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Feasibility of Out-of-Hospital Cardiac Arrest Ultrasound by EMS Physicians
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Prehospital cardiac arrest ultrasound

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Feasibility of Out-of-Hospital Cardiac Arrest Ultrasound by EMS Physicians

Introduction: Point-of-care ultrasound (POCUS) has been suggested as a useful tool to predict survival and guide interventions in out-of-hospital cardiac arrest (OHCA). While POCUS has been deployed in prehospital settings, little data exists on prehospital use, particularly by personnel with limited ultrasound experience. We aimed to characterize the feasibility and barriers to prehospital POCUS during OHCA by EMS physicians in training.

Methods: We deployed the SonoSite iViz portable ultrasound device for use by EMS physicians for OHCA in an urban EMS system. All physicians received POCUS education as part of their graduate medical training and were provided an instructional video on use of the SonoSite iViz device. POCUS use was limited to identifying cardiac motion during pulse checks, without interrupting resuscitation, and the results could be used to supplement management at the physicians’ discretion. Data were recorded prospectively by saving images on the device and through a custom electronic form within the patient care report. The primary measure was the frequency of use of POCUS during OHCA. Secondarily, we characterized agreement by expert (ultrasound fellowship trained) faculty (using a kappa statistic) and identified reported barriers to the use of prehospital POCUS.

Results: From November 2016 to March 2017, 348 physician field responses were reviewed, including 127 cases of OHCA. There were 106 patients remaining in arrest on physician arrival, with 56 (52.8%) cases of POCUS use. Still or video images were recorded in 48 cases; video in 34 cases. From video images, agreement in identifying cardiac motion between the EMS physician and expert reviewer occurred in 91% of cases ($K=0.82$). Reasons cited for not using POCUS included return of circulation soon before or after arrival, prioritizing clinical
interventions, not having the ultrasound device, mechanical failure, and cessation of resuscitation per advanced directives.

**Conclusion:** Use of POCUS by EMS physicians to detect cardiac activity in OHCA is feasible and correlates with expert interpretation. Several avoidable barriers were identified and should be considered in the future implementation of prehospital POCUS. Larger studies are needed to determine what role POCUS may play in prehospital cardiac arrest management.
INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is commonly encountered by emergency medical services (EMS) with approximately 350,000 cases per year in the United States\(^1\) and survival reported in 8% of cases.\(^2\) Common challenges in managing OHCA include decisions regarding field termination of resuscitation efforts, particularly in the presence of non-shockable rhythms, as well as treatment decisions beyond the standardized algorithms of basic and advanced life support care. While parameters like bystander CPR, rhythm, and duration of resuscitation are widely used in decision rules for field termination,\(^3,4\) these decisions are often made subjectively\(^5\) and could benefit from additional information. This is particularly true for patients with non-shockable rhythms that do not meet standardized criteria.

Point-of-care ultrasound (POCUS) has been suggested as a useful tool that can supplement the management of OHCA,\(^6-9\) particularly in cases of pulseless electrical activity (PEA). More recent studies have suggested good predictive value regarding survival to admission or hospital discharge.\(^10-13\) However, these studies used more experienced sonographers\(^10,11\) or were otherwise performed after arrival in the emergency department.\(^12,13\) Some more novice providers, including resident physician trainees have been shown to use POCUS during in-hospital cardiac arrest,\(^14\) but these studies were small and not conducted prehospital.

Despite a paucity of data on prehospital use of POCUS, ultrasound devices are being used in EMS systems and by physician trainees who function as EMS physicians. We aimed to evaluate the implementation of prehospital POCUS during out-of-hospital cardiac arrest (OHCA) in one such program, where Emergency Medicine residents and EMS fellows have an established role as EMS physicians in an urban EMS system. To do this, we sought to 1) characterize the
frequency of POCUS use in OHCA, 2) determine the agreement of the trainee’s interpretation of ultrasound images compared to expert review, and 3) identify barriers to prehospital POCUS use.

METHODS

Study Setting and Design

We retrospectively reviewed data collected from an ongoing quality improvement project from November 10\textsuperscript{th}, 2016 to March 22\textsuperscript{nd}, 2017 when point of care ultrasound was implemented for use by EMS physicians working with the City of Pittsburgh Bureau of EMS. In this urban EMS setting, Emergency Medicine residents and EMS fellows staff a 24-7 EMS response vehicle, providing online medical direction and field response alongside EMS personnel. During the study period, EMS physicians consisted of thirty-two second and third year residents and two EMS fellows, with the most common call for in-person consultation being OHCA. Additional details of our field response program have been previously described.\textsuperscript{15} In cases of OHCA, EMS physicians are dispatched to the scene with paramedics based on preestablished determinants and may be requested to respond by on scene paramedics when patients have witnessed cardiac arrest. As part of a quality improvement (QI) project, a portable ultrasound device (SonoSite iViz, FUJIFILM SonoSite, Inc., Bothell, WA) was provided to these physicians for their use in management of OHCA based on a structured protocol described below. We performed a retrospective analysis of data obtained during this quality improvement project using a de-identified dataset of cases where POCUS videos or interpretations were obtained at the discretion of the EMS physician. The implementation of POCUS was approved as a QI project by the UPMC Quality Improvement Review Committee. This study using data from the original QI project was considered exempt by the University of Pittsburgh Institutional Review Board.
**POCUS Protocol and Data Collection**

