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Major approaches on the use of ultrasound at the point-of-care at the pre-hospital level: a systematic review

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Abstract

Introduction: Point-of-Care Ultrasound (POCUS) has been established as an ideal imaging modality when used by clinicians trained in the clinical setting. Thus, sophisticated but relatively inexpensive handheld devices have also contributed to point-of-care ultrasound (POCUS) becoming the norm at the prehospital level. **Objective:** This study aimed to present, through systematic review, the main considerations about the use of ultrasound at the point of care at the prehospital level. **Methods:** The present study followed a systematic review model. After the criteria of literary search using MeSH Terms clinical studies were collated and submitted to the eligibility analysis. The search strategy was performed in the PubMed, Embase, Ovid and Cochrane Library, Web Of Science, ScienceDirect Journals (Elsevier), Scopus (Elsevier), and OneFile databases. **Results and Conclusion:** A total of 156 articles were found. Initially, duplication of articles was excluded. After this process, the abstracts were evaluated and a new exclusion was performed, removing the articles that did not include the theme of this article, resulting in 112 articles. A total of 64 clinical studies were collated and submitted to the eligibility analysis and, after that, 20 studies were selected for the systematic review, dated from 2016 to 2022. On-site ultrasound is spreading through Emergency Medicine, Critical Care, and Prehospital Care. However, there is an underlying inherited conflict with established specialties by conducting comprehensive examinations. Thus, in-service ultrasound in the light of disruptive innovation is a different perspective than ultrasound that had not been academically examined before. Therefore, it can be concluded that ultrasound in the hospital can be implemented in several medical fields for the bedside examination of patients, especially in the prehospital environment. Scientific evidence supports the fact that the addition of ultrasound technology in daily practice (portable ultrasound device), called by some 'future stethoscopes', improves patient care and allows early diagnosis in a hospital setting.

Keywords: Ultrasound. POCUS. Point-of-Care Ultrasound. Prehospital.

Introduction

Point-of-Care Ultrasound (POCUS) has been established as an ideal imaging modality when used by trained emergency physicians in the clinical setting [1,2]. It can quickly and accurately diagnose many life-threatening conditions, including hemoperitoneum, pericardial effusion, cardiac tamponade, pneumothorax, and abdominal aortic aneurysm. Furthermore, POCUS offers portability, ease of use, speed, and delivery of dynamic real-time information without exposing patients to ionizing radiation. These attributes make POCUS an attractive tool in the pre-hospital setting [2,3].

In this regard, POCUS is especially useful in the setting of cardiac arrest. A previous study showed that all patients with cardiac arrest on initial ultrasound die before leaving the emergency department [4-6]. Although the lack of cardiac movement has been shown to guide the interruption of resuscitation efforts in the hospital environment, no studies have evaluated cardiac ultrasound in the prehospital environment [7].

Although its application in the measurement of hemodynamics remains controversial, the technical aspects of image acquisition are not outside the limits of the skills of healthcare professionals. Medical service providers can perform and interpret extended focused assessments with trauma ultrasound and effectively assess the lungs for pneumothorax [8].

In this context, in the US currently, 4% of prehospital services use ultrasound and 21% are considering its implementation. In addition, they can be used as a decision-making tool for continuing or terminating resuscitation efforts. However, based on studies recommended by the American Heart Association, echocardiography should be used as an adjunct to patient assessment. The point of care in the United States is less understood. In Europe and Australia, physicians in the prehospital environment have demonstrated the ability to identify treatable pathologies in most patients, but this is not established in the United States [9].

Thus, sophisticated but relatively inexpensive portable devices also contributed to POCUS becoming the norm at the pre-hospital level [10]. It has been argued that ultrasound will become the next stethoscope for healthcare professionals. For this to become a reality, however, training is needed in increasing familiarity with the correct use of the machine and transducers and in the accurate interpretation of anatomy, followed by the identification of pathologies. Thus, using training sessions similar to those provided to physicians and medical students, numerous simulation studies have tested paramedics' abilities to learn and retain US skills [10].

