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How to perform Point of Care Ultrasound at resuscitation and when it is useful

Daniel Wastl[1], Michael Blaivas[2], Rudolf Horn[3], Guido Michels[4], Armin Seibel[5], Simone Schwarz[6], Beatrice Hoffmann[7], Oliver Hoffmann[7], Dieter von Ow[8], Christoph F Dietrich[8]

[1]Hochtaunus Kliniken Bad Homburg, Germany, [2]University of South Carolina School of Medicine, Department of Medicine, Columbia, South Carolina, USA, [3]Center da sandà Val Müstair, Sta. Maria, Switzerland, [4]Notfallzentrum. Krankenhaus der Barmherzigen Brüder Trier, Trier, Germany, [5]DRK Krankenhaus Kirchen, Interdisciplinary intensive care medicine, Germany, [6]Department of Neonatology and Pediatric Intensive Care Medicine, Sana Hospital Duisburg, Duisburg, Germany, [7]Department of Emergency Medicine, Beth Israel Deaconess Medical Center, Boston MA, Harvard Medical School, USA, [8]Department Allgemeine Innere Medizin (DAIM), Kliniken Hirslanden Beau Site, Salem und Permanence, Bern, Switzerland

Abstract

Point of Care Ultrasound (POCUS) can be useful as a tool before, during and after the performance of cardiopulmonary resuscitation (CPR). Before or after resuscitation it can help with monitoring unstable hemodynamics, has the potential to identify reversible causes if patient deteriorates. During resuscitation POCUS can help detect potentially treatable causes of the cardiac arrest. Performance of POCUS while resuscitation requires experienced sonologists and a good team structure to embed the examination in advanced cardiovascular life support (ACLS) algorithms. This article gives an overview and tips about how to detect potential reversible causes of patient deterioration in all three phases of CPR. We describe some special situations in which resuscitation could take place. Further we give a comment about sonographic education of physicians and nonacademic medical staff.

Keywords: cardiopulmonary resuscitation; POCUS; hemodynamics, guideline; advanced cardiovascular life support (ACLS)

Introduction

Point of Care Ultrasound (POCUS) can be a useful tool before, during and after the performance of cardiopulmonary resuscitation (CPR). Before or after resuscitation it can help monitoring unstable hemodynamics [1,2]. During resuscitation it can help detect potentially treatable causes [3] of the cardiac arrest.

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Corresponding author: Prof. Dr. Christoph F Dietrich
Department Allgemeine Innere Medizin,
Kliniken Hirslanden, Beau Site,
Salem und Permanence
Bern, Switzerland
E-mail: c.f.dietrich@googlemail.com
Phone: +41765397277

In this article we give an overview of available literature and practical recommendations on performing POCUS in each of those situations.

Pre-Resuscitation

Pre-Resuscitation refers to any patient condition with the potential for deterioration into a resuscitation scenario. Common clinical conditions include hypotension, hypoxia/dyspnea, chest pain, acute abdomen and an acute altered mental status (dizziness, confusion). Table I lists clinical diagnoses beyond those symptoms, which can degenerate into shock.

For rapid but accurate diagnosis, POCUS-protocols are helpful in guiding providers through standardized approaches [4]. Such protocols make results comparable, help focus provider on the most relevant findings and

Table I. Some diagnoses and conditions related to symptoms of hypotension, hypoxia, altered mental status.

	Diagnoses and conditions
1	Acute coronary syndrome
2	Pulmonary embolism
3	Aortic syndrome with cardiac tamponade or rupture of abdominal aorta
4	Hypovolemia
5	Tension pneumothorax
6	Infections (with or without sepsis) (pneumonia, cholecystitis, uro-genital infections etc.)
7	Free abdominal or thoracic fluid after trauma or medical interventions

limit the risk of overlooking essential findings [5,6]. The most commonly used protocols include:

- Bedside Lung Ultrasound in Emergency (BLUE) and Fluid administration limited by lung sonography (FALLS)-Protocol [7,8]
- Extended Focused Assessment with Sonography for Trauma (E-FAST) [9]
- Focused Echocardiography in Acute Medicine [10,11]
- Compression-Sonography of Deep Veins [4]
- Rapid Ultrasound in Shock (RUSH) Protocol [12]

BLUE – Protocol

The BLUE and FALLS Protocols are useful to detect causes for dyspnea, like pleural effusion, atelectasis, pneumothorax, pneumonia and pulmonary hyperhydration/edema. Together with clinical symptoms the protocol helps by interpretation of B-Lines, consolidations and pleural movement. Sonologists should be cautious of only examining the pleura (tissue-air interface) and its pathological findings, as any deeper changes may be missed [13].

