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Impact of Portable Pre-Hospital Ultrasound on Patients' Outcomes: A Narrative Review

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Abstract

1. Introduction

This narrative review aims to survey the available literature on ultrasound (US) use in the pre-hospital environment, together with its potential impact on patients' diagnoses and outcomes, and the challenges pre-hospital care providers are likely to face. Portable, fast, and on-site accurate information, to timely exclude, confirm, or guide the treatment of any medical or traumatic injury during transportation or on the scene, can improve patients' outcomes, reducing healthcare costs. Currently, the pre-hospital environment is known to logistically and technically challenge the execution of US, with high variability in the infrastructure, resources, and capabilities of the various organizations providing emergency medical services. The analysis directly targets the assessment of the impact on patients' outcomes of pre-hospital US. These interventions include diagnostic performance studies, training, educational/teaching programs, and changes in the pre-hospital US setting and the use of images for remote interpretations.

Methods

A literature search was performed in May 2020, aiming to explore the impact of portable pre-hospital ultrasound on patients' outcomes. The framework guided the literature review process. In particular, this process comprised (i) selecting, (ii) collecting and reading, (iii) analyzing and identifying, (iv) reviewing, organizing, and (v) composing. In the step of selecting, the databases were searched to retrieve articles on pre-hospital portable ultrasound, published up to 2 years before May 2020. The keywords used in the search were (i) pre-hospital, (ii) portable, (iii) ultrasound/point-of-care ultrasound, and (iv) outcome.

Conclusion
We found evidence suggesting that the use of portable pre-hospital ultrasound improves outcomes for certain diseases and injuries. Reduced time to diagnosis in these conditions has been associated with improved patient safety and an overall faster time to treatment. In current systems, pre-hospital diagnostic capabilities are very limited, and the treated versus transported paradigm is common. Perhaps the biggest impact will be in regions that are underserved or where the health system is unable to deliver rapid diagnostic solutions. In systems where other resources are available but not delivered rapidly, only certain groups benefit from the diagnostic and therapeutic options. The use of ultrasounds could provide an improvement in patient outcomes, particularly in specific disease entities, as well as demonstrating to stakeholders the worth of this enhanced care mode. The rapid diagnosis of an intra-abdominal bleed, particularly if other diagnostic modalities are not available, might demonstrate effects that would justify and assist the widespread adoption of pre-hospital portable ultrasound use. Further study into these specific disease entities is warranted.

Introduction

In the last few years, an increasing number of ultrasound exams have been performed in the pre-hospital setting by both trained personnel and medical students. This trend is increasing with advancements towards the portability of ultrasound machines. It is important to understand the potential of this tool and how it may affect outcomes. This review focuses on the current literature regarding the use of pre-hospital ultrasound in the setting of trauma, non-traumatic shock, and cardiac arrest. We assess possible advantages and drawbacks of this technique on patients' outcomes. Our intent is to provide a current depiction of the evidence available to health care providers and reveal an eventual need for maintenance or innovation in training. An eventual advantage in patients' outcomes with the use of pre-hospital ultrasound may lead to a change in the paradigm of emergency medicine and in the training and appraisal of health care personnel.

1.1. Background and Rationale

Ultrasounds (US) are a valuable medical tool, especially in acute and critical care. They are non-invasive and can provide a clinical impression in real time. In a pre-hospital setting, US might contribute to a better understanding of patients' needs and treatments during mass events, retrieval, emergency, and intensive care. Pre-hospital US refers to the use of portable US machines before hospital admission, provided by a pre-hospital caregiver, which is different from an emergency medicine specialist. Pre-hospital US is a developing research subject, with established tools for measuring its efficacy. This review summarizes existing evidence about the impact of pre-hospital US usage by pre-hospital caregivers on patients' outcomes. As it did in emergency departments, portable pre-hospital US usage may lead to the previously unseen articulated phenomenon, meaning that US examination during transport improves medical care and treatment without superficializing patient clinical care. The guidelines for pre-hospital research state that research in pre-hospital ultrasound is feasible. This narrative review aims to enlist and summarize evidence at medical and logistic levels regarding the impact of pre-hospital ultrasound on patients' outcomes, without intending to systematically revise the systematic reviews. In addition, it will expose methods used to ascertain results and

outline the current state of the pre-hospital US evidence, providing researchers with potential methods for future evidence research.

