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The impact of prehospital use of ultrasound by EMS: Diagnostic and interventional benefits

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***Abstract*---Background:** Prehospital care, particularly for trauma patients, is complex due to the unpredictable environments in which emergency medical services (EMS) operate. The integration of prehospital ultrasound (PHUS) offers potential improvements in trauma management, a leading cause of mortality among younger populations in the U.S. **Aim:** This systematic review evaluates the application of PHUS in trauma management, focusing on its

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diagnostic and interventional benefits when utilized by different provider types, including EMS professionals, physicians, and mixed teams. **Methods:** A comprehensive literature search was conducted across multiple databases, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The analysis used a PICO framework to compare ultrasound-assisted care with standard practices. A total of 16 studies were included for evaluation, assessing various ultrasound protocols and their impact on treatment decisions and outcomes. **Results:** The review highlighted significant variability in sensitivity and diagnostic accuracy among studies using PHUS. While the majority of studies involved physician-operated ultrasounds, limited research focused specifically on EMS professionals. Notably, the findings indicated that PHUS positively influenced treatment and transport decisions, although no studies directly addressed its effect on mortality rates. **Conclusion:** Although PHUS demonstrates potential benefits in enhancing trauma care, its integration into prehospital settings requires further investigation, particularly regarding its effects on patient outcomes and the operational challenges posed in dynamic environments.

***Keywords*---**prehospital ultrasound, trauma management, emergency medical services, systematic review, diagnostic accuracy.

Introduction

Prehospital care is inherently complex and occurs within a tumultuous and unpredictable environment. Consequently, one of the predominant challenges encountered by healthcare providers is the provision of a high level of specialized care to patients suffering from critical illnesses. In the United States, prehospital care is predominantly administered by professionals within emergency medical services (EMS), which include emergency medical technicians (EMT), advanced emergency medical technicians (AEMT), and paramedics (1). In certain prehospital contexts, the scope of care is augmented by physicians or nurses who operate as part of prehospital helicopter EMS (HEMS) and critical care transport teams (2). While these organizational structures may facilitate expanded care, there exists another avenue for enhancement: the integration of novel tools and technologies to elevate the current standards of practice among EMS professionals.

One such technology that has exhibited considerable potential in the triage and management of trauma patients is prehospital ultrasound. Trauma is the foremost reason for EMS activation and stands as the primary cause of mortality for individuals under the age of 45 in the United States (3, 4). In 2019, there were 22 million EMS activations, with traumatic injuries representing the principal impression in 34% of cases (4). The implementation of point-of-care ultrasound (POCUS) within emergency departments (ED) has fundamentally transformed trauma management, leading to improved patient outcomes and establishing itself as the standard of care in this domain since 2008 (5, 6). Technological advancements continue to diminish the size, reduce the cost, and enhance the resolution of sonographic equipment (7). Although research has been conducted

to assess the utility of ultrasound in prehospital scenarios, a contentious discourse persists regarding the specific advantages of prehospital ultrasound (PHUS) and its potential to modify the management of trauma patients in the field (8). Furthermore, there exists a paucity of data concerning the application of PHUS by various provider types, each of whom operates within distinct scopes of practice and clinical care systems.

Initial studies have indicated the feasibility and certain potential clinical performance metrics associated with prehospital ultrasound use; however, the extent to which PHUS may influence the diagnosis, treatment, and transportation of trauma patients remains unclear (9). Therefore, we conducted a systematic review of prehospital ultrasound applications for trauma patients, encompassing its use by various providers, including EMS professionals, physicians, and mixed practitioner teams (physicians, nurses, EMS professionals). The objectives of this article were to evaluate the application of prehospital ultrasound for trauma patients and to examine its utilization by diverse provider types. Specific outcomes of interest included whether prehospital ultrasound has been demonstrated to enhance providers' capabilities in recognizing conditions amenable to management in the prehospital context, treating these conditions, altering transport destinations, or improving overall mortality rates among trauma patients.