E-FAST

The primary objective of the E-FAST-exam is to detect signs of intraabdominal or thoracic injury through detection of free fluid in the abdominal or thoracic cavities, pericardial effusion or evidence of pneumothorax [14,15]. In the FAST-Exam (focused assessment with sonography for trauma) the focus is on identification of free fluid in the abdomen and for potential pericardial effusions. The E-FAST (extended focused assessment with sonography for trauma) also examines the chest cavity for a potential pneumothorax or pleural effusion. An experienced operator can perform the E-FAST exam in less than 5 minutes and receive a considerable amount of information regarding possible pathology. In case of negative results repetition of ultrasound or CT-imaging is indicated, especially if patient's clinical condition deteriorates [16].

Focused Echocardiography in Acute Medicine

Echocardiography in acute medicine should be the test of choice in all situations before cardiac arrest and should be combined with pleural sonography. The German guidelines for cardiogenic shock recommend focused echocardiography [17]. Beside the above-mentioned information, focused echocardiography allows understanding the cardiac and valvular function. Examiners should be educated by a curriculum and follow examination protocols including short and long axis and four chamber view. Doppler methods should be used as well as M-mode [11,18]. The International Evidence-Based Recommendations for Focused Cardiac Ultrasound the suggested targets of the FOCUS examination as the follows [19]: LV dimension, systolic function; RV systolic function; volume status; pericardial effusion, tamponade physiology; gross signs of chronic heart disease; gross valvular abnormalities; and large intracardiac masses

These examinations do not have to be carried out by a cardiologist but by an emergency physician.

Compression-Sonography of Deep Veins

With that method deep vein thrombosis can be confirmed or ruled out rapidly. Nowadays it is the diagnostic method of choice [20]. The two-point sonography of the groin and popliteal fossa may be enough in emergent situations. To rule out thrombosis of the calf greater experience is necessary, and more time will be required to complete the examination.

RUSH – Protocol

The RUSH-Exam can be viewed as an essential element of prehospital focused sonography in non-traumatic patients with shock and easy remembered by the mnemonic tank, pump and pipes [12,21-23] (Table II). It entails focused abdominal sonography (free fluid, aneurysm of abdominal aorta), focused chest sonography (hemothorax, pneumothorax, pulmonary edema), focused echocardiography (pericardial effusion, left ventricular dysfunction, dilated right heart and volume status based on evaluation of the inferior vena cava) and compression sonography in search of thrombosis of femoral veins.

In a state of shock, this protocol can be completed in a few minutes and as many findings as possible collected. Individual findings may be incidental (e.g. pre-existing abdominal aortic aneurysm) and should not be considered as a cause of shock unless other findings match.

Table II. Ultrasound-differentiated diagnosis of shock using the RUSH-protocol adapted from [12].

	Pump	Tank	Pipes
Hypovolemic Shock	Hypercontractile and small LV	Flat IVC / jugular veins Pleural / peritoneal Fluid	Abdominal aortic aneurysm / dissection
Cardiogenic Shock	Hypo contractile heart Dilated heart	Distended IVC, jugular veins B-Lines Pleural / peritoneal fluid	Normal
Obstructive Shock	Hypercontractile heart Pericardial effusion RV strain Cardiac thrombus	Distended IVC / jugular veins Absent lung sliding	Deep vein thrombosis
Distributive Shock	Hypercontractile or hypo contractile heart (stadium depended at sepsis)	Normal or small IVC Peritoneal fluid Pleural fluid	Normal