In this sense, POCUS is spreading across Emergency Medicine, Critical Care, and Prehospital Care. However, there is an underlying inherited conflict with established specialties performing comprehensive examinations. Thus, POCUS in light of disruptive innovation is a different perspective from an ultrasound that has not previously been examined academically.

Thus, the present study aimed to present, through a systematic review, the main considerations on the use of ultrasound at the point of care at the pre-hospital level.

Methods

Study Design

The present study followed a systematic review model from January to March 2023, following PRISMA (Transparent reporting of systematic reviews and meta-analyseshttp://www.prisma-statement.org/).

Search Strategy and Information Sources

The search strategy was carried out in the PubMed, Embase, Ovid and Cochrane Library, Web Of Science, ScienceDirect Journals (Elsevier), Scopus (Elsevier), and OneFile (Gale) databases, followed the following steps: search by MeSH Terms: *Ultrasound. POCUS. Point-of-Care Ultrasound. Prehospital*, and use of Booleans "and" between mesh terms and "or" between historical findings.

Study Quality and Risk of Bias

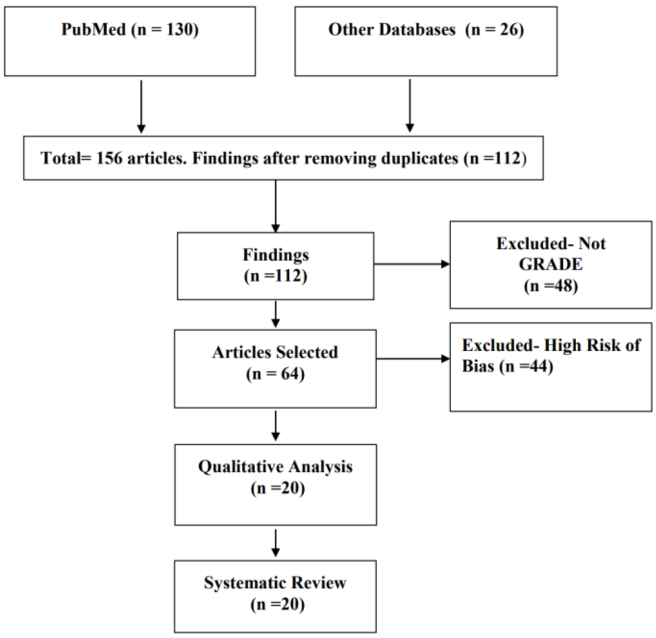
Study quality was based on the GRADE instrument. The highest rankings were for controlled clinical studies with a statistically significant sample size. The risk of bias was analyzed according to the Cochrane instrument, based on the effect size of each study versus the sample size.

Results and Discussion

Summary of Findings

A total of 156 articles were found. Initially, duplication of articles was excluded. After this process, the abstracts were evaluated and a new exclusion was performed, removing the articles that did not include the theme of this article, resulting in 112 articles. A total of 64 clinical studies were collated and submitted to the eligibility analysis and, after that, 20 studies were selected for the systematic review, dated from 2016 to 2022 (Figure 1). Considering the Cochrane tool for risk of bias, the overall assessment resulted in 44 studies with a high risk of bias and 48 studies that did not meet GRADE

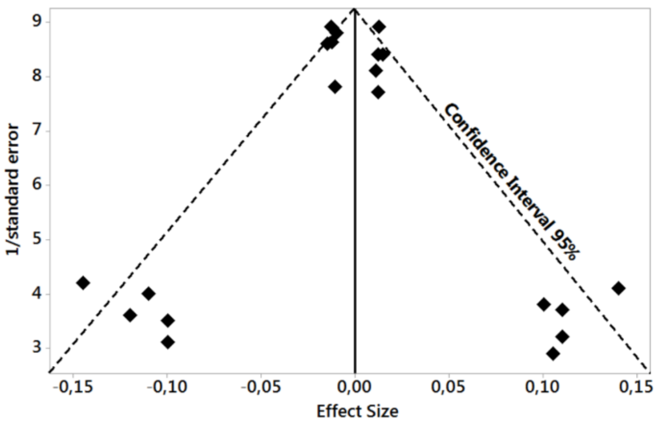
Figure 1. Flow chart.