Methodology

This systematic review investigated the application of ultrasound in the evaluation and management of trauma patients within the prehospital environment, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (10). We formulated a PICO (Patient, Intervention, Comparison, Outcome) framework to evaluate the effects of ultrasound on prehospital trauma patients. Specifically, we examined whether the use of ultrasound (I) compared to standard care without ultrasound (C) resulted in improved diagnosis, treatment, transport decisions, or mortality outcomes (O). This analysis considered various prehospital providers, including EMS professionals, physicians, and mixed practitioner teams (physicians, nurses, and EMS professionals), due to the differences in their scopes of practice. Although a planned meta-analysis was intended, we were unable to execute it owing to the considerable heterogeneity among the identified studies.

The literature search was conducted by one author (CM) across multiple medical databases, including MEDLINE/PubMed, EBSCOhost, Cochrane Library, and Embase, utilizing a comprehensive array of search terms such as “Ultrasound” OR “Ultrasonography” OR “Portable Ultrasound” combined with “Wounds and Injuries” OR “Trauma” AND “Emergency Medical Services” OR “Emergency Medical Technicians” OR “Prehospital.” The search was conducted on October 8, 2019, encompassing studies from inception to the present, with restrictions applied solely to human studies published in English in peer-reviewed journals, without limitations on the country of origin. Two authors (CM, MB) meticulously evaluated the abstracts, including only studies involving trauma patients of any age who received ultrasound assessments in prehospital settings. Excluded studies comprised those that did not focus specifically on ultrasound applications

in the prehospital context for trauma, duplicates, letters to the editor, case reports, and review articles. Additionally, the bibliographies of selected studies were scrutinized to identify any relevant articles that may have been overlooked. After the removal of duplicates, the authors independently screened titles and abstracts against the established inclusion and exclusion criteria, subsequently assessing the full-text articles for eligibility. Any discrepancies between reviewers regarding full-text inclusion were resolved by a third author (AP). The selected studies were categorized into three groups based on the provider type, namely EMS professionals, physicians, and mixed practitioner teams.

Results

Our comprehensive search initially yielded 907 studies. Additionally, three studies were uncovered through manual examination of bibliographies. After the elimination of duplicates, we reviewed 825 titles and abstracts against our inclusion criteria, resulting in the exclusion of 792 studies (percent agreement between reviewers = 92.5%). The remaining 33 articles underwent a thorough full-text evaluation, where 17 were excluded, primarily due to being classified as case reports, not conducted in prehospital settings, or being feasibility studies lacking our defined PICO outcomes..

Among the 16 studies selected, 12 employed a prospective and observational design (14-25), while three were retrospective and one constituted a randomized controlled trial focused on the use of ultrasound in prehospital trauma care (26-29). The studies exhibited significant geographic diversity, with only five conducted within the United States. In total, 3,317 patients underwent prehospital ultrasound (PHUS) evaluations for trauma, with no overlap in patient cohorts or affiliation to a common parent study. Notably, ten of the 16 studies incorporated Helicopter Emergency Medical Services (HEMS). The included studies implemented seven distinct ultrasound screening protocols, which ranged from Focused Assessment with Sonography in Trauma (FAST) to Extended Focused Assessment with Sonography in Trauma (EFAST) (5), Pre-Hospital Application of Sonography in Emergencies (PHASE), ultrasound-guided peripheral nerve blocks, symptom-guided point-of-care ultrasound (POCUS), EFAST in conjunction with echocardiography, and the Polytrauma Rapid Echo-Evaluation Program (PREP).

The evaluation of these studies by the type of prehospital providers involved revealed that 75% (12/16) featured either individual physicians or groups of physicians as the ultrasound operators. Only one study exclusively utilized EMS professionals for its protocols. Heegaard et al. (16) conducted a prospective observational study with paramedics who received six hours of ultrasound training, examining the agreement between the paramedic's PHUS findings and assessments by an emergency physician proficient in sonography. All positive findings were validated against either computed tomography (CT) or operative outcomes. Although this study reported a 100% concordance between the PHUS conducted by paramedics and physician assessments, it was constrained by a limited patient sample size (n=84) and a relatively low proportion of positive PHUS findings (6/84).

