Original Article

Pre-hospital assessment with ultrasound in emergencies: implementation in the field

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BACKGROUND: Point-of-care ultrasound (US) is a proven diagnostic imaging tool in the emergency department (ED). Modern US devices are now more compact, affordable and portable, which has led to increased usage in austere environments. However, studies supporting the use of US in the prehospital setting are limited. The primary outcome of this pilot study was to determine if paramedics could perform cardiac ultrasound in the field and obtain images that were adequate for interpretation. A secondary outcome was whether paramedics could correctly identify cardiac activity or the lack thereof in cardiac arrest patients.

METHODS: We performed a prospective educational study using a convenience sample of professional paramedics without ultrasound experience. Eligible paramedics participated in a 3-hour session on point-of-care US. The paramedics then used US during emergency calls and saved the scans for possible cardiac complaints including: chest pain, dyspnea, loss of consciousness, trauma, or cardiac arrest.

RESULTS: Four paramedics from two distinct fire stations enrolled a total of 19 unique patients, of whom 17 were deemed adequate for clinical decision making (89%, 95%*CI* 67%–99%). Paramedics accurately recorded 17 cases of cardiac activity (100%, 95%*CI* 84%–100%) and 2 cases of cardiac standstill (100%, 95%*CI* 22%–100%).

CONCLUSION: Our pilot study suggests that with minimal training, paramedics can use US to obtain cardiac images that are adequate for interpretation and diagnose cardiac standstill. Further large-scale clinical trials are needed to determine if prehospital US can be used to guide care for patients with cardiac complaints.

KEY WORDS: Prehospital ultrasound; Cardiac ultrasound; Emergency ultrasound

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INTRODUCTION

Point-of-care ultrasound (US) has been established as an ideal imaging modality when used by trained emergency physicians in the clinical setting. It can rapidly and accurately diagnose many life-threatening conditions including hemoperitoneum, pericardial effusion, cardiac tamponade, pneumothorax, and abdominal aortic aneurysm.[1–5] Arguably, it has become the initial imaging modality of choice in critically-ill patients because of its portability, ease of use, speed, and provision of dynamic real-time information without exposing patients to ionizing radiation. These attributes make US an attractive tool in the prehospital setting.

Point-of-care ultrasound is especially useful in the setting of cardiac arrest. Traditionally, clinicians follow advanced cardiac life support (ACLS) protocols to search for an etiology for the arrest. A previous study[6] has shown that all patients with cardiac standstill on initial ultrasound die before leaving the emergency department. While lack of cardiac motion has been shown to guide the termination of resuscitative efforts in the hospital setting, no studies have evaluated cardiac ultrasound in the prehospital setting. While its application in measuring hemodynamics remains controversial, the technical aspects of acquiring images are not outside the skill boundaries of basic health care providers.[7–10] Backlund et al[9] and Press et al[10] have shown that emergency medicine service (EMS) providers are able to perform and interpret extended focused assessment with sonography for trauma (eFAST) and evaluate the lungs for pneumothorax with efficacy.

Importance

For prehospital personnel, there is a growing role for US in decision-making. Currently, 4% of EMS systems use ultrasound and 21% are considering its implementation.[10] While it is widely believed that adherence to the ACLS guidelines results in improved outcomes, there is growing belief that US can be used as a decision-making tool on whether to continue or terminate resuscitative efforts. Based on studies recommended by the American Heart Association, echocardiography should be used as an adjunct to patient evaluation.[11] While this topic has been previously studied in the emergency department, point of care US in the hands of EMS is less understood. In Europe and Australia, physicians in the pre-hospital setting have shown an ability to identify treatable pathology in a majority of patients, however this is not established in the United States.[12–14]

Using similar training sessions as those provided to physicians and medical students, numerous simulation studies have tested the capabilities of paramedics to learn and retain US skills.[13–15] Brooke et al[16] demonstrated in a prospective observation cohort study that, after 10 hours of training, paramedics were able to achieve lung US technical skill at an adequacy threshold similar to expert physician sonographers. While one study has demonstrated moderate accuracy of eFAST examinations by helicopter EMS providers, further large-scale clinical trials are needed to determine if pre-hospital personnel can effectively use point of care US to help direct patient care.

Goals of the investigation

The primary objective of this pilot study was to determine if paramedics could perform cardiac ultrasound in the field and obtain images that were adequate for interpretation. A secondary outcome was whether paramedics could correctly identify cardiac activity or the lack thereof in cardiac arrest patients.

