

Chapter 25

Ultrasound in Disaster and Pre-hospital Use

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Emergency POC Ultrasound During Disaster and Mass Casualty Incidents

Objectives

- Review the utility and limitations of emergency ultrasound during disaster and mass casualty incidents
- Understand the importance of including emergency ultrasound during disaster preparation and protocol development

Introduction

Disaster and mass casualty incidents (MCI) are unfortunately becoming more common worldwide. These events, while unpredictable, can be prepared for with emergency management plans and disaster drills. Point of care US (POC US) can be a valuable tool in patient triage, evaluation and management during disaster scenarios both in the prehospital and hospital environment. Its use has been driven by the established role of ultrasound in emergency and trauma evaluation and the widened availability and portability of ultrasound technology. Emergency ultrasound should be included as part of comprehensive disaster preparedness planning.

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Ultrasound During Triage

Mass casualty triage often occurs in two stages. The first is onsite triage by emergency providers to identify patients on scene that require immediate transport or evacuation, and the second is hospital-based triage of arriving patients to direct the timing of access to care. There are various triage scoring systems. The most commonly recognized and utilized triage scoring system in the United States is START, but all variations follow very similar principles with regard to categorization based on severity (see Table 25.1).

The core principle behind triage scoring systems is the rapid evaluation and appropriate triage of sick patients to definitive care and appropriate utilization of resources. These categorization systems are typically based on the physical exam and assessment of vital signs. However, this evaluation with limited available data can increase the risk of over- or under-triage of patients to higher levels of care.

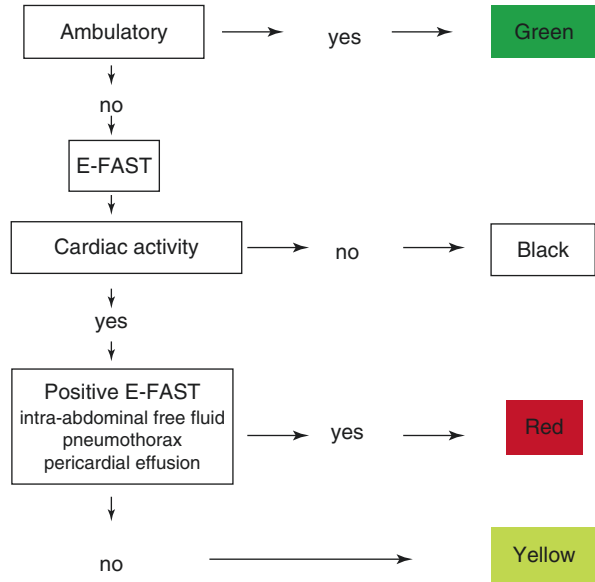
The most heterogeneous patient group within the triage categories is the urgent but not immediately life-threatening (yellow) category of patients. Because of its diversity, this group could benefit from a secondary evaluation using ultrasound to identify subgroups with potentially life-threatening injuries that would benefit from re-triage. There is an opportunity to design new triage-based protocols involving ultrasound, both for identifying occult life-threatening injuries within this category and further subclassifying stable ambulatory patients with extremity injuries in order to streamline further diagnostic evaluation (see Table 25.2). Focused assessment with sonography in trauma (FAST) incorporated into the START triage algorithm has been used to identify yellow category patients with hemoperitoneum [1, 2]. Stawicki et al. have also proposed a triage-specific ultrasound protocol for evaluation of mass casualty patients focused on a modified E-FAST (Extended FAST incorporating thoracic ultrasound for pneumothorax), IVC, and limited musculoskeletal evaluation [3]. Many of these triage protocols have been made with adults in mind, but could likely be extrapolated to children and other unique populations. Given the unpredictable nature of disaster events, it may be difficult to empirically demonstrate a potential mortality benefit with the use of ultrasound.