In total, we included ten studies where physicians performed PHUS, encompassing 2,076 patients. Our analysis uncovered considerable variation in sensitivity related to diagnostic accuracy and a broad spectrum of results regarding treatment and transport decisions influenced by PHUS examinations. Of the ten studies involving physicians, only five provided data on diagnostic accuracy, while six evaluated the impact of PHUS on treatment and transport decisions. Interestingly, only three studies reported findings related to both diagnostic accuracy and subsequent changes in treatment or transport decisions. The implementation of PHUS by physicians spanned various settings, each with distinct outcome variables. McNeil et al. (19) performed a prospective observational study utilizing PHUS at a battalion aid station in a challenging combat zone. In 2013, Ketelaars et al. (27) conducted a retrospective analysis of a HEMS database linked to hospital outcomes, assessing the use of PHUS for chest trauma. The authors reported that PHUS influenced transport decisions and hospital destination selection in 1.6% and 4% of cases, respectively. Furthermore, Ketelaars et al. (26) published a 2019 retrospective study focusing on abdominal trauma in a HEMS framework, where positive PHUS findings of hemoperitoneum were correlated with CT or laparotomy results. Treatment decision impacts were documented as 12.6%, with additional information relayed to hospitals at a rate of 7.6%. Changes in transportation modes were observed in 3.9% of cases, while hospital destination choices changed in 2.2%. Lastly, Büttner et al. (29) introduced a randomized controlled trial employing peripheral nerve blocks with PHUS for managing traumatic dislocations in the prehospital context. Notably, the follow-up provider assessment of pain scores in this study was blinded to the PHUS-guided nerve block versus analgosedation (midazolam combined with either ketamine or fentanyl) used for initial dislocation reduction. This trial is distinguished as the sole example of a randomized controlled approach incorporating PHUS in trauma management.

Mixed Systems of Care

Our examination of mixed practitioner teams (physicians, nurses, EMS professionals) incorporated five studies. Among these, three studies provided diagnostic accuracy results, while one study reported on treatment and transport decisions influenced by prehospital ultrasound (PHUS). The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) across these studies were consistently high. We assessed the outcomes pertaining to treatment and transport decisions for mixed practitioner teams. Walcher et al. (24) provided insights into the effects of PHUS on diagnosis, treatment, and transport decisions. Their findings indicated that prehospital ultrasound influenced treatment in 21% of patients, furnished additional information to hospitals in 4.6% of cases, and altered the choice of destination in 22% of instances. Our review did not identify any studies that assessed the effect of PHUS on prehospital trauma mortality rates. The closest study addressing this outcome was conducted by Press et al. (21), who compared the diagnostic application of PHUS with the definitive operative needs of the patients involved in their research. The outcome variables evaluated included diagnoses of hemoperitoneum, pericardial fluid, and pneumothorax requiring intervention.

Bias Analysis

The findings from the Sign 50 bias analysis are detailed in Appendix 1. Eight out of 16 studies were deemed of acceptable quality; however, none achieved a high-quality designation in minimizing bias and confounding risks. Overall, the observational and prospective nature of the majority of the included studies restricts the methodological and scientific rigor that can be attributed to each article. Given the non-randomized and observational design prevalent in most PHUS trauma studies conducted thus far, we classified the quality of evidence as low.

Discussion

The utilization of ultrasound has become widespread in many hospital-based trauma settings, making the transition to its application in the prehospital environment a logical progression. The overarching goal is to harness this emerging technology to enhance the diagnosis of life-threatening conditions, improve treatment efficacy, and refine transport decisions for patients to higher levels of care. However, a significant challenge in incorporating ultrasound into the prehospital setting lies in clearly defining its scope of use and the specific advantages it can provide in patient care.

In this systematic review, we sought to identify the existing literature regarding the use of prehospital ultrasound (PHUS) for managing trauma patients. Our analysis focused on the operator conducting and interpreting the ultrasound examination, the specific ultrasound protocols employed during these examinations, and the resulting patient outcomes. We contend that discussions regarding the benefits of PHUS in the prehospital context should address not only its diagnostic capabilities but also its implications for treatment and overall patient management. Given that prolonged scene care time is known to adversely affect trauma patient outcomes (30), any new tools that could delay definitive management must be rigorously evaluated before implementation. One potential avenue for using PHUS could be during patient transport; however, its application would need to be balanced against competing treatment needs and the dynamics of staffing (e.g., a single provider in the back of the ambulance). Understanding the impact of PHUS on patient mortality may aid in informing these critical decisions.