IVC = inferior vena cava; LV = left ventricle; RV = right ventricle

Peri-Resuscitation

The performance of POCUS during CPR can be challenging. Numerous factors (e.g., emphysema, subcutaneous air in case of pneumothorax, excessive adipose tissue, and possible interference with resuscitative efforts) complicate image acquisition and interpretation. Current CPR guidelines recommend that the duration of pulse checks be limited to 10 seconds, since minimizing interruptions is associated with improved rates of return of spontaneous circulation and survival to hospital discharge [3,24]. This arouses concern that using POCUS for characterization of cardiac arrest might prolong the time to the pulse check [25,26]. European Resuscitation (ERC) Guidelines [3] recommend that POCUS operators need to be well trained at assessing cardiac function during the brief periodic interruptions of chest compressions. Short interruptions are keystones for good CPR-performance and outcome [3,25-28]. Application of POCUS requires the operator to be competent in rapid image acquisition in a 10-second period that is conventionally used to perform a pulse check (i.e., seek a palpable pulse) during CPR. Focused Echocardiography in Life Support (FEEL) describes, how to implement the echocardiography in a cardiac arrest situation [10,29,30].

The following are potential important findings during an examination:

- Right heart strain as an indication of pulmonary artery embolism (PAE). Echocardiography in suspected PAE may be helpful in diagnostics (like right ventricular overload / enlargement, hypokinesia, tricuspid valve regurgitation, right atrium enlargement, the presence of thrombi in the right atrium and ventricle). Based on the fact that the right ventricle (RV) is frequently dilated during resuscitation from cardiac arrest [31,32], ultrasound should be combined with relevant evidence from patient history regarding PAE.
- Pericardial tamponade
- Highly reduced pump function
- Hypovolemia
- Pseudo-pulseless electrical activity (PEA) vs. PEA. Pseudo–pEA is defined as organized cardiac activity identified by echocardiography in the absence of a detectable pulse. In contrast, pEA is characterized by a lack of cardiac activity on echocardiography.

For the performance of FEEL two persons are useful. The first person performs the ultrasound, the second person counts down from ten (fig 1). If the second person is the resuscitation team leader, he or she should check the pulse and rhythm while counting. The optimal anatomic region for FEEL is the subxiphoidal area, because there is less interference with chest compression providers or devices. Also, it allows a “search” for the heart while chest compressions are still ongoing [33]. During the ten second pause, the first person should scan and store videos or still images for interpretation after that time. If it is impossible to get an adequate scan in subxiphoidal area, standard cardiac areas can be helpful, i.e.

Fig 1. Sonographer and team leader directly right of patient of resuscitation. Sonographer is waiting for operation.

apical four chamber window, knowing that finding the correct position while chest compression in this situation is often impossible.

During another pulse check, lung pleura can be scanned for pneumothorax, effusion or atelectasis. If 10 seconds is too short, left and right pleura can be scanned in two different "sessions". The ventilator should hyperventilate in that short non-flow period to make pleural sliding visible, if present.

E-FAST can be easily performed during chest compressions (video 1, on the journal site). It enables detection of free fluid as a cause for the resuscitation or secondary to resuscitation. The abdominal aorta also should be checked for rupture or aneurysm (fig 2a). The inferior vena cava has potential to yield information regarding a patient's fluid status (fig 2b) [6,34].

In our experience more expertise is required when scanning the pleura in addition to the FAST during chest compressions or pulse check (Video 2, on the journal site), but it helps evaluate some causes listed in Table II. However, ultrasound is not yet considered an established component in cardiopulmonary resuscitation algorithms. Table III and IV summarize ERC recommendations to peri-arrest POCUS.