Source: Own authorship.

Figure 2 presents the results of the risk of bias of the studies through the Funnel Plot, showing the calculation of the Effect Size using the Cohen Test (d). Precision (sample size) was indirectly determined by the inverse of the standard error (1/Standard Error). This chart had a symmetrical behavior, not suggesting a significant risk of bias, both between studies with small sample sizes (lower precision) that are shown at the bottom of the chart and in studies with large sample sizes that are shown at the top.

Figure 2. The symmetrical funnel plot does not suggest a risk of bias among the small sample size studies that are shown at the bottom of the plot. High confidence and high recommendation studies are shown above the graph (n=20 studies).



Source: Own authorship.

Highlight Findings

Ultrasound is a well-established medical imaging technique, with pioneering work conducted by Professor Ian Donald and his colleagues at the University of Glasgow from the mid1950s onwards, in terms of its introduction as a diagnostic tool in the field of obstetrics and gynecology [1]. Since then, ultrasound has been widely used in clinical and research contexts. Few imaging techniques have undergone such rapid and successful evolution since their development. Currently, diagnostic ultrasound benefits from two-dimensional (2D), three-dimensional (3D), four-dimensional (4D), and a variety of Doppler modes with technologically advanced transducers (probes) producing images of high anatomical fidelity [2-5].

In the future, there may even be a place for ultrasound in molecular imaging, allowing microscale visualization. Ultrasound is characterized by non-invasive real-time scanning, relative ease of administration, and lack of ionizing radiation. All these features make ultrasound an attractive option in educational settings for learning topographic anatomy and potentially enhance future clinical practice for professional students [6].

In this context, sophisticated but relatively inexpensive handheld devices have also contributed to POCUS becoming the norm for bedside and pre-hospital scanning. It has been argued that ultrasound will become the next stethoscope for healthcare professionals. For this to become a reality, however, training is needed in increasing familiarity with the correct use of the machine and transducers and in the accurate interpretation of anatomy, followed by the identification of pathologies [7].

The above calls for the incorporation of ultrasound teaching into undergraduate curricula, outside the realm of opportunistic bedside learning, accompanied by ethical considerations such as the management of accidental discoveries and careful evaluation of its pedagogical impact, cross-sectionally and longitudinally [11].

In this regard, medical ultrasound has continued to spread across medical specialties and now has ever-increasing roles in various hospital departments. This was exemplified by the rapid spread of POCUS use in resource-limited settings abroad. Although POCUS has been proven in numerous studies to be effective in the hands of trained clinicians, it is believed that the technical aspects of image acquisition can be easily mastered by basic healthcare providers and educated adults with adequate training. Nurses, astronauts, and medical students have proven this concept in several studies [11].

In yet another study, paramedics have shown promise in learning to use POCUS in various simulation studies, however, real-world studies are sparse. British paramedics were able to achieve US lung technical skills at a threshold of adequacy similar to specialist medical sonographers with only 10 hours of training [10].

Despite these studies, there is no consensus on the use of POCUS nor the amount of proficiency training. One study determined whether emergency providers were able to identify cardiac anatomy and differentiate cardiac activity from cardiac arrest after just three hours of ultrasound training. Therefore, continuing education of paramedics will be necessary to continue to establish pre-hospital care. Furthermore, in patients who present with time-sensitive critical conditions, there may be a key role for POCUS in reducing morbidity, mortality, and resources [10].

In this scenario, the greatest role for prehospital POCUS may be in both advanced cardiac life support and advanced trauma life support. With this, a physician can see the patient and tangibly assess the etiology of a cardiac arrest during early intervention. Thus, adding POCUS to the clinical decision-making protocol can help determine when to proceed or discontinue resuscitation based on cardiac activity [2,3].