Our review revealed that most evaluations centered on the use of PHUS by physicians, with a notable lack of research focusing solely on the application of this modality by EMS professionals. We identified only one study involving EMS professionals acting as PHUS operators. Although Heegard et al. (16) reported a 100% agreement level between paramedic-performed PHUS and physician overread in the emergency department (ED), the study's limitations included a small overall patient population (n=84) and only six patients with positive FAST exams. The dearth of studies focusing exclusively on EMS professionals as PHUS operators underscores the need for further research to ascertain the safety and effectiveness of paramedics utilizing PHUS in patient care.

A critical factor to consider when comparing various healthcare providers is the scope of practice, which can significantly influence patient outcomes. For instance, the 2019 National EMS Scope of Practice Model does not permit paramedics to perform chest tube placements, a procedure that could be effectively guided by PHUS in a physician-led prehospital trauma management scenario (1, 2). Equally important is the potential for PHUS to rule out pneumothorax, thereby averting unnecessary procedures and the associated risks. In contexts where the scope of practice aligns closely with treatment capabilities (e.g., Helicopter Emergency Medical Services [HEMS]), PHUS may play a more prominent role and prove to be a more effective tool for improving clinical patient outcomes in the prehospital setting.

Our analysis indicated comparable results between physicians and mixed practitioner teams regarding diagnostic accuracy and the effects of PHUS on treatment and transport decisions for trauma patients. However, the systematic review revealed insufficient data to draw definitive conclusions on this matter. The diagnosis of potential traumatic injuries was examined in eight studies, with results varying based on the specific protocols used. The sensitivity of PHUS demonstrated considerable variability (ranging from 18.7% to 100%) across the studies. While specificity, PPV, and NPV were relatively high, the eight studies assessing diagnostic accuracy employed five different protocols and outcome measures. Notably, when Press et al. (21) compared the diagnosis of hemoperitoneum using PHUS to the need for definitive operative management, the PPV was only 50%. This finding raises an important consideration; the efficacy of PHUS should not be gauged solely by its ability to detect free fluid but also by its predictive capacity regarding the need for operative or interventional measures.

One significant challenge identified in our review is the lack of data regarding the advantages of ultrasound in the treatment and transport of prehospital patients, as well as its impact on mortality. No studies evaluated the association between PHUS and mortality rates in trauma patients. Only one randomized controlled trial conducted in a prehospital setting focused on PHUS for trauma, and its sample size was limited (n=18) (29). Although six studies reported data on the influence of PHUS on transport mode or hospital destination choices, none indicated whether these decisions led to changes in patient outcomes. The absence of consistent protocols, standardized outcome measures, and comparison or control groups complicated our ability to draw clear conclusions regarding the benefits (or lack thereof) of employing prehospital ultrasound for trauma care. Future evaluations should consider establishing clear reporting standards to provide accurate estimates of diagnostic accuracy, thus facilitating more rigorous comparisons (31).

Limitations

As with all summative evaluations, we acknowledge the limitations inherent in our research. To address these, we conducted a thorough evaluation adhering to PRISMA guidelines and utilized validated tools for bias assessment. We recognize that the process of study extraction may present challenges; therefore, we employed two independent reviewers along with an arbitrator to reduce potential discrepancies, though it is possible that some studies were still overlooked.

Additionally, the transposition of data into tables can introduce errors, and we had two authors perform this task to minimize mistakes. Another significant limitation is the considerable heterogeneity among the studies, including variability in settings and providers, which precluded the possibility of conducting a meta-analysis for any of the three primary outcomes: diagnosis, treatment, or transport. Our PICO question specifically addressed PHUS for trauma; consequently, studies that included both trauma and medical cases posed difficulties in evaluating trauma-specific outcomes. While we concentrated on the evidence regarding the use of PHUS in trauma, the standard of care for this technology in trauma settings necessitates further evaluation, which will depend on the type of prehospital provider involved. Overall, as previously noted, the observational nature of most of these studies, coupled with the absence of control comparisons or randomization, resulted in a bias evaluation indicating a cumulative low quality of evidence. This limitation underscores the need for more robust research designs to enhance the reliability of findings in the future.