Post-Resuscitation

Post resuscitation in case of return of spontaneous circulation can be divided into early and late phases. In the early phase it may be helpful to repeat a RUSH examination if the cause for resuscitation is still unknown. Also, it helps eliminate potential diagnoses, if any uncer-

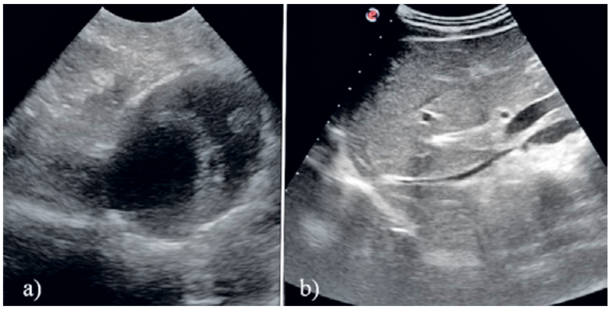

Fig 2. a) Abdominal aorta with dissection; b) Lack of volume. Collapsing V. cava.

tainties exist or if scanning during the resuscitation was not done. When ST-elevations are absent, Focused Echocardiography should be performed by an experienced examiner, if possible. In case of ST-elevation immediately angiography is recommended, and echocardiography should not delay it [35]. "Emergency echocardiography is recommended in patients with suspected acute coronary syndrome presenting with cardiogenic shock or suspected mechanical complications (recommendation: class I, level C). Emergency echocardiography should be considered at triage in cases of diagnostic uncertainty but this should not result in delays in transfer to the cardiac catheterization laboratory if there is suspicion of an acute coronary artery occlusion (recommendation: class IIa, level C) [36]." At the late phase ultrasound helps to seek out any reasons if patients deteriorate by using the described protocols. On daily rounds POCUS helps to guide fluid and vasopressor therapy [2,34,37-40]. Furthermore, it can be integrated with physical examination and helps detect pleural effusion, ascites or ileus [41] (fig

Table III. Use of ultrasound imaging during advanced life support (adapted from the ERC-Guidelines 2021)

General recommendations
Only trained operators should use intra-arrest point-of-care ultrasound (POCUS).
POCUS must not cause additional or prolonged interruptions in chest compression.
POCUS may be useful for diagnosing treatable causes of cardiac arrest such as cardiac tamponade and pneumothorax.
Right ventricular dilation in isolation during cardiac arrest should not be used to diagnose massive pulmonary embolism.
Do not use POCUS for assessing the contractility of the myocardium as a sole indicator for terminating CPR.

Table IV. Summary ERC and AHA recommendations to peri-arrest POCUS.

	AHA-recommendation	**ERC-recommendation**
Chest compression	Real-time audio-visual feedback	
Recharging automatic external defibrillator		Ongoing chest compression
Witnessed cardiac arrest		Three defibrillations in a row
Shockable cardiac arrest rhythms	1 mg adrenaline iv/io after 2nd shock	1 mg adrenaline iv/io after 3rd Shock
Intubation		The usage of a video laryngoscope, pausing chest compression max. 5 seconds
Reversible causes of cardiac arrest listed different		Using sonography if applicable and advanced life support can be continued

3a). Specific questions like the cause for suspicious lab results can be answered (e.g. elevated bilirubin, creatinine). Handheld ultrasound (HHUS) may be helpful to get information about effusions and fluid status rapidly on rounds. For more detailed information HHUS should be used with caution [5,6]. Furthermore, ultrasound has shown great potential for the hemodynamic assessment of critically ill patients [41]. Finally, ultrasound can help with insertion of central intravenous lines or arterial cannulas, a standard of care in many settings [42] (fig 3b, Video 3, on the journal site).

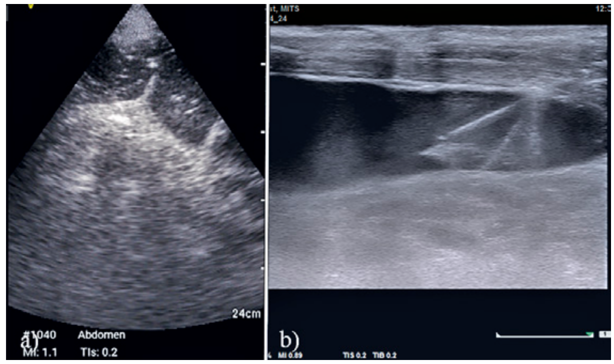

Fig 3. a) Ileus; b) Needle inserted in a vein.