METHODS

Study design and setting

This was a prospective, interventional study using a convenience sample of Orange County Fire Authority paramedics who voluntarily participated. The participants signed consent forms and completed Health Insurance Portability and Accountability Act (HIPAA) training before enrollment. The institutional review board (IRB) of our institution had approved the study which was perdformed between August 2012 and September 2014. We trained a total of 20 paramedics based on the Pre-hospital Assessment with Ultrasound for Emergencies (PAUSE) protocol; however, 4 different paramedics participated in data collection (Figure 1).

All paramedics had no US experience. They received a three-hour training session on point-of-care ultrasound, including didactic and hands-on training. The two-hour didactic portion included ultrasound physics, image acquisition, machine functionality, and basic image interpretation. Video podcast lecture presentations from an online medical school curriculum were viewed using iTunesU. Then, the paramedics participated in a one-hour hands-on session with healthy models to demonstrate the following views: subxiphoid, four-chamber cardiac, and left parasternal long axis.

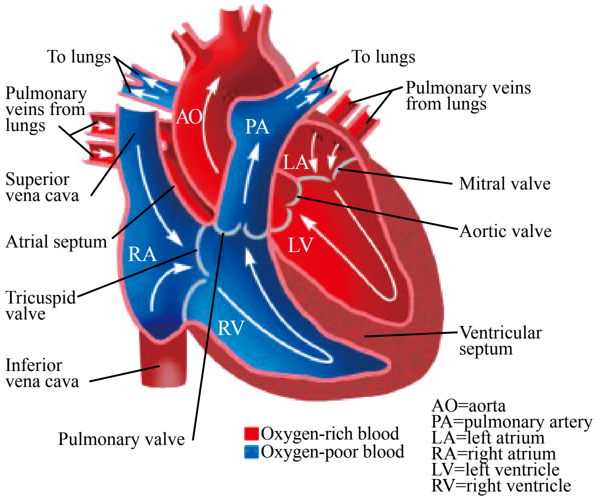
We used two US machines: Mobisante (Redmond, WA) Mobius SP1 with a 3.5 MHz phased array transducer and a GE (Fairfield, CT) Vscan with a 1.7–3.8 MHz phased array transducer. We instructed the paramedics on how to save video clips for later review by the research study team. We then gave the paramedics two tests to assess the efficacy of their training. The first was a test on ultrasound clips aimed at differentiating cardiac standstill from cardiac motion. The second test was a series of 20 questions concerning the operation of the machines and proper ultrasound technique. We deemed the paramedics to be adequate for study enrollment if they received greater than 80% on the written examination and were able to demonstrate the ability to obtain all cardiac views.

Paramedics performed and recorded point of care ultrasound on patients presenting with multiple cardiac complaints including: dyspnea, chest pain, loss of consciousness, chest trauma, and cardiac arrest. Our institutional review board approved a waiver of consent. During cardiac arrest calls, one paramedic performed

Prehospital Assessment with Ultrasound in Emergencies (PAUSE) 2: Paramedic Reference Sheet

Ultrasound basics
–Ultrasound imaging/ultrasonography: reflected sound waves used to image the body.
–Noninvasive and does not emit radiation like CT scans or X-rays.
–Sound passes through or reflects off various tissues at different speeds: it CANNOT go through bone.
–Sound beam comes out of the probe in a shape like a slice of pizza.
–Indicator on probe corresponds to screen indicator: helps to orient user.
–Sound beam depth can be adjusted to maximize size of relevant anatomy.

Heart anatomy review and scanning windows
Blood flow:
From body → R. Atrium → Tricuspid valve → R. Ventricle → To lungs
From lungs → L. Atrium → Mitral valve → L. Ventricle → Aorta to body



Heart position in chest:
– Right side of heart is anterior
– Left side of heart lies behind and to the outer left

Parasternal long-axis:
– Indicator to the patient's left elbow–hip
– Easiest view to acquire on obese patients
– Good left ventricular contractility needed to pump blood to body

Subxiphoid:
– Indicator to patient's right side
– Aim probe to patient's left shoulder
– Imagine 2D slice sitting just behind sternum
– Both left and right heart chambers can be seen