Table 25.1 Triage categories

Modified triage categories
Expectant, unsalvageable or deceased—Black
Immediate life threatening—Red
Urgent, not immediately life threatening—Yellow
Ambulatory or delayed care—Green

Modified from START triage algorithm—START TRIAGE. Available at <http://www.start-triage.com>. Accessed 20 July 2016.

Table 25.2 Ultrasound incorporated into triage algorithm



Trauma and Diagnostic Ultrasound

Ultrasound is an ideal modality for initial diagnostic workup during domestic and international natural and manmade disasters [4–7]. Typically, the E-FAST exam is the most valuable diagnostic tool to rapidly evaluate for life-threatening intrathoracic and intra-abdominal pathology when performed by experienced providers. Some disaster response teams currently utilize portable ultrasound and this use will likely expand with increased training opportunities. We recommend EMS services have a portable ultrasound available for MCI assessment performed in the field by reliable trained personnel. In addition, hospital radiology resources are often quickly overwhelmed leaving portable clinician performed ultrasound an ideal diagnostic modality in the emergency department for patients awaiting advanced radiology imaging.

There exists a significant patient injury burden that does not fall into the initially life-threatening category and a bedside E-FAST exam can help to rule out significant intrathoracic or intra-abdominal trauma and potentially avoid further imaging. The majority of patients presenting for evaluation and care after MCIs will fall into the yellow and green categories, with a significant proportion of injury burden from extremity, soft tissue, and orthopedic injuries. From the experience after the Boston Marathon Bombings, approximately 74% of patients presenting to two level one hospitals had shrapnel injuries [8]. Unique to organized terrorist attacks with shrapnel containing explosive devices and mass shootings, radiographic images are vital

for potentially radiolucent foreign body identification. However, radiation-based modalities can often miss radiopaque substances such as glass and wood. Non-radiopaque foreign body identification is enhanced with ultrasound and a recent meta-analysis reports that ultrasound is approximately 72% sensitive and 92% specific in detecting foreign bodies [9].

The development of US-based protocols for triage assessment could also be extended to modified bedside reassessment protocols during the longitudinal emergency department evaluation. Repeat targeted FAST exams or modified shock ultrasound protocols, such as the RUSH exam [10], are potential tools for monitoring evolving cases within the initially less critically injured appearing patient population, that subsequently develop physical exam or vital sign abnormalities.

Ultrasound for Procedural Guidance

In addition to triage and diagnostic evaluation, ultrasound can be used therapeutically to guide procedures such as vascular access and peripheral nerve blocks. Lippert et al. suggest that the use of US-guided interscalene, forearm, femoral, and popliteal nerve blocks are potentially valuable procedures that could improve pain control in a disaster setting [11]. Ultrasound-guided peripheral nerve blocks are well described in the emergency medicine literature as being within scope of practice of emergency physicians competent in ultrasound. These procedures can provide pain relief during wound washout and repair as well as orthopedic reduction and splinting when procedural sedation would have been otherwise indicated, but nearly impossible due to significant resource and time constraints. A systematic review of multiple earthquakes victims found that on average 68% of patients presented with extremity injuries [12]. Providers caring for patients after the earthquake in Haiti utilized ultrasound-guided nerve blocks for pain relief and to assist with orthopedic procedures and wound care [13]. Basic information regarding the types of blocks as well as limitations and challenges of each proposed procedure are listed in Table 25.3.

Incorporating Ultrasound into Disaster Planning

Protocols and procedures for emergency ultrasound performed both in the field and in emergency department settings should be included in comprehensive disaster planning. A well-documented bottleneck in the ED evaluation of MCI injuries is the high demand on diagnostic radiology. From military data we know that combined X-ray, CT, and US evaluations may be required for complete injury evaluation [14]. The number of radiology studies and the report response times after the Boston Marathon Bombing were both noted to be significantly increased compared to baseline [8]. Brunner et al. suggest “radiology departments should maintain a