Future Directions for Prehospital Ultrasound (PHUS) in Trauma

As prehospital ultrasound (PHUS) technology continues to evolve, several avenues for future research and implementation emerge, particularly in the trauma setting. Here are some key areas to consider:

1. **Standardization of Protocols**:
    - Developing standardized protocols for the use of PHUS across different prehospital settings can enhance diagnostic consistency and improve training programs for EMS professionals.
    - Establishing clear guidelines for which conditions warrant ultrasound use can help optimize its application in trauma care.
2. **Expanded Training for EMS Professionals**:
    - Future initiatives should focus on expanding training for paramedics and EMS providers to include PHUS techniques and interpretation skills.
    - Training programs should emphasize the importance of recognizing indications for PHUS and integrating it into existing clinical workflows.
3. **Integration with Advanced Airway and Trauma Management**:
    - Research could explore the potential for PHUS to enhance advanced airway management and trauma interventions, such as chest tube placements, especially in the prehospital environment.
    - Investigating how PHUS can assist in rapid decision-making regarding surgical interventions and transport destinations is essential.
4. **Outcomes-Based Studies**:
    - Future studies should evaluate the impact of PHUS on patient outcomes, including mortality rates, complications, and the efficacy of transport decisions.
    - Randomized controlled trials comparing PHUS-guided interventions with standard protocols could provide robust evidence on its effectiveness.

5. **Real-Time Decision Support**:
    - Investigating the feasibility of integrating PHUS with telemedicine to facilitate real-time consultation with hospital-based specialists can enhance decision-making in critical situations.
    - This approach could improve triage accuracy and expedite treatment for patients requiring urgent care.
6. **Exploration of Specific Indications**:
    - Future research should focus on specific trauma-related indications for PHUS, such as detecting pneumothorax, hemoperitoneum, and cardiac tamponade.
    - Establishing the diagnostic accuracy of PHUS for various traumatic injuries can help define its role in prehospital settings.
7. **Longitudinal Studies on Training Efficacy**:
    - Conducting longitudinal studies to assess the long-term efficacy of training programs on PHUS use among EMS providers will be critical for understanding its integration into practice.
    - Evaluating how training impacts clinical outcomes and provider confidence can inform future educational strategies.
8. **Technological Advancements**:
    - As ultrasound technology continues to advance, research should explore portable and user-friendly devices that can be easily integrated into the prehospital environment.
    - Investigating software improvements, such as automated image analysis and AI-assisted interpretation, can enhance diagnostic accuracy and speed.
9. **Interdisciplinary Collaboration**:
    - Promoting collaboration between emergency medical services, trauma surgeons, and radiologists can facilitate the development of best practices for PHUS in trauma management.
    - Interdisciplinary teams can help create a more holistic approach to patient care, ensuring that all aspects of trauma management are addressed.
10. **Policy Development and Guidelines**:
    - Establishing policies and guidelines for the use of PHUS in the prehospital setting, developed in collaboration with regulatory bodies and professional organizations, will support consistent practice.
    - These guidelines should emphasize the importance of quality assurance and continuous education for practitioners.

By addressing these areas, the future of prehospital ultrasound in trauma care holds promise for enhancing patient outcomes, improving diagnostic accuracy, and optimizing the overall management of traumatic injuries in prehospital settings.

Conclusion

The integration of prehospital ultrasound (PHUS) into trauma care represents a significant advancement in emergency medical services (EMS) that could enhance the diagnostic and interventional capabilities of providers operating in high-