Physicians were instructed to perform a POCUS view of their choice (ie, subxiphoid or parasternal) during ten second pulse checks, remaining compliant with ACLS guidelines that aim to minimize pauses in compressions. Pulse checks occurred between cycles of 200 continuous compressions, pausing to perform a pulse check with POCUS and/or deliver defibrillation as indicated. Given no clear evidence yet exists that prehospital POCUS use improves patient outcomes, use of ultrasound was optional. The protocol was developed based on the common in-hospital use of POCUS to stratify patients that may benefit from ongoing resuscitation, to identify potentially reversible conditions, and to facilitate existing treatment protocols, particularly for patients in PEA or Asystole. Recommended actions in conjunction with POCUS videos were provided based on consensus of the project leaders and the EMS system medical directors, and treatment decisions were ultimately at the discretion of the EMS Physician.

Physicians choosing to use POCUS were asked to save a video clip (standardized to no more than six seconds in length) for review by fellowship-trained expert sonographers who serve as ultrasound fellowship faculty at the University of Pittsburgh Medical Center Department of Emergency Medicine (EL, MR). The EMS physicians recorded their image interpretation (cardiac wall motion – yes or no) and barriers to using ultrasound (free text – e.g. patient habitus, scene factors, device limitations) using a custom form in the physician-generated electronic patient care record (emsCharts, Inc., Warrendale, PA). The custom form was electronically transmitted in a de-identified manner to the principal investigator (JF) as part of the quality improvement project. We linked records to the saved ultrasound clips based on date of service and a unique identification label generated at the time of image collection. All videos obtained
by EMS physicians were uploaded regularly via WiFi from the device at weekly mandatory educational conferences attended by EMS physicians. Videos were reviewed by the ultrasound faculty, who documented their interpretations. To identify rates of image capture, we determined the total number of OHCA cases attended by physicians through a query of the physician electronic prehospital medical records for any records categorized as cardiac arrest.

The participating residents and fellows all had preceding ultrasound training as part of their ACGME residency. While most participants were part way through residency training, all had already completed online ultrasound training modules, hands-on scanning didactics with ultrasound faculty, and attended ultrasound specific lectures. Training directed to this project included a 35-minute online training module and an in-person demonstration session. Physicians were provided with guidelines on the use of POCUS in OHCA based on the protocol outlined above, and this is detailed further in Figures 1 and 2.

Data Analysis

We determined the number and proportion of OHCA cases where ultrasound videos were successfully obtained by the EMS physicians. The interpretation of cardiac wall motion in ultrasound videos by the trainee physicians was compared with that of expert faculty using the kappa statistic. We secondarily describe the self-reported barriers to the use of POCUS. Data were recorded and analyzed using Microsoft Excel (Microsoft, Inc., Redmond, WA).
RESULTS

Between November 10th, 2016 and March 22nd, 2017, there were 348 in-field physician responses, with 127 cases of out-of-hospital cardiac arrest. Of cardiac arrest cases, there was return of spontaneous circulation before or soon on arrival in 21 cases. Of the 106 patients remaining pulseless, there were 56 reported uses of prehospital POCUS; 23 attempts at parasternal view, 18 attempts at subxiphoid views, 8 with multiple views and 7 with other or indeterminant views. The responding physician was able to save an image 48 times, and 34 of those images were reviewable video clips. Reviewable images were obtained by 11 of the eligible physicians during the study period.

Of the 34 cases with reviewable video images, the EMS physicians recorded observing cardiac wall motion in 13 cases, whereas faculty reported motion in 16 cases, demonstrating strong agreement ($K = 0.82$). All three cases of disagreement were reported as no wall motion with the EMS monitor interpreted as asystole, where expert review reported fine ventricular fibrillation (Figure 3). The frequency of use by provider is reported in Figure 4.