Table 25.3 Ultrasound-guided nerve blocks in mass casualty incidents

US-guided nerve block	Injuries	Difficulty	Challenges	Estimated procedural time, minutes ^a
Femoral	Knee	Basic	Risk of inadvertent arterial puncture; partial pain control	10
	Femoral neck Proximal femur			
Popliteal (distal sciatic nerve just proximal to the popliteal fossa)	Distal tibial fracture	Advanced	Excludes saphenous innervation of the medial foreleg, ankle, and foot; increased level of difficulty if patient unable to move to prone position; inadequate block without targeted anesthetic deposition	10
	Fibular fracture			
	Majority of foot and ankle injuries Soft tissue injuries lower leg			
Forearm (median, ulnar, radial nerves)	Isolated hand injuries	Basic	Radial nerve can be difficult to visualize in forearm	5
Interscalene (brachial plexus)	Shoulder dislocation Humerus fracture Elbow dislocation	Intermediate	Complex anatomy in the neck. Higher risk of complications: Pneumothorax, phrenic nerve paralysis	10

Reproduced from Lippert et al. [10]

^aEstimated procedural time includes ultrasound setup, nerve identification, preparation of the injection site, and deposition of local anesthetic around the peripheral nerve identified.

comprehensive mass casualty plan to address the surge in imaging needs that arise from blast injuries. This may require mobilization of additional portable imaging equipment or cancellation of non-emergent imaging on CT scanners or nearby fixed X-ray units to create additional capacity” [8].

POC US can be used to expand diagnostic evaluation of patient injuries while awaiting operative care or advanced diagnostic radiology, and the same principles apply in regard to a preparing a comprehensive mass casualty plan. Mobilization of resources including personnel trained in ultrasound and additional ultrasound systems from other locations, such as radiology departments or ICUs, should be prepared and planned for in advance. There should also be a yearly comprehensive review of the available equipment within emergency department to ensure that there is easy identification and regionalization of necessary equipment, such as spare battery packs or functional probes, and that each machine has a linear and curvilinear probe available for the most common imaging modalities. There is also a role for review and education of providers in obtaining necessary imaging with suboptimal probe availability, such as obtaining eFAST with a phased array probe, in the event of equipment damage or unavailability of ideal probes (see equipment chapter).

IMAGING STUDIES

<input type="checkbox"/> EFAST: _____	

XRAY	CT
<input type="checkbox"/> C-spine: _____	<input type="checkbox"/> Head: _____
_____	_____
<input type="checkbox"/> Chest: _____	<input type="checkbox"/> C-spine: _____
_____	_____
<input type="checkbox"/> Pelvis: _____	<input type="checkbox"/> Chest: _____
_____	_____
<input type="checkbox"/> T/L/S spine: _____	<input type="checkbox"/> Abd/Pelvis: _____
_____	_____
<input type="checkbox"/> Extremities: _____	<input type="checkbox"/> T/L/S-spine: _____
_____	_____
<input type="checkbox"/> Other: _____	<input type="checkbox"/> Other/Incidental: _____
_____	_____
_____	_____

Fig. 25.1 Example of paper MCI and downtime documentation

Communication between emergency department providers and specialists during MCIs can be challenging, potentially putting patient care at risk. Emergency departments must weigh heavily on the strength of their information systems for patient flow, resource allocation, ordering, proper documentation of point of care imaging, and procedures. Disaster planning must include documentation systems such as the use of paper versus electronic medical records, or a hybrid system for the timely collection and sharing of valuable findings between team members [15]. If paper charting is utilized during down time or disaster scenarios, it should include an area for ultrasound documentation (see Fig. 25.1), a lesson learned during the Boston Marathon Bombing experience [16, 17]. Pertinent ultrasound findings are only valuable if the results are easily communicated between the medical and surgical teams. This is particularly important if ultrasound is being used in the prehospital environment or on scene where diagnostic information or specific diagnoses may have already been obtained prior to ED arrival. Pertinent positive findings could be documented either directly on the patient or via an adhesive such as masking tape, to ensure that this information does not get lost in transit, during triage, or patient decontamination.

