# Ultrasound applied to nursing in the Emergency Medical Service (EMS): a scoping review

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**Enrico Lucenti[1], Lucrezia Lavelli[2], Maurizio Beretta[3], Walter De Luca[4]**

*[1]RN, Emergency Nurse Specialist, Department of Pre-Hospital Emergency, Piacenza Hospital; Adjunct professor, Nursing School of Piacenza, University of Parma, Italy, enricolucenti@gmail.com*
*[2]RN, Casa di Cura Piacenza, Italy*
*[3]RN, Nursing School of Piacenza University of Parma-Piacenza Hospital; Piacenza Nursing Council Board Member, Italy*
*[4]RN, Emergency Nurse Specialist, Emergency Medical Service, Ravenna Hospital, Italy*

**Abstract**

**Background:** In the last years, ultrasound (US) has represented a new field of application for nursing practice. Point of Care US (POCUS) has been defined as an essential skill in the pre-hospital setting. The primary aim of this paper is to describe the main US techniques applied by nurses in the pre-hospital emergency setting, while the secondary aim is to identify the characteristics of the different training courses to learn the necessary ultrasound skills.

**Methods:** We conducted a scoping review. The following databases were consulted: PubMed, Cochrane Library, CINAHL and Google Scholar. For the extraction of valuable articles, after screening for inclusion and exclusion criteria, the PRISMA methodology was used. Two authors independently analyzed the included papers and, in case of discordance, a third author intervened.

**Results:** 815 records were initially retrieved. After duplicates removal and screening for inclusion and exclusion criteria, 6 articles were identified for qualitative analysis. The most discussed topic was the recognition of pneumothorax; two studies analyzed a specific educational US program for flight nurses; three articles evaluated the use of US to verify the correct insertion of devices; two papers explored nurses' skills in performing US scans. Nurses showed moderate levels of sensitivity and high levels of specificity in using ultrasound in trauma and non-trauma patients. Despite the methodological differences of the selected records, the main US techniques implemented by nurses in the Emergency Medical Service (EMS) are Focused Assessment with Sonography for Trauma (FAST), extended-FAST (E-FAST), evaluation of pneumothorax and visualization of correct insertion of devices (i.e. Endotracheal Tube, Nasogastric Tube).

**Conclusions:** Given the heterogeneity highlighted in the

structuring of training courses, both in terms of hours of theory and of controlled practice, no definitive conclusions on training courses for nursing US scans can be drawn.

**Keywords**: Pre-hospital, Setting, Care, Emergency, Medical service, Nurse, Ultrasound, Sonography, Sonographer

## Introduction

In the last years, ultrasound (US) has represented a new field of application for nursing. Features like non-invasiveness, repeatability and cost-effectiveness have allowed a rapid diffusion, mainly and initially, in the intra-hospital environment for Point-of-care US (POCUS)[1], intravenous catheters' insertion[2] and, bladder assessment[3]. However, only recently, Emergency Medical Service (EMS) has begun to implement US in healthcare plan. POCUS is one of the main skills to invest in pre-hospital research and training[4]. EMS nurses should be trained to implement advanced interventions on the patients' rescue to restore and maintain their vital functions[5]. In the pre-hospital setting there is the possibility to perform patients' assessment using US techniques with a significant reduction of door-to-CT scan or door-to-operating theatre time[6].

The literature in the EMS setting regarding US performed by nurses is still lacking. Thus, it is necessary to investigate in-hospital studies for a starting point. In 2010, a study comparing the results obtained from different ultrasound techniques, performed by emergency nurses and physicians, showed that nurse practitioners can perform a focused US examination with a high degree of accuracy[7]. Accordingly, same accuracy in emergency care is found in nursing implementation of the Extended Focused Assessment with Sonography in Trauma (E-FAST) compared with the medical staff [8]. Patients' care, in the pre-hospital setting, consists in the assessment and treatment of imminent dangerous and life threatening conditions, followed by continuous observation related to new interventions or action changes.

The US allows the healthcare professionals to increase the quality of care, also, with a positive cost-effectiveness impact[9]. Some literature reviews stressed out the importance of US in pre-hospital patients' assessment[4,10,11] yet, deepening the topic regarding US efficacy is required through patients' outcome analysis[12,13]. EMS nurse-led sonography still lacks evidence; indeed, there are mainly studies involving the US performed by technical personnel (Emergency Medical technicians - EMT) or paramedics, since dedicated specific training courses already exist in other countries[14,15,16].