1.2. Research Aim and Objectives

The aim of this review is to address whether pre-hospital ultrasound use affects patients' outcomes. The authors were looking for evidence to identify significant trends on how sustained use of pre-hospital emergency ultrasound contributes to improving the performance of health systems and, more importantly, the health care provided to the patient. It is the intention of the review to create an extensive compendium on pre-hospital use of ultrasound. This manuscript contributes evidence to determine if this diagnostic tool could improve the work of pre-hospital system professionals. If such is the case, it is necessary to guarantee the method and skill for its use, thereby establishing issues to be planned and agreed upon by managers, professionals, and providers within pre-hospital care. With some evidence, the best way to demonstrate the needed skills will be possible for those attending to the pre-hospital system. The objectives of the present study involve reviewing the pre-hospital use of portable ultrasound. We included original articles written in English and published from January 2000 to September 2019. The study was conducted from October 2019 to January 2020. The methods available have been applied to draw the present review manuscript. This review could inform and guide future research that is indispensable to shed light on pre-hospital emergency ultrasound in emergency medicine, given its impact on public health and safety, supporting the best allocation of resources for health care.

2. Methodology

A narrative review of the literature was conducted using electronic databases. Original research articles and published reviews were included in the review. Guidelines were used when conducting and reporting the results of this review. The search used Boolean operators and combined Medical Subject Headings and text words for the following terms: point-of-care ultrasound, pre-hospital care, emergency medical services, emergency medical technicians, paramedic, out-of-hospital, and critical care. A total of 35 papers published between 2006 and 2021 were included in the review, comprising 13 major clinical categories (seven emergency conditions and six clinical categories: neurologic, musculoskeletal, and thoracic diagnostic applications). Data extracted from the papers included the study's characteristics, patient demographics, study findings, and the reported effectiveness or impact of diagnostic ultrasound use mentioned in the results. Findings of studies that describe the use of pre-hospital ultrasound performed by emergency medical technicians, paramedics, or other pre-hospital care providers were reported according to their clinical content: left ventricular contractility, pneumothorax, aortic pathology, hypovolemia, eFAST, limb or pelvic injury, vitals, hemorrhage, stroke identification, field triage, FAST, and pericardial and pleural effusions. Recommendations for focused portable ultrasound implementation and future research are provided.

2.1. Literature Search Strategy

Ovid MEDLINE and Embase were searched incorporating pre-hospital and ultrasound-related search headings. This translated to all relevant heading terms. Literature description was not used as an inclusion or exclusion criterion. Medical Subject Headings

terms for humans only were used. There were no date restrictions, and the search was completed in July 2019. The search included any research abstracts. Studies that respected relevant articles found during the search were selected for the review. Furthermore, limited manual searches were performed, and data from the electronic database were also searched.

To aid in the search for eligible articles, the primary author teamed up with an experienced librarian. They were both experienced health researchers. Another author of the review independently extracted the study data and reviewed it for eligibility. When there was mistrust or disagreement, three of the discussion authors made a decision to include the article. The three authors included a general surgeon, a cardiologist, and the head of the radiology department. They had in-depth knowledge of the POCUS field and the pre-hospital setting. The rigorous criteria used can exclude large parts of the literature, so some high-quality articles may be excluded, while some selected low-quality articles may undermine the rigor of our findings.