Equipment

Ultrasound systems for use during disaster and MCI should be portable, durable, and function on battery power. Use of both linear and curvilinear transducers allows for a range of applications from procedural guidance to E-FAST. In addition to the

appropriate ultrasound machines, comprehensive disaster planning must include easy availability of backup battery packs or alternative energy sources as well as equipment such as gel, cleaning solution, and probe covers. In case of hazmat scenarios, machines and equipment may become compromised and we recommend including protocols for identification of potentially contaminated equipment, training personnel on appropriate procedures, and having backup equipment readily available (See Chap. 12 – Ultrasound Equipment and Purchase).

Conclusion

Ultrasound is increasingly being utilized during disaster and MCI incidents throughout the world. Evaluation of life-threatening traumatic injuries and reevaluation of undifferentiated patients is important for the triage and management of large numbers of patients in a short period of time. Even the most robust emergency departments quickly mirror any resource limited setting with a large and rapid influx of sick undifferentiated patients. Emergency departments as well as disaster management teams must be prepared with the appropriate ultrasound equipment including plans for portable, battery-powered, machines, trained personnel, and understanding of disaster scenario documentation and communication.

Key Recommendations

- Ultrasound can be incorporated into triage algorithms and utilized for both diagnostic and therapeutic indications during disasters.
- E-FAST is the most common application utilized during disaster and MCI situations.
- US-guided regional anesthesia can be used for extremity injuries and to facilitate wound care and orthopedic procedures.
- Expect and plan for a surge in imaging utilization during disasters.
- US machines used in disaster scenarios must be portable and rechargeable.
- Develop reliable disaster protocol documentation for ultrasound results to facilitate team communication.
- Emergency ultrasound should be included in comprehensive disaster response planning.

Ultrasound in the Prehospital Setting

Objectives

- Understand the utility and limitations of ultrasound in the prehospital setting
- Describe the role of telemedicine for prehospital ultrasound

Table 25.4 Principles of prehospital ultrasound

Principles of ultrasound application in the United States prehospital environment	
1.	Ultrasound training and skill maintenance EMS personnel
2.	Development of prehospital ultrasound protocols and guidelines based on available evidence
3.	Regular imaging QA by ultrasound credentialed director or establish prehospital US director
4.	Research and innovation for adaptive prehospital ultrasound practice

Introduction

The incorporation of ultrasound into the prehospital environment varies worldwide with different prehospital models of care delivery. It is more common in places like Europe, Scandinavia, and Australia where physicians typically staff prehospital transport and remains in the early stages of utilization in North America. Ultrasound has been utilized in the field by emergency medical services to assist in appropriate prehospital triage, diagnosis, management, and resuscitation of critically ill and injured patients. Increasing adoption of this technology will likely occur as ultrasound machines become even smaller and more durable, training opportunities expand, and the potential benefits to patient care are realized.

Currently the use of ultrasound in the American prehospital setting has focused mainly on air transport and some advanced paramedic units. General use by local EMS is limited but growing. A 2014 survey of EMS directors in North America found that only 4% of EMS systems were using ultrasound, primarily for trauma and cardiac arrest evaluations, but an additional 20% were considering implementation [18]. The expanding role for ultrasound within the American system will be centered on applications that are simple to teach, are reliable and answer clinical questions that have the potential change patient management (see Table 25.4).

Trauma Evaluation

The E-FAST examination is a valuable tool in the evaluation of trauma patients in both in the emergency department and in the prehospital setting. E-FAST can provide early identification of life-threatening injuries such as pneumothorax, hemoperitoneum, or cardiac tamponade. Prehospital providers can perform E-FAST exams reliably and quickly after brief training programs [19–22]. There is emerging literature to suggest that prehospital ultrasound has the potential to change patient management including prehospital therapies and altering hospital transport decisions [23–26].

