Point of Care Ultrasound with Cardiac Arrest

RWJBaranbas/HCCC Paramedic Program - Class 25

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Introduction

Portable, medical ultrasound device prototypes were developed in the military in the late 1990s. Lee, et al. (2020) These devices were small enough to be wheeled bedside on a cart. Within a decade these units became handheld and also began to appear in civilian contexts. Companies like GE Healthcare and Butterfly Network, now sell devices that cost under 5000 USD (2023). This level of portability has extended the use of such devices not only in clinical and outpatient settings but also bedside in hospital emergency departments and on ambulances and helicopters in a prehospital context.

POCUS (Point of Care UltraSound) has utility in quickly generating diagnostic images for patients with a variety of traumatic and medical issues. While the images do not have the resolution of larger dedicated devices, they can provide diagnostic information in the field or in the ED that may help triage and drive treatment plans. The American College of Emergency Physicians (ACEP) delineate POCUS scope of practice areas as: “resuscitation, diagnosis, procedural guidance, signs/symptom evaluation, and therapeutic or monitoring indications” Lee, et al. (2020). POCUS protocols can improve metrics like “time to surgical management” which in turn can improve outcomes. Current research on the feasibility of portable ultrasound use in the treatment of cardiac arrest is the focus of what follows.

POCUS research

Cardiac applications of POCUS are under very active research, particularly around the management of cardiac arrest. Quantitative research in this area is a challenge due to heterogeneity, particularly in these areas: the environment. OHCA or IHCA (“Out of” and “In Hospital Cardiac Arrest”); crew composition, training, expertise; development of POCUS protocols; research criteria and biases.

The location of cardiac arrest is one of the leading indicators of positive outcome. IHCA has much higher rate of survival - Gottlieb, et al. (2023) cite “rate-of-survival-to-discharge for out of hospital CA (OHCA) as around 9% and up to 35% when CA occurs in the ED”. IHCA are often observed and happen in a much more controlled environment. OHCA percentage jumps sharply when the arrest is witnessed and quality compressions/AED are applied in a timely fashion. Throughout the BLS/CPR training, the AHA uses the term “Chain of Survival” to show that the individual components are inherently linked and essential - immediate witnesses -> BLS -> ALS -> ER - any weaknesses or breaks in this chain reduce likeliness of a good outcome. For POCUS to have utility in CA it must not cause delays or inaccuracies in this process. The OHCA/IHCA distinction may not be as important as the continuity and quality of the chain of survival.

This ‘chain’ is subject to the extreme variety of OHCA. Much of the initial triage attempts to identify likely causes (MOI/NOI/patient history) as well as ways of reversing the arrest. Delays in crucial therapeutic response is critical - “time is brain” is a common motto for prehospital stroke response but also applies here. Some delays are unavoidable, OHCA are stabilized on scene and then transported. Making faster and better decisions on likely causes of CA and the feasibility of resuscitation is possibly the best application for POCUS in the CA context.

Each link, with different medical level and expertise, does not have the same exposure to ultrasound. POCUS is an educational tool used by first year medical students in many schools Lee, et al. (2020). Outside of some very specialized training and research programs Lema, et al. (2018) and Vianen, et al. (2023), for example) POCUS is a new area for Anglo American prehospital systems. In the US paramedics do not already have training experience with ultrasound.

Prehospital care, the composition of an ambulance crew or helicopter crew, differs in a Franco-German vs Anglo American context. Within the US the scope of practice can differ from state to state. In the UK scope of practice is national and the education is different as compared to its "Anglo American" cohort. An ambulance in Europe might have a physician, nurse and paramedic - in the US the ALS/ BLS paradigm of paramedics and EMTs. Differing levels of training and scope of practices also drive the development of protocols. Add in the capabilities of different POCUS devices in an industry rapidly developing new models and this is a research topic that is hard to generalize.

Walker, et al. (2017) note limitations to research in this area which involves "a lack of clarity of exclusion criteria…" One example noted is the comparison between trauma patients and medical cardiac arrest patients. Another confusion lies in the definitions of a positive outcome. This can be considered ROSC or release to the ICU or release from the hospital or 10 day survival out of hospital, etc (depending upon the study). Yet another example of variation lies in the criteria used to indicate that resuscitation should be ceased (discussed further below).