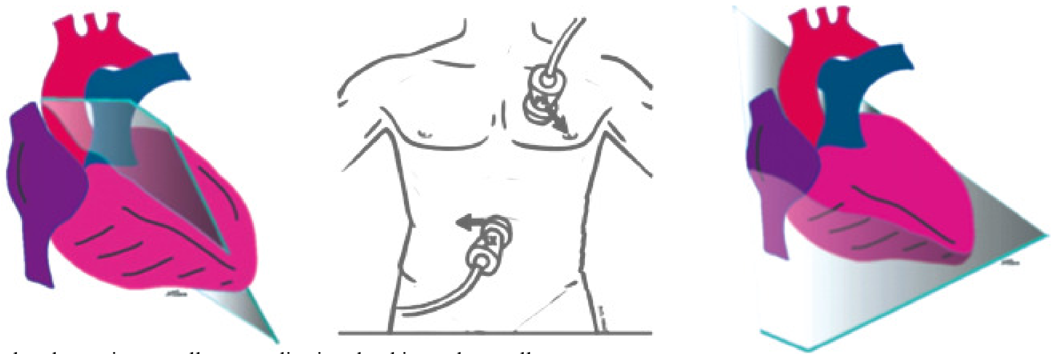


Figure 1. Basic hand-out given to all paramedics involved in study enrollment.

standard ACLS protocol on the patient, while the other used ultrasound to assess for cardiac standstill (Figure 2). The reassessment phase of resuscitation during the cardiac arrest protocol allowed opportunities during hospital transport to obtain cardiac US views. If at any moment, cardiac US interfered with treatment, paramedics would terminate the imaging protocol. The paramedics were told to use judgment on where to obtain the US images, either at the patient's pick-up location or en route to the nearest hospital.

Patients over 18 were eligible for enrollment. Children under 18, pregnant women, and prisoners were excluded from this study. A scan was recorded as adequate only if the paramedics felt they obtained one or more satisfactory views of the two axes taught. Similarly, for cardiac activity, the paramedics recorded the heart as "beating" versus "non-beating". Paramedics' scans and information was recorded in electronic study sheets for retrospective review (Figure 3). None of the information or clips obtained was used for clinical purposes. Two US-trained emergency physicians then reviewed the clips independently and used a 6-point scale to rate them (Figure 4). If reviewers disagreed, the clips were then reviewed together with a consensus score agreed upon. A score of 4

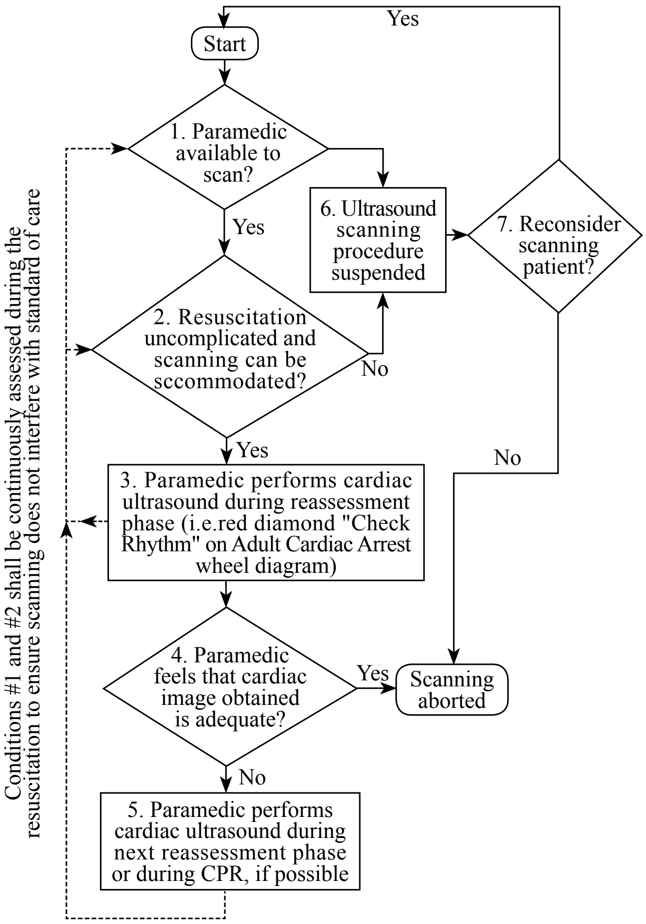


Figure 2. Patient enrollment flow sheet.

PAUSE 2 Project, Paramedic Study Shoot

Exam time and date info. (from machine):

Chief complaint: Full Arrest Chest Pain Dyspnea Loss of Consciousness Trauma

View obtained: Subxiphoid Parasternal long-axis

Adequate view? Yes No Scan aborted due to interference

Heart motion: Beating Non-beating

Notes:

Figure 3. Paramedic data collection sheet.