In addition to an initial E-FAST exam, ultrasound can be used to guide vascular access and provide augmented reassessment of trauma patients during prolonged

transfer. For example, monitoring for pneumothorax in ventilated patients, repeated FAST exam for the development of intra-abdominal free fluid, and management of fluid resuscitation management could be valuable data for receiving hospitals or for critical care transport teams to monitor between hospitals settings.

Limitations to wide spread adoption of EUS includes the costs of equipment and training as well as lack of specific guidelines and protocols. Likely this technology will be adopted first by advanced paramedics, aeromedical transport, and local units with prolonged transport times. With improvements in technology and recognition of improvements in clinical management of patients, we will likely see an expansion of ultrasound use locally with prehospital crews that have access to physician trainers who can create specific polices and guidelines that take into account experience of providers and local transport times.

Cardiac Arrest

Ultrasound is increasingly being incorporated into cardiac arrest resuscitation. EUS can diagnose potential etiologies of cardiac arrest such as pericardial effusion with tamponade, massive pulmonary embolism resulting in RV strain, or pneumothorax. The 2015 European resuscitation counsel guidelines now include ultrasound stating, “Peri-arrest ultrasound may have a role in identifying reversible causes of cardiac arrest” [27]. In addition, ultrasound can provide prognostic information. In a large multi-center trial of 793 cardiac arrest patients, in those with asystole, lack of cardiac activity on ultrasound had a sensitivity of 90% and positive predictive value of 99% for non-survival to hospital discharge [28].

Telemedicine

Another expanding field within the prehospital setting is the opportunity to combine telemedicine and ultrasound. Incorporation of tele-ultrasound for onsite personnel could provide valuable diagnostic resources to EMS providers with limited US experience, and in turn supply receiving hospitals with vital patient data prior to hospital arrival. This could provide time to prepare to arrange or resources such as massive transfusion protocol activation or operating room setup. Military, space, and civilian studies have demonstrated that the transmission of US images is both feasible and reliable with respect to specific imaging modalities [29, 30]. If the equipment is available, but the providers on scene have limited training, appropriate images could be obtained through coaching using remote guidance from experienced emergency providers. While concerns regarding patient confidentiality and image quality are limitations to its widespread implementation, it is an area of potential growth and innovation.

Limitations

Obstacles to the widespread adoption of ultrasound in the prehospital setting include the cost and resources necessary for equipment and training and lack of large-scale data demonstrating clinical outcome benefits. However, with advances in technology ultrasound machines will continue to become cheaper and more portable. A proliferation of online resources provides ample opportunities for education. The adoption of EUS within American prehospital systems will need to be symbiotic with the primary focus on short scene time and rapid transport to definitive care. Systems with short transportation intervals between scene and hospital may find limited uses for US such as trauma, cardiac arrest, and vascular access. Rural locations with longer transport times or critical care transport teams will likely have expanded indications for ultrasound. The acquisition of this new skill set for emergency medical providers will require a time and financial commitment, training and competency assessment, outcomes assessments, and a significant frequency of use to maintain proficiency. This process has been well delineated for emergency physicians in the 2016 ACEP Emergency Ultrasound guidelines and could be adapted for prehospital providers. Emergency physicians with advanced ultrasound training will be crucial in facilitating the development of prehospital POC US.

Conclusion

Ultrasound use in the prehospital setting is an emerging frontier with increased interest and adoption of this technology. Emergency physicians trained in ultrasound have a unique opportunity to pair with local EMS providers to develop training protocols and procedures unique to regional EMS systems. Protocols will need to take into account the unique practice environment of medical transportation including time, space, and training constraints. New solutions and applications will be possible with advancing technology including a potential role for telemedicine. Lastly, ongoing research is needed into the role of prehospital POC US regarding the potential to change patient management and outcomes.

Key Recommendations

- Ultrasound is increasingly utilized in the prehospital setting, especially for trauma and cardiac arrest patients as well as patients with prolonged transport times.
- Challenges to widespread incorporation include costs and logistics of training and equipment as well as need for protocol development.
- Use of telemedicine has the potential to advance the use of ultrasound in the prehospital environment.

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