pressure environments. This systematic review sought to evaluate the existing literature on PHUS application for trauma patients, revealing both the promise and the challenges associated with its adoption. Our findings indicate that while ultrasound has become a standard of care in hospital settings, its transition to the prehospital environment has not been extensively studied, particularly regarding its use by EMS professionals. The review identified 16 studies, primarily focused on physician-operated PHUS. The results suggest that PHUS can influence treatment and transport decisions significantly, indicating its potential for improving patient management in prehospital contexts. For instance, in several studies, ultrasound findings led to changes in transport destinations and treatment plans, underscoring its utility in the field. Despite these positive indications, there remains a notable gap in robust evidence linking PHUS to improved patient outcomes, specifically in terms of mortality rates. The majority of included studies were observational, limiting the ability to draw definitive conclusions about the efficacy of PHUS in enhancing trauma care outcomes. Furthermore, the heterogeneity in study designs and ultrasound protocols employed complicates the interpretation of results and diminishes the overall quality of evidence. A key consideration moving forward is to establish clear protocols that define the specific contexts and conditions under which PHUS should be utilized in prehospital settings. As prolonged scene times can adversely affect trauma patient outcomes, any interventions that could delay definitive care must be critically evaluated. Future research should focus on standardizing training and protocols for EMS personnel and investigating the impact of PHUS on patient mortality and long-term outcomes. This will be crucial for integrating ultrasound into standard prehospital practices and optimizing trauma care delivery in emergency situations. In conclusion, while PHUS holds substantial potential to enhance the care provided to trauma patients in the prehospital environment, further studies are necessary to elucidate its clinical benefits and establish guidelines that maximize its effectiveness. Only through rigorous research and practical evaluations can we ensure that such technologies are implemented in a manner that genuinely improves patient care and outcomes in the challenging prehospital landscape.

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أثر استخدام الأشعة فوق الصوتية قبل المستشفى من قبل خدمات الطوارئ الطبية: الفوائد التشخيصية والتداخلية

الملخص:

خلفية :الرعاية قبل المستشفى، وخاصة لمرضى الصدمات، معقدة بسبب البيئات غير القابلة للتنبؤ التي تعمل فيها خدمات الطوارئ الطبية. يوفر دمج الأشعة فوق الصوتية قبل المستشفى (PHUS) تحسينات محتملة في إدارة الصدمات، التي تعد سببًا رئيسيًا للوفاة بين الفئات الشابة في الولايات المتحدة.

الهدف :تقيّم هذه المراجعة المنهجية تطبيق الأشعة فوق الصوتية قبل المستشفى في إدارة الصدمات، مع التركيز على فوائدها التشخيصية والتداخلية عند استخدامها من قبل أنواع مختلفة من مقدمي الخدمات، بما في ذلك محترفي خدمات الطوارئ الطبية، والأطباء، والفرق المختلطة.

الطرق :تم إجراء بحث شامل في الأدبيات عبر عدة قواعد بيانات، وفقًا لإرشادات العناصر المفضلة للتقارير للمراجعات المنهجية والتحليلات التلوينية .(PRISMA) استخدمت التحليلات إطار عمل PICO لمقارنة الرعاية المدعومة بالأشعة فوق الصوتية مع الممارسات القياسية. تم تضمين 16 دراسة في التقييم، تقيّم بروتوكولات مختلفة للأشعة فوق الصوتية وأثرها على قرارات العلاج والنتائج.

النتائج :أبرزت المراجعة وجود تباين كبير في الحساسية والدقة التشخيصية بين الدراسات التي استخدمت الأشعة فوق الصوتية قبل المستشفى. بينما شملت الغالبية العظمى من الدراسات الأشعة فوق الصوتية التي يديرها الأطباء، كان هناك بحث محدود يركز بشكل محدد على محترفي خدمات الطوارئ الطبية. ومن الجدير بالذكر أن النتائج أشارت إلى أن الأشعة فوق الصوتية قبل المستشفى أثرت بشكل إيجابي على قرارات العلاج والنقل، على الرغم من عدم وجود دراسات تناولت بشكل مباشر تأثيرها على معدلات الوفيات.

الاستنتاج :على الرغم من أن الأشعة فوق الصوتية قبل المستشفى تظهر فوائد محتملة في تعزيز رعاية الصدمات، إلا أن دمجها في البيئات قبل المستشفى يتطلب مزيدًا من التحقيق، لا سيما فيما يتعلق بتأثيراتها على نتائج المرضى والتحديات التشغيلية التي تطرأ في البيئات الديناميكية.

الكلمات الرئيسية :الأشعة فوق الصوتية قبل المستشفى، إدارة الصدمات، خدمات الطوارئ الطبية، مراجعة منهجية، الدقة التشخيصية.