A pilot study showed that, paramedics with close supervision can correctly obtain and interpret the FAST and, abdominal aortic US[17]. Additionally, EMT, and paramedical staff perform chest US scans with adequate/sufficient quality image to determine whether or not a pathology is present[18]. Even in the case of cardio-circulatory arrest, EMTs perform correct cardiac US scans to evaluate the contractile activity of the heart[19].

## Aim

The primary aim of this review is to describe the main US techniques applied by EMS nurses in the pre-hospital emergency setting. While, the secondary objective is to identify the characteristics of the different training courses to learn the necessary US skills.

## Methods

A scoping review to describe the state of the art of US performed by EMS nurses was conducted [20,21].

The research question was formulated using the PICO (population, intervention, comparison, outcome) methodology[22] (Table 1).

Table n°1

| | | |
|---|---|---|
| P | Patient | Pre-hospital patient |
| I | Intervention | Nurse ultrasound |
| C | Comparison | N/A |
| O | Outcome | Identify the ultrasound techniques described. |

The keywords obtained from the PICO, and used for the literature search, were the following: pre-hospital; setting, care; emergency; medical service; nurse; ultrasound, sonography, sonographer.

The database search included PubMed,

Cochrane Library, CINAHL, and Google Scholar. Search strategies and applied filters are shown in Table 2. The selection of the articles, according to the PRISMA methodology[23], was performed according to the following inclusion criteria: pre-hospital setting; application of ultrasound techniques; implementation by nurses. Papers were excluded if presented these criteria: in-hospital setting; military setting; studies on mannequins/simulators; implementation of the ultrasound by other professionals or rescue technicians; qualitative studies; grey literature.

The literature search on the databases took place during August 2021. The review was carried out by two independent researchers. Any conflicts were analyzed and solved by a third member of the review team. Finally, the selected papers were summarized in a table showing the following topics:

- Author, country and year of publication;
- Aim of the study;
- Design of the study;
- Healthcare professionals that used US assessment;
- Nursing Training;
- US techniques;
- Results.

Table n°2

| Database | Search Strategy | Limits |
|---|---|---|
| PubMed | (prehospital or "prehospital setting" or "pre-hospital care" or "prehospital emergency" or "emergency medical service") AND (nurse or nursing or nurses) AND (ultrasound or US or sonography or sonographer) | Text availability: 10 years;<br>Publication date: 10 years;<br>English language;<br>Full text. |
| Cochrane Library | (prehospital or "prehospital setting" or "pre-hospital care" or "prehospital emergency" or "emergency medical service") AND (nurse or nursing or nurses) AND (ultrasound or US or sonography or sonographer) | Text availability: 10 years;<br>Publication date: 10 years;<br>English language;<br>Full text. |
| Google Scholar | Prehospital and nurse<br>and (ultrasound or<br>sonography) | Text availability: 10 years;<br>Publication date: 10 years;<br>English language;<br>Full text;<br>Scientific articles. |
| CINAHL | (prehospital or "prehospital setting" or "pre-hospital care" or "prehospital emergency" or "emergency medical service") AND (nurse or nursing or nurses) AND (ultrasound or US or sonography or sonographer) | Text availability: 10 years;<br>Publication date: 10 years;<br>English language;<br>Full text. |

**Results**

As shown in Table 2, 815 records were retrieved, resulting in 810 after duplicates removal to screen for inclusion and exclusion criteria. 17 remaining papers were furtherly evaluated according to the eligibility criteria. Among these, 11 papers were excluded for the following reasons: the patients' population did not belong to the pre-hospital setting, or ultrasound was not performed by nurses. Finally, 6 papers were selected for qualitative analysis (PRISMA flow diagram, figure 1). The studies' results are summarized in Table 3.