Figure 5 displays all OHCA cases with a physician present during this study. The most common reason cited for not using ultrasound was the patient already had return of spontaneous circulation (ROSC) before, or soon after their arrival and was no longer in cardiac arrest ($N=21, 30\%$). In 15 cases (21\%), use was deferred as the provider was occupied with other interventions, such as airway management or establishing vascular access. Other reasons cited included provider preference to defer ultrasound use, not having the device available in the vehicle, executing an advanced directive, or mechanical/device failure.
DISCUSSION

In this analysis of a field POCUS implementation program, we identified that the use of prehospital POCUS in OHCA by EMS physicians is feasible, including by EMS physicians in training that commonly take part in EMS systems. Excluding cases where the patient had experienced ROSC just before, or at the time of physician arrival, EMS physicians performed POCUS in over half of cardiac arrest cases (52.8%), while following standard ACLS protocols. When they captured video images, trainee physician interpretation of cardiac wall motion had high agreement with expert review. Recorded images were obtained by 11 different users, indicating multiple novice physicians within our EMS system were able to obtain and interpret images correctly. The 3 cases of discordance between EMS physicians and ultrasound faculty occurred in cases of asystole that on scene were interpreted as fine ventricular fibrillation. The significance of this finding is unclear, and we emphasized the importance of correlation with the electrical monitor. Additionally, we did note that physicians who seemingly used POCUS more were more likely to successfully save a video (Figure 5), however we acknowledge the amount of time each physician worked was unknown and likely varied widely between providers based on pre-existing work schedules that rotate monthly. This may have impacted providers’ ability to use the device and thus their comfort level using during resuscitation.

Our study adds to existing literature that has demonstrated that use of POCUS by trainee physicians is feasible, similar to a study conducted by Aichinger in 2012.11 Also using prehospital POCUS during pulse checks in OHCA, the authors found ‘ultrasound inexperienced’ providers documented 42 successful uses over their 1-year study period. However, those providers were not trainee physicians, and had more formalized training prior to use. Thus, our results suggest the ability to obtain and accurately interpret cardiac activity is even more
generalizable than previously thought with novice providers. Pilot studies of POCUS performed by paramedics for patients with cardiac arrest and respiratory distress have also been described and have reported variable success in obtaining adequate images.\textsuperscript{16, 17} Additional investigation in the use of POCUS by non-physician novice sonographers for a variety of applications would add to this growing body of knowledge.

Barriers and challenges to implementing POCUS use are informative and may assist other programs in implementing prehospital ultrasound. Challenges in operating the device included ensuring the device was handed off between providers on one of three physician response vehicles on duty at any given time. Device battery life and availability of replacement batteries are an important consideration when implementing a new device, as only a few uses can be performed on a single battery charge. Proper use and powering down of the device allowed for several uses over consecutive 12-hour shifts. However, regularly stocking spare batteries and chargers as part of daily equipment checks was needed for optimal operations. We found attention to these small details could significantly impact use rates. Also, several providers accidentally saved ‘still’ images rather than videos needed for review. The device recorded a still image with a click of a button and video clip if the button was held. While unclear if education or logistical factors attributed more to cases without video clips recorded, this finding demonstrates the need to make the device as user friendly as possible.

Other barriers that were repeatedly cited in cases where POCUS was not performed include prioritizing other critical interventions, such as airway management or vascular access. There were also several non-uses otherwise categorized as provider preference to defer ultrasound use. Further chart review and email follow up identified difficulties accessing the patient in narrow spaces, and difficulties with body habitus that limited the ability to perform
POCUS. We also identified some providers’ personal lack of comfort performing ultrasound in this setting. Future prehospital POCUS efforts should include education and didactics addressing these barriers while performing appropriate resuscitation. This research should also comment on which echocardiographic view to first attempt, given such limited time to perform POCUS during ten-second pulse checks. We attempted to collect this data, however several cases attempted different views on subsequent pulse checks, or otherwise had indeterminant views, limiting this aspect of data interpretation. Further research as to which view (subxiphoid versus parasternal) is needed to optimize POCUS use with the unique operational challenges of in-field resuscitation.

An additional consideration to this study was the careful planning to limit interruptions in chest compressions, adhering to our current ACLS protocols. Educational material provided to participants included strict instructions on this, along with suggestions on how to conduct pulse checks with a team of EMS providers while using POCUS. Furthermore, video clip length was limited to 6 seconds by our protocol, with instruction to begin on start of the pulse check. It was noted as part of data collection that all participating providers did self-report pulse check duration no longer than 10 seconds. However, we recognize some limited in-hospital data recently published indicated POCUS may increase the time duration of pulse checks, so future work should include more objective data on pulse-check duration. With continuing emphasis on minimizing compression interruption, additional studies should continue to outline a safe, feasible protocol that facilitates larger studies evaluating patient outcomes.
LIMITATIONS

We identified several limitations to this work. It is possible that more formal hands-on didactics, run concurrently with a simulated resuscitation, could have improved overallprehospital use of POCUS. Additionally, each physician had varying degree of opportunity to use prehospital POCUS due to existing staffing schedules, and the use of ultrasound was optional at physician’s discretion. Our design setup lacked blinding and randomization to the use of POCUS, potentially biasing expert interpretations and use of POCUS by physicians that had more experience and were more facile in POCUS use. Data were also recorded retrospectively, requiring chart review and follow up email by the PI to complete missing portions. This design, along with previously mentioned device and circumstantial limitations, impacted our sample available for study.