1) No myocardium visualized
2) Myocardium visualized
3) Partial ventricle visualized
4) Multiple partial chambers visualized (including at least one ventricle)
5) Full ventricle visualized
6) Multiple full chambers visualized (including at least one ventricle)

Figure 4. Demonstrates grading rubric used to judge adequacy of images.

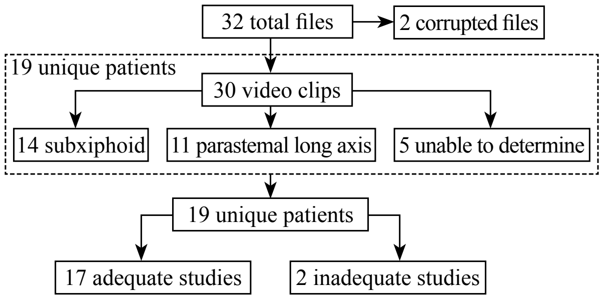


Figure 5. Flow chart illustrating enrolled patients.

was used as the threshold for "adequate" cardiac view as this required partial ventricular visualization.

Outcome measures

Depending on the patient's presenting chief complaint, we measured two primary outcomes. First, we reviewed each scan for adequacy in medical decision-making. Second, in patients presenting with loss of consciousness or cardiac arrest, point of care US was used to determine the presence of cardiac activity. For all patients, the paramedics recorded a dichotomous variable in the ambulance after obtaining imaging. This variable was the judgment call made by the paramedics on the readability of the scan obtained in the ambulance. The paramedics judged a scan as adequate if they obtained either: 1) Left parasternal long axis view or 2) Subxiphoid four-chamber view of the patient's heart. If the paramedics believed that neither the parasternal long axis view nor subxiphoid-four chamber view was readable, they logged the patient scan as "inadequate". For cardiac arrest and unconscious patients: dichotomous variable ("beating" OR "non-beating") describing heart movement recorded by a paramedic in the ambulance after this paramedic obtained heart imaging that was judged to be adequate.

Primary data analysis

We put all data into a spreadsheet (Excel, Microsoft Corporation, Redmond, WA). We reported the percent of scans that were adequate and the percent of correct results for cardiac activity and cardiac standstill with 95% exact binomial confidence intervals. One-sided intervals were presented for estimates of 100%.

RESULTS

Four of 20 eligible paramedics scored greater than 80% on the initial written examination. These four paramedics from two distinct fire stations enrolled a total of 19 unique patients, of whom 17 were deemed adequate for clinical decision-making (89%, 95%*CI* 67%–99%) (Figure 5). Two inadequate studies were performed on

Table 1. Unique patient-specific results

Patient	View	Quality	Motion
1	Subxiphoid	Adequate	Beating
2	Subxiphoid	Adequate	Not beating
3	Parasternal long axis	Adequate	Beating
4	Parasternal long axis	Adequate	Not beating
5	Parasternal long axis	Adequate	Beating
6	Parasternal long axis	Adequate	Beating
7	Parasternal long axis	Adequate	Beating
8	Subxiphoid	Adequate	Beating
9	Subxiphoid	Adequate	Beating
10	Subxiphoid	Adequate	Beating
11	Inadequate	Inadequate	Beating
12	Parasternal long axis	Adequate	Beating
13	Subxiphoid	Adequate	Beating
14	Inadequate	Inadequate	Beating
15	Subxiphoid	Adequate	Beating
16	Subxiphoid	Adequate	Beating
17	Subxiphoid	Adequate	Beating
18	Parasternal long axis	Adequate	Beating
19	Parasternal long axis	Adequate	Beating

one patient in whom there was a successful parasternal long axis view, just not a sub-xiphoid view. Paramedics accurately recorded 17 cases of cardiac activity (100%, 95%*CI* 84%–100%) and 2 cases of cardiac standstill (100%, 95%*CI* 22%–100%). Therefore, 89% of the paramedics were successful in obtaining point-of-care cardiac US scans and 100% in differentiating cardiac activity versus standstill (Table 1).

DISCUSSION

Currently, there are few studies that assess the utility of point of care US in the prehospital setting. To date, there are no other portable imaging modalities that can achieve visualization of the heart during cardiac arrest.[17,18] New technological advances have created US devices with small footprints, allowing for use on ambulances and helicopters.[13] Furthermore, multiple studies have shown that US minimally disrupts resuscitative efforts in critically ill patients and can potentially alter their outcome.[19] Despite these advances, there is currently no widely recognized US protocol that specifically addresses immediate needs of pre-hospital providers.