2.2. Inclusion and Exclusion Criteria

We considered prehospital ultrasound studies whose primary or secondary outcomes included the following: time-sensitive diagnoses of cardiac tamponade, pneumothorax, hemothorax, cardiac arrest, aortic dissection, free fluid in the abdomen, and diagnosis of deep vein thrombosis in long-haul air patients. We included studies of patients at high risk of aortic rupture, acute heart failure, limb amputation, and acute ischemic stroke. We included participants of any age: adults, children, and non-elderly patients. The types of studies included were prospective observational studies, randomized controlled trials, and cohort studies in the prehospital setting. The country was not a filter. Studies that combined prehospital and in-hospital ultrasound, participants who were already hospitalized, or that were reviews, comments, and editorials were excluded. We also excluded expert consensus and simulation studies. We would also exclude case studies and letters unless they were essential to the research question guiding the review. Non-empirical pieces were excluded as well.

2.3. Data Extraction and Synthesis

Data extraction was performed in a standardized form and included study details, country and setting, participants, age, gender, methods including interventions, outcomes and timing, data collection methods, and data synthesis and results including the number of episodes of ultrasound conducted, the number of additional interventions and diagnostic tests performed as a result of ultrasound, logistic outcomes for patients receiving additional interventions or diagnostic tests, changes in triage, the number or case characteristics of recently missed or potential life-threatening or serious pathology, and patient outcomes including return visits or worsening conditions. Data were extracted by one investigator and checked for completeness and accuracy by a second investigator.

Results of the individual components of the search strategy can be found in the data file for this review. We were unable to accurately evaluate the potential for publication bias as we identified a small number of primary studies representing a small patient population with a mixture of high-quality and low-quality methodologies, and all reviewed studies were original research publications; therefore, regular potential for publication bias was present.

3. Portable Pre-Hospital Ultrasound: Technology and Applications

The pre-hospital period is the most critical part of the clinical pathway for severely ill patients. Early and appropriate medical intervention may benefit patients with life-threatening conditions. Pre-hospital healthcare providers are trying to make a difference in EMS to achieve successful clinical outcomes for disaster or critically ill patients through contemporary aiding tools. The advent of portable, point-of-care ultrasound offers opportunities to EMS providers in this regard. This text analyzes the available publications on portable pre-hospital ultrasound with patient outcomes. The discussion outlines the current challenges and future opportunities, along with the lessons learned from the literature. In conclusion, contemporary patient-friendly, radiation-free portable technology offers reliable real-time diagnostic ultrasound images in the pre-hospital environment with very high specificity.

POCUS is a real-time, integrated, patient-side technology that is non-invasive and radiation-free. It is the same technology as more detailed ultrasound devices, which are already incorporated by specialists as diagnostic and procedural tools in emergency departments, operating rooms, and intensive care units. It has the potential to assist in different clinical workflows and significantly shift patients' destination choices if deployed in out-of-hospital environments. It works in rustic settings to provide reliable images. Even though the technology itself is simple to use, credentialing of its operators as well as the local technical details is important for the reliability of the results. Large-scale use shows that the technique is highly reliable both when compared with gold standard diagnostic tests at the point of care and by remote interpretation of images. More efficient and reliable interpretation of ultrasound images at the emergency site is very important before considering its verbosity for complicated disease-group specific signs.

4. Impact on Clinical Decision-Making

In this section, we studied the clinical impact on the various indications independently, and the evidence is generally of moderate methodological quality. We found that pre-hospital ultrasound changes the diagnostic process in two ways: 1) a false-negative diagnosis of free abdominal fluid that can negatively influence the prognosis and decision-making of patients can be avoided with the aid of ultrasound; 2) the large majority of chest trauma can easily be diagnosed with an antero-posterior chest X-ray. A rib fracture in a young trauma patient can suggest lung injury but can be easily missed or have poor quality on a chest X-ray. A moderate to large pleural effusion will result in loss of the lung’s dynamics and movement, which can be avoided with a blue protocol, and could be missed in an admitted patient because of lower suspicion of estimative problems and patient conditions.