We report on the use of POCUS by both Emergency Medicine residents and Emergency Medical Services fellows who regularly function as EMS physicians in a 24/7 physician response program. Similar providers are used in other academic EMS programs but may not be representative of EMS physicians that have completed EMS training. On the other hand, these trainees’ recent experience in performing POCUS in the hospital may not be representative of EMS physicians who lacked ultrasound training during their own residency education. Also, we did not aim or were powered to detect differences in POCUS use between these levels of trainees, which could be addressed with future investigation. Lastly, all providers did self-report that pulse-checks were no longer than 10 seconds; however, objective measures of time used to perform prehospital POCUS should be included in future studies.
CONCLUSION

Performance of prehospital POCUS by EMS physicians to detect cardiac wall motion in OHCA is feasible and interpretations correlate well with expert review. We identified important barriers to performing prehospital POCUS, including return of circulation soon before or after arrival, prioritizing interventions, not having the ultrasound device, mechanical failure, and cessation of resuscitation per advanced directives.

REFERENCES


Disclosure of Interest

This work was supported by a contribution from FUJIFILM comprised of loaning the ultrasound device for use during the study period and subsequently returned. There were no direct funds provided to perform this study. FUJIFILM or its agents made no contribution to the writing, editing, or final review of this manuscript. No authors have received direct contributions from this or any work from FUJIFILM. All authors report no other disclosures related to this or related work.

Figure 1. Guideline for use of POCUS by EMS physicians

Figure 2. Guideline for management of cardiac arrest patients based on POCUS findings

Figure 3. Comparison of POCUS video clip interpretation between trainees and expert sonographers for detection of cardiac wall motion

Figure 4. Frequency of POCUS use by provider

Figure 5. Number of OHCA cases with physician present
Initial ACLS Bundle

Other Considerations
- Confirm family/POA presence
- Consider termination of resuscitation if DNR
- If ROSC:
  - Continue airway management
  - Consider epinephrine infusion
  - Use POCUS if time permits

Cardiac Arrest Confirmed
- Quality Compressions / DeBib
- Vascular Access
- Airway Management
- Medication Administration

Ventricular Fibrillation
Ventricular Tachycardia
- Defibrillation
  - Epinephrine, Amiodarone

Pulseless Electrical Activity
Asystole
- Epinephrine
- Review H's and T's

Consider POCUS, review prognostic factors
Consider transport or termination of resuscitation

Poor Prognostic Indicators
- Unwitnessed arrest
- No bystander CPR
- Asystole
- ETCO₂ <20 at 20 minutes
- Advanced age
- Prolonged duration of CPR
- POCUS: Cardiac standstill
Obtain 6-second Video Image

- Effusion or Right Heart Strain
- Ventricular Fibrillation
  - Correlates with Monitor Rhythm
  - Defibrillate
- Coordinated Wall Motion (~2 beats)
  - Does not correlate with Monitor Rhythm
  - Resume ACLS, consider pre-charging defibrillator
- Minimal Wall Motion (~1 beat)
  - Good prognostic factors
  - Continue ACLS, reassess at next pulse check
- No Cardiac Wall Motion
  - Bad prognostic factors
  - Consider termination of reanimation

### EMS Physician

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<th>Ultrasound Expert</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
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<tr>
<td>Yes</td>
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<td>3*</td>
<td>16</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>18</td>
<td>18</td>
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<tr>
<td>Total</td>
<td>13</td>
<td>21</td>
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Kappa = 0.82

*All 3 disagreements had fine ventricular fibrillation*
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<th>Reason</th>
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<td>Total OHCA Cases</td>
<td>127</td>
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<tr>
<td>Ultrasound Used</td>
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<td>44%</td>
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<td>Ultrasound Not Used</td>
<td>71</td>
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<td>ROSC before/soon after arrival</td>
<td>21</td>
<td>17%</td>
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<tr>
<td>Provider preference</td>
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<td>12%</td>
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<tr>
<td>Busy with other interventions</td>
<td>15</td>
<td>12%</td>
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<tr>
<td>Did not have ultrasound device in vehicle</td>
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<td>7%</td>
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<td>3%</td>
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<tr>
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<tr>
<td>Other</td>
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ROSC = Return of spontaneous circulation
DNR = Do not resuscitate