Special ultrasound findings

US in hypovolemia

Hypovolemia can be suspected if the following points occur [40,43]:

- Small inferior vena cava (smaller than 1 cm) and a respiratory diameter variance of more than 30% in inspiration, if patient is being ventilated. Complete collapse can be seen during inspiration if patient breathes spontaneously. However, in mechanical ventilation and high PEEP-strategy, expiratory collapse may be missing, even in the presence of hypovolemic shock.
- Kissing papillary muscles of the left ventricle (if contraction is visible), often called kissing ventricle sign
- Small size of right ventricle
- Assessing for internal bleeding by using eFAST or RUSH Protocol.

Cardiac tamponade

A pericardial effusion is hemodynamically relevant, if it influences the perfusion of end organs. Usually, the free wall of the right atrium is indented inward, the wall of the RV is indented second in sequence as pressure increases. This is seen in the apical four-chamber view, at the subxiphoid window and sometimes also in the parasternal long axis view (fig 4, Video 4, on the journal site).

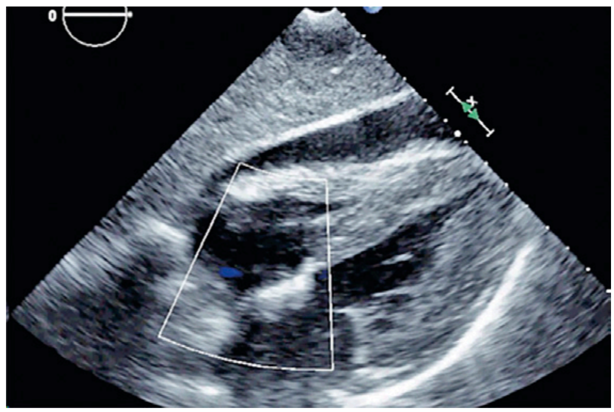
Fig 4. Pericardial tamponade with compression of right ventricle.

Thrombosis coronary

After ROSC the 12 lead ECG is the most important diagnostic tool for detecting myocardial infarction. If there is no ST-elevation myocardial infarction differential diagnosis becomes important. In those situations, echocardiography can help identify potential etiology. For this purpose focused or a complete echocardiography can be performed [17,18].

Thrombosis pulmonary

Echocardiography can help by diagnosing pulmonary embolism [44]. The absence of echocardiographic evidence of RV overload or dysfunction can virtually rule out pulmonary artery embolism as a cause of hemodynamic instability. Right ventricular enlargement or its dysfunction, along with hemodynamic instability, suggests pulmonary embolism as a cause for cardiac arrest. Some typical signs indicating a massive pressure overload of the RV due to a central pulmonary embolism include [45,46]:

- Diameter of RV in the apical four-chamber view greater than the left ventricle
- McConnel sign: preserved function of RV apex and reduced function of midventricular wall of right ventricle.
- Tricuspid annular plane systolic excursion (TAPSE) <18 mm
- Elevated pulmonal arterial pressure (>50 mmHg)
- The 60/60 sign in 2D transthoracic echocardiography (TTE) - a combination of pulmonary acceleration time (PAT) less than 60 milliseconds and tricuspid regurgitation (TR) jet gradient of less than 60 mmHg
- Flattening of the interventricular septum in apical four-chamber view
- D-shape appearance to the interventricular septum in parasternal or subcostal short axis view (Video 5, on the journal site).

A thrombus in the pulmonary artery can sometimes be directly visualized in the parasternal short axis view or may be noted in a subxiphoid short axis window. The triple diagnostic approach for pulmonary embolism has a sensitivity of 93% and a specificity of 92%. Triple diagnostic approach means typical consolidation in lung ultrasound, signs of pressure overload of RV and thrombosis seen in the femoral vein seen in compression ultrasound (video 6, on the journal site). Current guidelines on pulmonary embolism suggest that if pulmonary embolism is suspected and a deep vein thrombosis (DVT) is seen on venous ultrasound, the diagnosis of pulmonary embolism can be accepted [20,47].