The studies included showed substantial differences regarding methodology, study design and country of provenience. All the included papers studied nurse-led ultrasound used on patients in the pre-hospital setting. In particular, their objectives were: to evaluate if US can contribute to the correct initial assessment of patients by helicopter rescue nurses and, describe the theoretical/practical educational program[24]; to implement an US program for pneumothorax and, endotracheal intubation issues by helicopter rescue nurses[25]; establish whether non-medical personnel could acquire lung US images and interpret them with sufficient accuracy to identify pneumothorax in the pre-hospital setting[26]; define whether adequate use of US in the pre-hospital setting may play a key role in improving patients' outcome[27]; assessing accuracy of US in detecting the correct

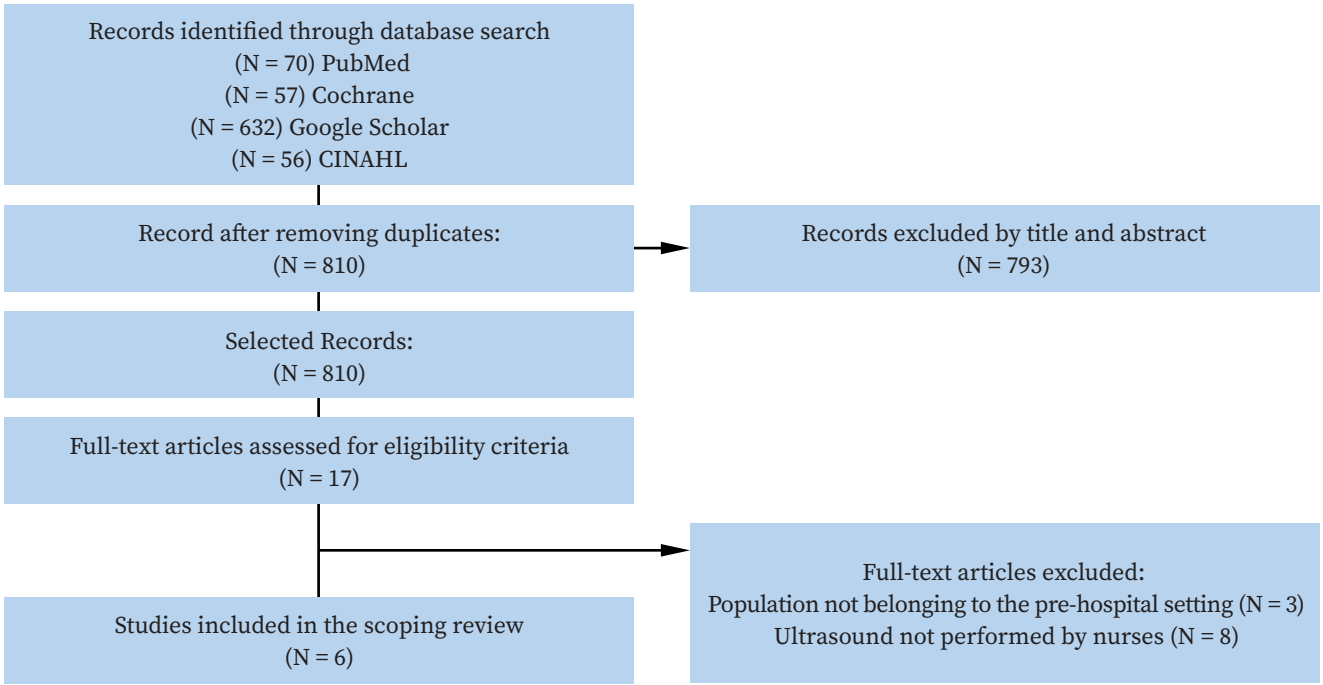
nasogastric tube (NGT) positioning[28]; describe the use of pre-hospital US in trauma patients[11].

Cover et al.[24] in the United States (USA) studied the implementation of a useful educational program for US in the pre-hospital setting by the flight nurses (FNs). The skills acquired by the FNs included: the detection of pericardial tamponade presence; the functionality of the left ventricle; the difference between pulmonary A and B lines; the measurement of the inferior vena cava caliber; the correct performance of an E-FAST. Another research, in the USA, concerned the implementation of an US curriculum for FNs to identify pneumothorax and, to guide the correct insertion of the tracheal tube: it was carried on with adequate results over two months, through a training course of 3 sessions of one hour each[25].