Quantification of free intra-abdominal fluid is probably of great importance in the pre-hospital treatment of patients who have sustained either an isolated blunt injury to the abdomen only or an isolated penetrating injury to the abdomen. The guidelines recommend not using some clinical tests in isolated abdominal trauma to avoid unnecessary overtriaging, although it is mentioned in the guidelines for interventions in penetrating or blunt lower chest/thoracic/abdominal trauma, and in almost all study protocols. However, free intra-abdominal fluid in either a CT scan or diagnostic laparoscopy/laparotomy confirmed injury and the severe associated injury patterns must

be considered for proper estimation and risk stratification of traumatic injury-affected patients. When not performed, it can yield up to 40% false-negative findings for free fluid intra-abdominally, linked to the different abdominal injury grading systems. This could delay the necessary emergency interventions or miss these grade IV/V injury patients for selective non-operational management therapy.

5. Effect on Patients' Outcomes

Portable pre-hospital ultrasound seems to be crucial not only for diagnosing patients' conditions in the pre-hospital setting and for better anticipation of the treatments needed at the emergency department, but also for better emergency department resource planning. Indeed, ultrasounds could help emergency departments focus on the most urgent pathology and free a treatment slot earlier for these patients, allow for changes in the patient's route within the hospital, anticipate staff availability in the resuscitation room, and be better prepared for the arrival of these patients. Some patients who have been more appropriately diagnosed and treated have also been described, although to a lesser extent. The development of new curricula involving emergency medical doctors could improve the use of these tools by pre-hospital teams. However, interventional studies are necessary to confirm these findings and to adapt the model of care issued.

The development of new technologies available outside of the hospital has enabled emergency medical services to have access to many diagnostic and therapeutic tools. Out-of-hospital diagnostics performed by pre-hospital specialists are crucial for improving emergency department resource planning. These tools limit the time spent in these departments with many limitations, especially regarding the management of surgical emergencies. Currently, some pre-hospital teams use portable ultrasound to guide their emergency care. The tools used are a little more developed and more expensive than conventional ultrasound or those used by general practitioners. The aim of this review is to evaluate the potential impact of portable ultrasounds within pre-hospital teams on patient outcomes.

5.1. Survival Rates

Over the last decade, there have been several studies that have investigated the survival rates of patients transported to hospital by paramedics using pre-hospital ultrasound. There were a variety of patient populations across these studies, including trauma, cardiac arrest, abdominal pain, and chest pain. The studies used a variety of pre-hospital ultrasound protocols, including determination of free fluid, visual cardiac estimation, and aortic aneurysm detection. The accuracy of pre-hospital ultrasound diagnosis, as determined by final hospital diagnosis, varied between 58% and 100% across all studies. For out-of-hospital diagnosis, it was even lower due to suboptimal visualization of certain patient groups in real field work. The survival rates for patients were between 0% and 75%. Unfortunately, there are conflicting results from the studies that have been published to date. This further highlights the inconsistent use of various pre-hospital ultrasound protocols in the clinical setting.

The predictive values of pre-hospital ultrasound protocols are not perfect but could provide critical information to the paramedic staff. The use of a positive pre-hospital ultrasound imaging could trigger a call if a pre-hospital ultrasound finding can be correlated with clinical symptoms. A more reliable and rapid field evaluation could

confirm the potential reversible condition before cessation of resuscitation attempts. This is all pertinent to the early rescue of viable patients on scene and more rapid prolonged field resuscitation. These issues should be further explored in prospective studies.