Medical ultrasonography has continued to spread across medical specialties and now has ever-expanding roles in various hospital departments.[3] This has been exemplified by the rapid dissemination of US use in limited-resource settings abroad.[20,21] While US has been proven in countless studies to be effective in the hands of trained physicians, the technical aspects of image acquisition is believed to be easily acquired by basic health care providers and educated adults, given adequate training. Nurses, astronauts and medical students have proven this concept in multiple studies.[22–25] Our study determined if this concept can be applied to EMS providers in identifying basic cardiac anatomy and differentiating between cardiac standstill and cardiac activity. However, only four of 20 paramedics scored high enough on the written examination to enroll patients. This may be due to the limited amount of lecture training, given the need for hands on instruction. Future studies may consider increasing the length of training before allowing paramedics to use ultrasound.

In other studies, paramedics have shown promise in learning to use point of care US in numerous simulation studies; however real-world studies are sparse. British paramedics were able to achieve lung US technical skill at an adequacy threshold similar to expert physician sonographers with only 10 hours of training in US clip identification and practical scanning.[16] A study of United States Army intermediate paramedics trained in cardiac echocardiography introduced a new measure for adequacy judgment of echocardiograms on a 6-point Cardiac Ultrasound Structural Assessment Scale (CUSAS).[9] Chin and colleagues[17] then used the CUSAS measure to evaluate 20 paramedics on a written test of saved video clips with successful results. The most robust and practical pre-hospital study to date was published in 2010 and involved paramedics using US in the field to perform FAST scans. Heegaard and colleagues[26] reported a 100% of agreement of paramedics with physicians over readers on FAST and abdominal aortic aneurysm screening exams.

Despite these studies, there is no consensus for the scope of ultrasound in the hands of EMS nor the amount of training for proficiency. Our study determined if EMS providers were able to identify cardiac anatomy and differentiate cardiac activity from cardiac standstill after only three hours of ultrasound education. Although the total number of paramedics involved[4] and patients enrolled[19] is small, our pilot study can potentially carry widespread implications. As with original in-hospital US, our study was limited by a variety of factors. Our portable, hand-held units had short battery life and required frequent charging. Short commute times for EMS personnel often discouraged US given the need for EMS to obtain a history and physical exam, establish intravenous access, and obtain electrocardiogram. Lastly, we were only able to obtain two machines for patient enrollment. This meant that if a machine was already on an ambulance, it could not be used at another site. Despite these hurdles, we find that paramedics can obtain basic US views of cardiac anatomy. Continued education of paramedics, coupled with integration of US into EMS protocols will be needed to continue to establish US into pre-hospital care. Ultimately, in patients presenting with time-sensitive critical conditions, there may be a role for US to reduce morbidity, mortality and resources.

The greatest role for pre-hospital US may lie in both advanced cardiac life support (ACLS) and advance trauma life support (ATLS). While it is not yet a formal step in the ACLS algorithm, several groups have advocated a placeholder for simple point of care US exams in the ACLS protocol.[27,28] With US, a clinician can see into a patient and tangibly evaluate the etiology of a cardiac arrest while initiating intervention.[7,18,29,30] This is important given that pre-hospital personnel are often the initial medical contact in critically ill patients. Adding US to the clinical decision-making protocol can be useful in determining when to proceed with or discontinue resuscitation based on cardiac activity. We believe that given the promising results of our study, further large-scale studies are warranted to determine if EMS providers can use US to visualize and interpret cardiac ultrasound for improved decision-making in the pre-hospital setting.

Limitations

Our study is limited due to the small number of EMS providers and total number of patients enrolled. Of the 19 patients enrolled, only 2 patients were found to have cardiac arrest. Only 4 different paramedics were used to enroll patients and their ultrasound capabilities may not be generalizable to all EMS personnel. The number of EMS providers was limited due to our requirement that they score above 80% on a standardized examination. This may indicate that additional training is required to achieve competency. A convenience sample of both patients and EMS personnel was used. Many patients were not enrolled due to lack of US machine, lack of battery power, and short transit time. Cardiac standstill was identified in only two cases.

In conclusion, our pilot study suggests that with minimal training, some paramedics may be able to visualize basic cardiac ultrasound and differentiate between cardiac activity and cardiac standstill. Further large scale clinical trials are needed to determine the amount of training required and if pre-hospital US can be used to determine if resuscitative efforts should be continued or stopped based on the results of cardiac US.

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Ethical approval: The institutional review board approved the study.
Conflicts of interest: The authors declare there is no competing interest related to the study, authors, other individuals or organizations.
Contributors: Shadi L proposed the study and wrote the first draft. All authors read and approved the final version of the paper.

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