RV dilatation alone is not necessarily evidence of massive pulmonary artery embolism. Based on the unique geometry of the RV, there is no single echocardiographic parameter that provides rapid and reliable information about morphology or function. In addition to the diagnosis of pulmonary embolism, echocardiography is also important with regard to risk stratification (high-, intermediate- and low-risk) and risk-adapted management of acute pulmonary embolism. In suspected high-risk pulmonary embolism, as indicated by the presence of hemodynamic instability, bedside echocardiography or emergency CTPA (depending on availability and clinical circumstances) is recommended for diagnosis [47].

Furthermore, right ventricular dilatation and/or dysfunction is also described as a pathophysiologic post cardiac arrest phenomenon [31,32,48-50]. That means, right ventricular dilatation after ROSC cannot be necessarily interpreted as a sign of massive pulmonary embolism.

Chronic pulmonary hypertension also results in right heart changes such as ventricular and apical dilation, hypertrophy of the RV (>5 mm), high pulmonary regurgitant velocity [51,52]. Peri-resuscitation this can be very confusing.

(Tension) pneumothorax

A tension pneumothorax is a clinical sign. That means, that a patient in shock, where a pneumothorax is detected by ultrasound, likely has a tension pneumothorax and must be treated (thoracocentesis) right away. The sonographic signs of pneumothorax are [4,7,13,53-55]:

- The lack of lung sliding: the absence of the movement between the parietal and visceral pleura in a normal lung, M-Mode shows a “seashore sign” with transition of lines differentiating movement at the pleural lines, whereas pneumothorax prevents detection of motion creating a single “bar code” pattern.
- Absence of normal comet tail or reverberation artifacts: this artifact arises from the visceral pleura. It should normally move during respiration and is absent when a pneumothorax is present (fig 5a).
- Lack of lung pulse: the lung pulse refers to the subtle, back and forth, rhythmic movement of the visceral upon the parietal pleura with cardiac oscillations. Pneumothorax does not exhibit a lung pulse. During resuscitation, searching for the lung pulse is not helpful while there is no cardiac activity. The lung pulse can be documented with M-Mode, color Doppler or by saving a cine loop. The color Doppler shows lung sliding or lung pulse with color below the pleural line, and without color above the pleural line (fig 5b). In case of a pneumothorax, no color should be seen, but in many cases, this is not true. Since the Doppler only reacts to movement, but patients with pneumothorax usually show severe dyspnea and do the corresponding work of breathing, color can also be detected on the pneumothorax side.
- Proof of lung point: the lung point is the location where the pneumothorax and normal lung artifacts meet and the region where the pneumothorax causes the parietal and visceral pleura to separate. In large pneumothoraxes, the lung never reaches the chest wall, thus the lung point is missing in this situation (fig 5c).