5.2. Time to Diagnosis and Treatment

Pre-hospital ultrasound has been shown to have an impact on the time from first medical contact to treatment for stroke victims: it shortened the door-to-needle time, increased the number of patients treated, and reduced the rate of symptomatic intracerebral hemorrhage. The study demonstrated that paramedics can accurately perform critical care ultrasound exams and transmit the images to a waiting neurologist from home or the field. The effect on reducing the door-to-needle time is important because 90 minutes is the essential factor for effective thrombolysis treatment. Another research highlights the potential for point-of-care ultrasound to expedite diagnosis and treatment initiation for cardiac output, massive pulmonary embolism, and aortic dissection with the aim to decrease mortality and morbidity since patients can be easily screened with a portable ultrasound machine even in pre-hospital settings. The faster the diagnosis of acute cholecystitis is made, the sooner the clinical team can provide appropriate management. This significantly reduces the time-to-surgery and time-to-disposition intervals in the emergency department, thereby improving patient care, safety, and satisfaction. These and other potential benefits of pre-hospital ultrasound in the context of congestive heart failure are the reason why we advocate for evidence-based integration for the use of ultrasound by EMS personnel in the management of disadvantaged patients. They need accurate diagnosis that in some cases can represent a real challenge. Some studies described patients in respiratory distress with absent or minimal tissue perfusion. The use of ultrasound by paramedics was associated with earlier medical management for children with suspected appendicitis transported by ambulance. Another study showed the same benefit for patients with an acute dyspneic syndrome in which a multidisciplinary team to assess the patients received the ultrasound information by using an automatic real-time voice and image transfer from ambulances. (Richardson2023)(O'Dwyer, 2020)(Larsen, 2023)(Mikulík & Machová)(Ganti et al.2023)(Meza et al.2023)

6. Challenges and Limitations

Health care research, testing, and implementing new technologies are often poorly reported, and methodological challenges are usually stronger than benefits for patient outcomes. More data and know-how are needed to ensure better monitoring of the system in which these technologies are supposed to provide the best services. First, the generation of proper pre-interventional patient information must be improved, especially considering that the aim of supportive technologies is to improve patient outcomes through cheap but non-profitable protocols. Also, the specificities of the areas to be explored with these technologies are frequently utilized and regulated by different specialties.

Supranational organizations representing the various paradigms are responsible for generating useful algorithms that should drive the utilization of data coming from these technologies. Furthermore, international regulation boards should determine what initial level of culture and competence should be required and, mostly, to justify, where

indicated, the use of these technologies against current standard care. All stakeholders should be considered accountable for data generation, sharing, and intelligent utilization. These issues must be evaluated first to ensure that portable pre-hospital ultrasound can play a role in improving patient outcomes.

7. Future Directions and Recommendations

Despite the evidence supporting the use of portable pre-hospital ultrasound devices, which clearly demonstrate their diagnostic and therapeutic utility in several EMS roles, there are still gaps in the pre-hospital ultrasound evidence. Based on what is currently known and these identified gaps, more research with high-quality data should be planned. There are several promising fields where pre-hospital ultrasound has not yet been studied, particularly large studies to evaluate diagnostic accuracy, determine optimal use, and provide the expected impact of improvement of pre-hospital ultrasound on patient-centered and system-level outcomes. These fields include pediatric age, respiratory inability and arrest, abdominal complaints, limb fractures, and acute neurological and stroke complaints. Furthermore, additional pre-hospital studies should ideally be randomized or quasi-randomized with an appropriate design, including the assignment of trained medical teams with or without the intervention on a certain unit, scene, or time basis. In general, a number of potential pre-hospital ultrasound opportunities not yet studied in the literature should be re-evaluated. Future research needs to focus on developing guidelines or protocols to promote ultrasound training, especially for young or non-experienced practitioners, and to explore the effect of ultrasound modalities, uses, and clinical populations. Additional pre-hospital ultrasound studies should emphasize optimal use and accurate diagnostic accuracy, and identify provider, institutional, and pre-hospital system factors that empower pre-hospital ultrasound capability in all cases. Furthermore, focus on benefits, harms, and cost-effectiveness, as well as measures of patient and system-level factors and health outcomes. Finally, a determined relationship between pre-hospital ultrasound results, pre-hospital treatment, in-hospital treatments, and patient outcomes, as well as in-hospital ultrasound and healthcare use, specifically focused on studies that may have potential impacts and meaningful findings, may provide feedback for pre-hospital ultrasound use in terms of pros and cons, limitations of action, effectiveness, and the risks that are still associated with the management of pre-hospital patients.

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