Therefore, a prospective study analyzed as a primary outcome whether paramedics could perform cardiac ultrasound in the field and obtain adequate images for interpretation. A secondary endpoint was whether paramedics could correctly identify cardiac activity or lack thereof in patients with cardiac arrest. Eligible paramedics participated in a 3-hour point-of-care session in the US. Paramedics used ultrasound during emergency calls and saved scans for potential cardiac complaints including chest pain, dyspnea, loss of consciousness, trauma, or cardiac arrest. Four paramedics from two different fire departments registered a total of 19 unique patients, of which 17 were considered suitable for clinical decision-making (89%, 95% CI 67% -99%). Paramedics accurately recorded 17 cases of cardiac activity (100%, CI 95% 84% -100%) and 2 cases of cardiac arrest (100%, CI 95% 22% -100%). Therefore, with minimal training, paramedics can use ultrasound to obtain cardiac images suitable for interpretation and diagnosing cardiac arrest. More large-scale clinical trials are needed to determine whether prehospital ultrasound can be used to guide the care of patients with cardiac complaints [5].

In this sense, a study evaluated the effectiveness of lung ultrasound in out-of-hospital nontraumatic respiratory failure. A case-controlled study was carried out in the most Vincentian area of ULSS 5 (Vicenza-Italy), with subjects with severe dyspnea caused by heart failure or acute exacerbation of chronic obstructive pulmonary disease. Medication administration, oxygen delivery, and laboratory tests were compared between patients with integrated ultrasound treatment and those without ultrasound. Prehospital lung ultrasound showed high specificity (94.4%) and sensitivity (100%) for the correct identification of alveolar interstitial syndrome using B lines, while the percentages obtained with pleural effusion were lower (83.3, 53.3 %, respectively). Patients with integrated ultrasound management received more appropriate pharmacologic therapy (p=0.01), and noninvasive ventilation was used more frequently in those with an acute exacerbation of chronic obstructive pulmonary disease (p=0.011). Laboratory tests and blood gas analysis were not significantly different between the two study groups. In a subanalysis of patients with profile A, a significantly lower PCO_2 concentration was observed in those with integrated ultrasound treatment (PCO_2: 42.62 vs 52.23 p 0.049). According to the physicians' opinion, prehospital lung ultrasound provided important information or changed therapy in 42.3% of cases, while it only confirmed the physical examination in 67.7% of cases. Therefore, prehospital lung ultrasound is easy and feasible, and the learning curve is fast. Our study suggests that heart failure and acute exacerbation of chronic obstructive pulmonary disease can be considered two indications for prehospital ultrasound and can improve the management of patients with acute respiratory failure [12].

In addition, a randomized prehospital clinical study was performed to compare two different ultrasound-guided peripheral venous catheters (PVC) insertion techniques and the conventional cannulation technique in the prehospital emergency setting, with a specific focus on the rate of procedural success and the time required to introduce the CPV. This prehospital prospective randomized controlled clinical trial allocated patients treated by emergency medical service to undergo fully ultrasound-controlled CPV insertion (guidance by ultrasound of the CPV tip until it penetrates the lumen, group A), partially controlled CPV insertion by ultrasound (target vein identification only, group B) or receiving CPV without ultrasound guidance (group C). Study results were monitored until patient admission. A total of 300 adult patients were enrolled. Firsttry success (group A: 88%, group B: 94%, group C: 76%, $p<0.001$) and overall success rate (A: 99%, B: 99%, C: 90%, $p <0.001$) was significantly higher in group A, followed by group B when compared to group C. The number of attempts was significantly lower (A: 1.18 ± 0.54, B: 1.05 ± 0.22, C: 1.22 ± 0.57, $p < 0.001$) and the time required for the shortest procedure (A: 75.3 ± 60.6, B: 43.5 ± 26.0, C: 82.3 ± 100, 9 s, $p < 0.001$) in group B compared to groups A and C. Therefore, both ultrasound-guided CPV placement techniques were associated with higher success rates than the conventional method. However, partially ultrasound-guided PVC insertion was superior to complete ultrasound guidance in terms of time and number of cannulation attempts required [13].