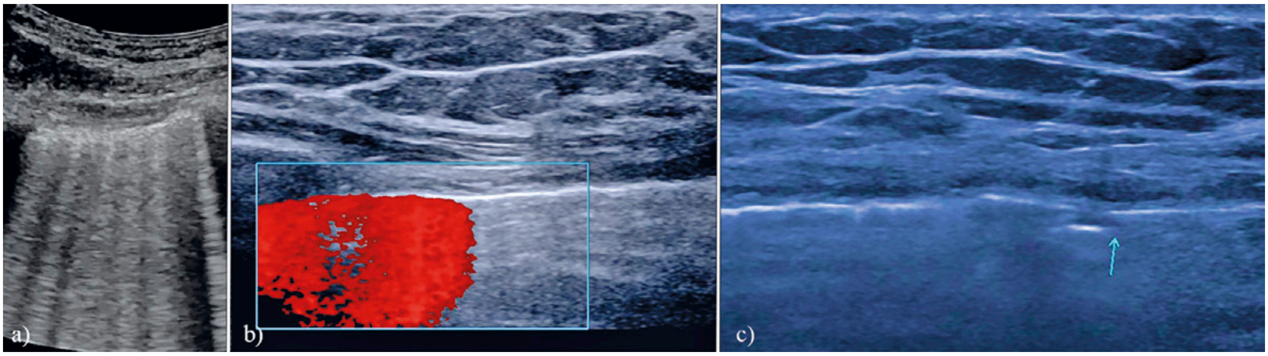

Fig 5. a) Reversible findings during resuscitation. Pulmonary edema in a nearly drowning patient. B-lines are shown [7,74]; b) Pneumothorax. Doppler ultrasound illustrates as well the gliding and non-gliding parts of the lung; c) Pneumothorax. Ultrasound does not reliably allow to differentiate between pneumothorax and tension pneumothorax [53,75,76]. The arrow shows the laceration of the lung surface, the most distinctive sign to identify the s-called lung point.

PEA arrest and Pseudo-PEA Arrest

POCUS can be used to differentiate between PEA arrest and pseudo-PEA arrest. PEA is a type of cardiac arrest where the heart still has some electrical activity, but no pulse. Pseudo-PEA is a condition where there is no palpable pulse, but the heart is still contracting.

If there is concern for PEA vs pseudo-PEA, flow in the carotid or femoral arteries can examined by Doppler ultrasound. A cardiac waveform indicates that the heart is still contracting, even if there is no palpable pulse. In patients with PEA arrest, there will be no cardiac waveform on POCUS. This is because the heart is not contracting effectively. The management should focus on identifying underlying causes and treatment [56,57].

Distinguishing between PEA and pseudo-PEA may seem to be academic and time consuming. In the authors' opinion it can help to decide to stop resuscitation or not. In case of pseudo-PEA, we would continue in case of PEA we would stop, if treatable causes are ruled out.

Specific setting, location of resuscitation

Prehospital cardiac arrest

In Austria and Germany out-of-hospital cardiac arrest (OHCA) often is managed by one emergency physician and a team of paramedics. The physician is acting as a team leader and essentially taking over airway management, the additional task of the sonologist can be taken over by a (trained) team member [30,58]. Paramedics and emergency physicians often do not know each other. This makes communication and knowledge of the guidelines very important. We recommend performing ultrasound as described. Teamwork between physicians and paramedics during cardiopulmonary resuscitation is needed to not delay or even negatively influence acute and emergency medical care. This includes the entire work process, even sonography. Rooney et al [59] evaluated paramedic's performance with POCUS and found that there was variability in the duration of pulse checks and concern for prolonged pauses in between compressions, but paramedics could discriminate between cardiac activity and standstill. As HHUS units are becoming cheap and widely available, a problem may be created for standardized performance of sonography and for results if non-trained personnel performs ultrasound [5,6]. Therefore, this group requires standardized educational programs not just for physicians but also for paramedics. Some German medical societies recently gave recommendations for education in ultrasound in medical intensive care and emergency medicine [60].

Additionally, the prehospital environment poses unique challenges, including limited space, patient movement, and time constraints, which may impact the feasibility and effectiveness of POCUS use. Although several studies have reported the feasibility and potential benefits of POCUS in prehospital arrest scenarios, the evidence base remains limited, primarily consisting of observational studies and small case series [61,62]. Randomized controlled trials evaluating the impact of POCUS on outcomes in prehospital cardiac arrest patients are warranted.

Finally, POCUS can be used to guide interventions in prehospital cardiac arrest.

Emergency department

Even in the emergency ward, there is no other examination method like ultrasound, which can confirm or exclude important diagnoses in minutes. It is recommended that sonography should be available 24/7 [63]. The already mentioned performance procedure should be used.

Comprehensive training in emergency sonography

To ensure nationwide curricular training in POCUS in Germany, Austria and Switzerland, a comprehensive 18-hour basic curriculum on the use of sonography in emergencies was developed in 2011 and has since been established and further developed (https://www.degum.de/fachbereich/arbeitskreise/notfallsonografie/kurscurriculum.html). Based on this, in 2023 seven professional societies have specified recommendations for training in prehospital POCUS [60,64]. These recommendations confirm the initial doctrine that POCUS should be performed in patients with OHCA to diagnose reversible causes. They also state that POCUS does not necessarily have to be performed by a physician but can be performed by any member of the treating team trained in this method. They postulate that POCUS can be effectively integrated into emergency medical services, subject to training and education [65]. As an example, a 16-hour training module including 8h of e-learning and 8h of practical training is presented. Four modules are mandatory and are divided into chest, abdominal, cardiac, and vascular scanning. At the end of the course, participants are required to pass a multiple-choice test. As recommended, courses are also open to non-physicians, as a team-based approach is essential in the prehospital treatment of critically ill patients.

