its ability to provide constant cardiac images without CA interruption, thus contributing to an early diagnosis and therapeutic decision. However, further studies are needed to confirm whether there is a relationship between the use of POCUS (TTE or TEE) with increased patient survival.

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