Furthermore, one study provided a detailed anatomy review and an ultrasound-guided technique for the placement of the iliac fascia block. Recently, the placement of iliac fascia blocks has been used successfully in the emergency department of geriatric patients suffering from hip fractures through POCUS follow-up. This technique can be easily mastered with proper training for use in the emergency room and pre-hospital settings, reducing hip fracture pain and associated risks of morbidity [14].

Besides, penetrating cardiac trauma to the left ventricle (LV) is a rare and serious injury. In cases of penetrating cardiac trauma, prehospital ultrasound by flight physicians can help identify specific pathologies. There are minimal cases reported where prehospital ultrasound provided a definitive diagnosis while at the same time providing prehospital blood transfusion. In 2017, in New South Wales, Australia, a new "Code Crimson" protocol was introduced to formalize a systemwide process in which prehospital medical teams can streamline a direct approach [15].

One study investigated whether POCUS is indeed a disruptive innovation. This is done by comparative analysis with the starting point in the theory of disruptive innovation known in the business world. Thus, it was discovered that a disruptive innovation process is taking place. This new knowledge allowed us to offer advice to interested parties in the field of ultrasound. It also allowed us to challenge the conventional pyramid of knowledge used to describe different types of ultrasound. The perspective of this article was the mutual understanding of the similarities and differences between conventional and point-of-care ultrasound. Only with this understanding, did stakeholders collaborate and used the full spectrum of ultrasound for patient benefit [16].

Also, verifying correct endotracheal tube (ETT) placement has been one of the most challenging airway management issues in the field of emergency medicine. Early detection of esophageal intubation through a reliable method is important for emergency physicians. Thus, a prospective observational study evaluated the diagnostic accuracy of rapid tracheal ultrasonographic examination (TRUE) to assess endotracheal tube misplacement during emergency intubation. A consecutive selection of 100 patients was included. TRUE was performed for all these patients and subsequently quantitative waveform capnography was performed. The later test is considered the gold standard. Of the total 100 eligible patients, 93 (93%) participants had TRUE positive results (tracheal intubation), and 7 (7%) patients had TRUE negative results (esophageal intubation). The quantitative waveform capnography report of all 93 (100%) patients who tested positive for TRUE was positive (appropriate tracheal placement). Sensitivity, specificity, positive predictive value, and negative predictive value of TRUE for detecting proper tracheal placement of TTE were 98.9% (95% CI, 93.3% to 99.8%), 100% (95% CI, 51 .6% 100%), 100% (95% CI, 95.1% to 100%) and 85.7% (95% CI, 42% to 99.2%), respectively. Therefore, running TRUE is convenient and feasible in many emergency departments and pre-hospital settings [17].

Another study aimed to determine the effect of implementing POCUS using a systematic education program on imaging skills and subsequent use and barriers in an anesthesiology department. Twenty-five anesthesiologists underwent a systematic POCUS education program during the fall of 2012. A POCUS specialist evaluated baseline images and assessments performed on two healthy subjects as useful or not useful for clinical interpretation. In August 2016, anesthesiologists employed in the department completed a questionnaire on POCUS use and perceived barriers to its use. The systematic education program increased the proportion of images useful for clinical interpretation from 0.70 (95%CI 0.65-0.75) to 0.98 (95%CI 0.95-0.99). This difference was significant when adjusted for previous cardiac ultrasound courses, previous clinical experience of cardiac ultrasound, ultrasound visualization, and ultrasound model ($p<0.001$). After 3.5 years, 15/25 (60%) of perioperative medication providers, 22/24 (92%) of critical care providers, and 21/21 (100%) of prehospital care providers used POCUS routinely, in selected patient groups or sporadically. Therefore, the implementation of POCUS through a systematic education program has increased imaging skills among anesthesiologists employed in the department. POCUS has been used in the intensive care setting, the pre-hospital setting, and, to a lesser extent, the perioperative setting. Furthermore, educational strategies to obtain images in difficult conditions, practical equipment, and evidence to affect patient outcomes are necessary for the full implementation of POCUS [18].