Another observational study evaluated the skills of the Advance Retrieval Practitioner (ARP-a nurse or paramedic employed in recovery operations) to perform US. ARP had 86.4% accuracy, 66.6% sensitivity and 100% specificity in using US. The authors stated that also non-medical personnel could acquire valid ultrasound images for evaluating pneumothorax in the pre-hospital setting[26]. Moreover, a literature review, explored the use of pre-hospital US, focusing on thoracic US during the performance of FAST[27]. US performers showed a sensitivity and specificity of 100% in non-trauma patients and a sensitivity of 60%, and a specificity of 93% in trauma patients. Another review summarized the best evidence regarding the diagnostic accuracy of the ultrasound to determine the correct positioning of the NGT in adult patients. The correct positioning of the NGT can be verified through the use of the ultrasound. However, there is no evidence to support this procedure[28].

Lastly, Mercer et al.[11] compared the use of US on trauma patients by medical and non-medical operators, comparing multiple training programs. The US use in a pre-hospital setting influenced the transport and the destination hospital. However, there was no difference in patients' evaluation by ultrasound performed by medical or non-medical personnel.

Figure 1 - PRISMA flow chart




## Discussion

The primary aim of this scoping review was to describe the main US techniques applied by EMS nurses in the pre-hospital emergency setting, then to focus on the differences between the US training courses. Currently, this is a topic not yet particularly developed except for some particular issue as pneumothorax. Indeed, in literature, the ability to recognize pneumothorax was addressed by 5 of the 6 analyzed papers; thus, pneumothorax represents the second most frequent injury in thoracic trauma and

requires early diagnosis and treatment[27,29]. Recognizing pneumothorax is considered a fundamental skill for FNs. In fact, educational programs focused on these specific skills[25,26]. The correct assessment of pneumothorax improves patient safety and reduces mortality, therefore, ambulance personnel should be able to perform US evaluation[26].

Another use of the US has been identified in the evaluation of the correct devices' insertions: the confirmation of the endotracheal tube (ETT) placement[11,25,27] and, the assessment of the correct insertion of NGT in the pre-hospital setting for adequate gastric decompression in the event of CPR[28].

EMS nurse-led FAST and E-FAST were discussed in three studies[11,24,27]. These techniques allow to significantly reduce the hospitalization and, treatment times of trauma patients[30]. Specifically, the implementation of FAST and E-FAST method, can bring to an immediate distinction between a critically ill patient and a not critically ill one. Furthermore, they can be useful to address the patient to the most suitable hospital and to get an early alert of the in-hospital trauma team[11,24,27]. The US utilization could help in early identification of the potentially reversible causes that make a patient critical and in anticipating the times of traditional diagnostics[26]. Also, the adequate use of ultrasound would allow an identification of the most suitable center for treatments to avoid care delay, hopefully, preventing irreversible damage[31]. The decision-making process, regarding the choice of means of transport, such as a vehicle on the ground or a vehicle in flight, can be influenced by preventive recognition of particular conditions thanks to US images[32]. Hence, US should be considered as an element of the physical examination itself[33].

The included papers were limited by small sample sizes, thus, the ability to perform accurate long-term US scans needs to be investigated furtherly. Heterogeneity has been identified in the studied educational programs. Indeed, duration of training varied from 3, 7 to even 10 hours[24,25,27]; also, more articulated courses in terms of didactic and practical sessions were described[11]. The trainings included different assessment methods: i.e. the ability to obtaining valid ultrasound images in healthy patients[24] or performing ultrasound scans during clinical practice on patients with actual problems, making the ultrasound more realistic[26].

Since a quantitative synthesis of the results could not be carried on, the effectiveness of the different programs cannot be defined; therefore, the best method to train nurses to perform accurate ultrasound scans needs to be searched.

Lastly, some limitations affected this scoping review: firstly, the lack of articles in the literature specifically related to the topic of nursing US in the pre-hospital setting. On the contrary, the literature on pre-hospital ultrasound carried out by physicians has seen a significant increase in publications in the last decade[4]. Secondly, the methodological differences of the included papers did not allow effective comparison between the patients' outcomes. Finally, another limitation is represented by the settings from which the studies originated, given that nursing acts and develops in different socio-political and educational contexts.

**Conclusions**

Ultrasound techniques represent a valid tool for emergency care nurses in the assessment and management of the patient rescue, according to the literature analyzed. However, the methodological heterogeneities of the published studies do not allow a concrete comparison of their results. Therefore, it is not possible to assess the quality of the educational programs applied for nurses. Indeed, US in the pre-hospital setting by EMS nurses is a novelty, worthy of further research both in terms of applicability, educational program features and, improvement of patients' outcomes.