Special population

Pediatric patients

Pediatric out-of-hospital cardiac arrest is a rare event with higher incidence and mortality in infants than in older children. In a Danish study, 49% of cases had a presumed reversible cause, with hypoxia being the most common cause of pediatric out-of-hospital cardiac arrest in all age groups [66]. Most pediatric cardiac arrests occur in the hospital in neonatal or pediatric intensive care units and other monitored areas and are precipitated by respiratory arrest or shock. In half of the events, bradycardia with poor perfusion is the initial rhythm, and only about 10% of events have an initial shockable rhythm [67]. Thus, pediatric cardiac arrest is less commonly caused by ventricular tachycardia and cardiac events than in adult patients [68].

During CPR, the same principles for identifying reversible causes and for the general use of POCUS apply, as in adults. In children, however, special attention should be paid to early detection and proper therapy in the phase before cardiac arrest in order to prevent CPR if possible and thus improve the prognosis. In this prearrest phase, ultrasound may help to ensure that appropriate therapy can be initiated in time. The causes of acute clinical deterioration in the neonatal intensive care unit (NICU) differ from those in the adult population because of the immature organ systems of premature and newborn infants and possible congenital malformations. Therefore, specific POCUS protocols have been developed for NICU patients [69,70]. Yousef et al suggest the SAFE-R protocol. The probe is first placed on the chest at the left parasternal or substernal axis to evaluate cardiac function and rule out cardiac tamponade. Then the probe is moved to the anterior chest wall bilaterally to assess bilateral pleural sliding (pneumothorax, incorrect intubation), afterward to the inferior posterolateral chest wall bilaterally to assess for pleural effusion and free intra-abdominal fluid. The probe is then moved to the substernal notch to assess the pulsatility of the abdominal aorta as screening of critical aortic occlusion and then to the iliac fossae to assess for abundant intra-abdominal free fluid. Finally, the probe is placed on the anterior fontanel to evaluate for severe intracranial hemorrhage [70]. Elsayeed et al describes a more detailed protocol developed for the NICU that includes cardiac POCUS, lung POCUS, abdominal POCUS and cranial POCUS [69]. The possibility of a congenital heart defect should always be considered, and detailed echocardiography should be performed as soon as possible [69,70].

Pregnancy

ERC recommends ultrasound for detection and treatment of reversible causes. But after 20^{th} week of gestation, it also recommends cesarean section within 4 minutes (before the 20^{th} week a cesarian section is recommended after 4 minutes). This has a big impact on time management, team management and material use. Performing sonography in such a setting demands a very strict protocol. There is not much experience and no studies are available to this topic. In our opinion POCUS should be performed before the cesarian. There should be no time delay in the evaluation of the fetus [71].

Postmortem ultrasound (after resuscitation, "US-Autopsy")

Ultrasound directly performed after failed resuscitation may improve the understanding of underlying diseases as described for classical autopsy. The advantages of post-mortem imaging include promptly determining potentially valuable findings that may help determine the cause of death directly after resuscitation at low cost [72,73]. Postmortem gas formation in the intestinal wall is not of importance directly after resuscitation, and, therefore, cannot be a major limiting factor for use of US in this scenario. The experience is based on limited personal experience.

Conclusion

Ultrasound can help to avoid resuscitation and to guide therapy after resuscitation [https://doi.org/10.3390/diagnostics14060593]. POCUS should be used according to an appropriate protocol. During CPR POCUS should only be carried out by sufficiently experienced and trained users or user teams. Unnecessary and prolonged interruptions during chest compression should be avoided (max. 10 seconds during rhythm analysis).

Conflict of interest: none

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