Also in this sense, although radiography is the gold standard in the evaluation of orthopedic injuries, the use of ultrasound at the bedside has several potential advantages, such as avoiding exposure to ionizing radiation, availability in pre-hospital environments, being widely accessible, and capable of being used at the bedside. Thus, a prospective study, with patients aged 18 years or older, in stable hemodynamics, with a Glasgow coma scale of 15 and signs or symptoms of a possible bone fracture in the extremities, evaluated the diagnostic accuracy of ultrasonography in detecting bone fractures in the extremities. extremities. After an initial assessment, an ultrasound of the suspect bones was performed by a resident trained in emergency medicine and the prevalence of true positive and false negative findings was calculated compared to plain radiology. A total of 108 patients with a mean age of 44.6 ± 20.4 years (67.6% male) were studied. Analysis was performed on 158 fracture sites, which were confirmed with plain radiography. It was suspected that 91 (57.6%) cases had a fracture(s) in the upper extremity and 67 (42.4%) had a fracture(s). The most frequent site of injuries was the forearm (36.7%) in the upper limbs and the leg (27.8%) in the lower limbs. The prevalence of positive cases and true false negatives for fractures detected by ultrasound was 59 (64.8%) and 32 (35.52%) for superiors and 49 (73.1%) and 18 (26.9%) for the lower limbs, respectively. Furthermore, the prevalence of true positive and false negative cases detected for intra-articular fractures was 24 (48%) and 26 (52%), respectively. Therefore, the present study shows moderate sensitivity (68.3%) of ultrasonography in detecting different bone fractures in the extremities. Ultrasonography showed the best sensitivity in detecting fractures of the femur (100%) and humerus (76.2%), respectively. However, it presented low sensitivity in the detection of intra-articular fractures [19].

Finally, the use of POCUS by non-radiologists has increased dramatically. POCUS is completely different from routine radiological studies. POCUS is a physiological, on-site extension of the clinical examination, unique and safe. A review work established the basic principles of using POCUS in the diagnosis of intestinal pathologies, to encourage intensive care physicians to learn and master this important tool. Addressed specific POCUS findings of the most common bowel pathologies encountered by physicians in critical care, including acute appendicitis, epiploic appendagitis, acute diverticulitis, pseudomembranous colitis, intestinal tuberculosis, Crohn's disease, and colon tumors. Thus, a deep understanding of the basic physics of ultrasound and its artifacts is the first step in mastering POCUS. This helps to achieve an accurate diagnosis of POCUS and avoid its pitfalls. With increased skills, detailed and accurate POCUS results of specific intestinal pathologies can be achieved and properly correlated with the clinical picture [20].

Limitations

However, there are still few studies that assess the usefulness of POCUS in the pre-hospital environment. To date, there are no other portable imaging modalities that can visualize the heart during cardiac arrest. Several studies have shown that POCUS minimally disrupts resuscitation efforts in critically ill patients and can potentially alter their outcomes. Despite these advances, there is currently no widely recognized protocol that specifically addresses the immediate needs of prehospital care providers.

Conclusion

Therefore, it is concluded that point-of-care ultrasound can be implemented in various medical fields for the bedside examination of patients, particularly in the pre-hospital setting. Scientific evidence supports the fact that the addition of ultrasound technology in daily practice (portable ultrasound device), called by some 'stethoscopes of the future', improves patient care and allows an early diagnosis in a hospital setting.

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Ethical Approval

Not applicable.

Informed consent

Not applicable.

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Data sharing statement

No additional data are available.

Conflict of interest

The authors declare no conflict of interest.

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