Researchers call for "more Randomized Controlled Trials (RCTs") and "clearer criteria for results" Walker, et al. (2017). In searching the Science Direct, PubMed, and CINAHL databases for "cardiac arrest ultrasound" most of the articles on this topic are from 2008 to present. Some of the studies Dudek, et al. (2023), Tsou, et al. (2017), Walker, et al. (2017) attempt large scale reviews of multiple existing studies. Gottlieb, et al. (2023), Vianen, et al. (2023) and Zanatta, et al. (2020) are more homogenous in that they focus on single systems over a time period. The studies reviewed showed a preoccupation with trying to identify the "feasible" and useful applications of POCUS as well as attempts to develop protocols for using it in an efficient and trainable way.

Cardio Pulmonary Resuscitation

CPR is grounded in the BLS skills of compressions/AED/ventilations; any application of POCUS needs to fit in this paradigm. Both the American Heart Association as well Red Cross guidelines for high quality CPR stress the importance of proper and uninterrupted compressions and any interruptions of this are to be minimized. From an AHA guideline citing "5 critical components of high-quality CPR" the first is "minimize interruptions in chest compressions" Meaney, et al. (2013)

There is consensus among the studies reviewed - Gottlieb, et al. (2023):

"One potential concern with POCUS in cardiac arrest has been the prolongation of these pauses, with retrospective studies reporting a 4- to 8-second increase in pause duration."

Brown, et al. (2021) note that to get useful images of the heart compressions need to be paused the typical time this happens could be during a pulse check. The main problem is that the "10 second window of interrupted compressions often are not adequate for quality images". The challenge of getting "feasible" images is possible note Reynolds, et al. (2022) but is dependent on practitioner skill and the challenges of the OHCA environment.

One interesting option (outside the scope of this discussion), TEE (transesophageal echocardiography) produces better cardiac images (especially posterior) and once in place would provide less of an interruption hazard. The use of TEE in OHCA would provide a significant training challenge and would add complexity to the placing of endotracheal tubes. Once the TEE were in place it would be much less interruptive to CPR.

Indicators of futility

Dudek, et al. (2023) note that POCUS helps distinguish "indicators of futility" from "potentially reversible causes of arrest". Futility is connected to lack of cardiac activity - electrical or mechanical. A number of terms are used across the studies:

- PEA (Pulseless Electrical Activity) Dudek, et al. (2023)
- lack of VWM (Ventricular Wall Motion) Walker, et al. (2017)
- SCM (Spontaneous Cardiac Motion (or Movement)) Brown, et al. (2021), Tsou, et al. (2017)
- Asystole (lack of any electrical activity) Dudek, et al. (2023))
- Cardiac Standstill (Gottlieb, et al. (2023), Simard, et al. (2019), Wharton, et al. (2022)

Brown, et al. (2021) noted a "troubling confirmation bias" in this area and suggested that a study take place where CPR is continued for a time period to confirm that CA is not reversible.

Research in this area notes PEA and asystole as the 2 indicators to cease CPR. Asystole is the lack of electrical activity on an ECG and PEA is electrical activity that is not organized nor sufficient enough to generate a pulse. One limitiation of an ECG is that is might not distinguish a condition called "pseudo PEA". Dudek, et al. (2023) see potentially reversible conditions that could be mistaken for futility indicators. By imaging the large arteries and myocardium it is possible to pick up activity that ECG and palpitation might miss. "Studies on the use of ultrasonography indicate that 10–35% of patients with asystole demonstrate myocardial contractile activity." Dudek, et al. (2023). There are cases where "pseudo" asystole and PEA are potentially reversible (bradycardia and hypovolemia for examples) Gottlieb, et al. (2023).

Along these lines, POCUS can provide the advantage of more accurate pulse checks. Simard, et al. (2019) describe a technique whereby the POCUS device is placed on the transverse orientation lateral to the trachea. From here the jugular vein and the more medial carotid artery are visible. With downward pressure the jugular visibly collapses but a beating carotid remains pusatile. If there is no pulse then the artery compresses as well. If the carotid is not accessible the femoral artery can also be used. "a POCUS pulse check can be consistently performed in < 5 s and is clearly determinate".