Table No. 3 - Results

| Author(s), Year and Country of publication | Aim of the study | Design of the study | Healthcare Professionals that used US assessment | Nursing Training |
|---|---|---|---|---|
| Cover et al. (2019) Michigan, United States [24] | To describe the creation of a Flight Nurse (FN) US program and to evaluate whether FNs critical care in the pre-hospital and inter-hospital setting can clarify patient assessment | Prospective cohort study | Helicopter rescue nurses | 4 months' period; including 5 didactic and practical 2 hours' sessions |
| Mason et al. (2018), United States [25] | To describe the implementation of an US curriculum for the identification of pneumothorax and esophageal intubation for FNs | Prospective cohort study | Helicopter rescue nurses | 2 months' period training of 3 sessions of 1 hour each<br><br>Pre-training test and post-training test was based on 15-question |
| Ronaldson et al. (2020) United Kingdom [26] | To assess the feasibility of ultrasound pneumothorax diagnosis non-, and assess the accuracy of the pneumothorax diagnosis | Observational study | Advanced retrieval practitioners (ARP) | Not specified |
| Sun JT et al. (2014) [27] | To review and discuss the use of prehospital ultrasound, with emphasis on trauma and chest ultrasound | Narrative review | Pre-hospital emergency nurses | A revised record deals with a 7-hour training course was carried out to improve theoretical and practical skills about the FAST ultrasound. |
| Lin T et al. (2017) France, China, Corea. [28] | To synthesize the best available evidence concerning the diagnostic accuracy of ultrasonography for determining NGT placement in adults. | Systematic review and meta-analysis of observational studies. | Pre-hospital emergency nurses and other professionals. | Not specified. |
| Mercer et al. (2020) (11) | To examine the use of prehospital ultrasound for trauma patients and the use by different provider types | Systematic review | Pre-hospital emergency nurses and other professionals | Training courses:<br>• 1-day nurses course on FAST<br>• 2-month training for nurses without knowledge of ultrasounds<br>• flight crew members trained for thorax US<br>• a 4 h of clinical practice preceded by 8 h of theory for flight nurses. |

| Ultrasound techniques | Results |
|---|---|
| Pericardial tamponade and effusion, systolic function of the left ventricle, difference between lines A and lines B, identification of pleural slip, evaluation of the caliber of the inferior vena cava, E-FAST. | the FNs evaluated 829 patients in 15 months and used US on 102/829 (12.3%) patients<br><br>US use clarified the semeiotics in 67.4% of the transported patients |
| Pneumothorax assessment by ultrasound technique and esophageal ultrasound to confirm correct endotracheal tube insertion. | 12 FNs were assessed for the pre-training test reporting a scores of 6.8 mean and 7 median (range 0-15) – while the post-training score was 13.6 and 14, respectively.<br><br>The training intervention resulted in an average percentage improvement of 45.6%, or 6.8 questions. |
| Evaluation of the pneumothorax | In 13 months' period, 87 patients were assessed with US- images of 12 patients were included in the analysis.<br><br>Of the 12 chosen, 50% were non-traumatic patients<br><br>the study showed that ARPs had 86.4% accuracy, 66.6% sensitivity and 100% specificity compared to the expert review. |
| Thoracic ultrasound for the recognition of pneumothorax, verification of the correct positioning of the endotracheal tube, pulmonary edema at high altitude, pericardial effusion / tamponade, pulmonary embolism, cardiac arrest, E-FAST. | Adequate use of prehospital US in critically ill patients may play a key role in improving patient outcome- FAST training course; nurses reported 100% sensitivity and specificity in non-trauma patients and 60% sensitivity and 93% specificity in trauma patients after one year of training |
| Ultrasound in visualizing the correct positioning of the NG tube | Ultrasonography diagnostic performance may be considered clinically useful to confirm correct NGT placement,<br><br>although there is insufficient evidence to suggest ultrasound as a diagnostic tool for incorrect<br><br>NGT placement |
| FAST and E-FAST in trauma patient; ultrasound evaluation of pneumothorax and correct positioning of the endotracheal tube | From 16 selected studies, Professionals performed ultrasound with the following results: pre-hospital ultrasound influenced patients treatment in 23% of cases, provided additional information to the hospital in 4.6% of cases, changed the mode of transport in 0.7% of cases, and changed the choice of destination in 0.7% of cases |

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