POCUS assisted resuscitation

When trying to identify subtle signs of pseudo-PEA/Asystole, a proper pulse check is essential. "Incorrect identification of a pulse can lead to delays in chest compressions, unnecessary chest compressions, or incorrect medication administration." Simard, et al. (2019) Pulse checks can improve the quality of CPR; other studies look at the impact that POCUS could have on resuscitation quality. Zanatta, et al. (2020) focus on the use of POCUS to guide CPR - "to assess the quality of chest compressions, to improve the cardiac massage quality by an ultrasound-guided change of the site of compression, and finally, to indicate which was the area of the thorax that should be compressed to obtain the best hemodynamic effect of CPR". This was verified using ETCO2. Dudek, et al. (2023) also notes this application in passing.) This is a notable study in that they attempt to control for subject bias as much as possible selecting for "adult patients with CPR for nontraumatic and witnessed OHCA".

Lema, et al. (2018) argue that ultrasound can confirm proper placement of the endotracheal tube to augment auscultation and capnography. This study took place with NY State paramedics using cadavers for test subjects. They claim "The "double trachea" or "double tract" signs had a PPV of 91.0%-98.8% and NPV of 99.0%-100.0% for the correct identification of esophageal intubation."

POCUS protocols to identify reversible causes of CA

Identifying reversible causes of CA can direct the response allowing for better interventions. POCUS imaging can pick up causes like: hypovolemia, cardiac tamponade, pulmonary embolism, pneumothorax, cardiac tamponade, AAA, papilary muscle rupture. (Tsou, et al. (2017); Dudek, et al. (2023); Gottlieb, et al. (2023)). This is promising in theory, however the placement of another device in the already crowded thoracic area during CPR is a logistical problem all its own. Patel, et al. (2023) and it is hard to grab images in time to avoid delaying compressions (during a pulse check, etc).

Taking the examples of cardiac tamponade and pneumothorax, correct identification has a real impact on positive outcome as Gottlieb, et al. (2023) note: “One study found that patients in cardiac arrest who underwent pericardiocentesis for suspected tamponade demonstrated a higher survival-to-discharge than all other patients (15% versus 1%). Therefore, when a pericardial effusion is identified and there is heightened suspicion for tamponade, pericardial drainage should be performed.” In cases of pneumothorax and cardiac tamponade it is not possible to reverse CA without first addressing the inter-thoracic pressure.

These applications are also very dependent on practitioner skill and protocols are developed to identify the most efficient way to get valuable images. There is a longer history of ultrasound protocols like the eFast trauma protocol Habrat, et al. (2022) which includes a thoracic scan to detect fluid or air. eFAST is used by the Dutch HEMS system and the study by Vianen, et al. (2023) notes “A tailored HEMS POCUS training curriculum should include ultrasound techniques for trauma and cardiac arrest.”

Balderston, et al. (2021), Gottlieb, et al. (2023) and Dudek, et al. (2023) noted a number of attempts to come up with protocols that would be trainable and repeatable with the goal of minimizing time wastage in the “windows” available to POCUS. Cardiac protocols like FOCUS (Focused cardiac ultrasound); FATE (Focused Assessed TTE Examination) or POCUS-CA (Point-of-Care Ultrasound in Cardiorespiratory Arrest) identify any applications which might interrupt compressions. Gottlieb, et al. (2023) note two ways to do this: “Perform non-cardiac applications (e.g., lung, airway, deep venous thrombosis) while compressions are ongoing” and “Place the transducer on the chest to identify the optimal cardiac window prior to pausing compressions.”

Conclusion

Point of care ultrasound has intriguing applications for the management of cardiac arrest. The heterogeneity of environments, practitioners, etiologies, protocols, equipment make it hard to generalize but it appears that POCUS may help diagnose situations where CPR is futile but also where it is not - diagnose possible reversible causes. Fundamental CPR remains the foundation of cardia resuscitation and POCUS must fit into this paradigm: the leitmotifs of: “above all, don’t interrupt compressions”, “we need more quantitative research” and “success is bound to skill and training levels” were consistently cited.

The most agreed upon application of POCUS for CA was to identify when CPR and resuscitation is futile. Giving providers more clarity in this area is good. The range in definitive target signs show that there is more work to make this a rigorous application.

The use of POCUS to identify likely causes of CA and possible therapeutic responses is also very promising. This area is very dependent on training and skill. The windows of time to grab such images in the crowded thoracic real estate of CPR leave little room for error and reattempts. More precise detection of pulse activity is an immediate improvement over manual checks and, according to some research, POCUS is better than ECG to detect pseudo-PEA or pseudo-Asystole.

The continued development of training and protocols to make POCUS for CA more efficient and definitive should make it more feasible to have POCUS devices in the prehospital environment.

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