Considerations for Ultrasound in the Urban Search and Rescue (USAR) Environment

Ricky C. Kue

Introduction

The field of urban search and rescue (USAR) was formally developed in the 1990's as a response to the growing concerns over organized response to building collapses and victim entrapment as a result of natural disasters such as earthquakes. In that time, the system developed in the United States under the Federal Emergency Management Agency (FEMA) is comprised of a national network of 28 Task Forces positioned throughout the country in nearly 19 states (Fig. 1). This program is known as the National Urban Search and Rescue Response System, which looked at regions at highest risk for earthquakes and building collapses within the United States and develop strategically located assets to best respond. These teams can be called upon into service in response to support heavy search and rescue capabilities at the request of local jurisdictions. Teams are able to deploy within 6 hours of notice and be self-sustained for 72 hours of operations. A typical USAR task force type-1 team is made up of 80 personnel (Fig. 2) specialized in a variety of disciplines providing technical search, rescue, hazmat management, structural engineering, communications, logistics, canine search/recovery as well as emergency medical capabilities [1]. In essence, USAR can be best described as the science of locating, reaching, medically treating, and safely extricating deeply entombed survivors of collapsed structures [2].

The USAR Medical Team

The medical team within a USAR task force is comprised of emergency physicians (referred to as medical team managers) and paramedics (referred to as medical specialists) who have undergone specialized training focused on medical care in a

R. C. Kue (✉)
Massachusetts Urban Search and Rescue Task Force-1 (MA-TF1), Beverly, MA, USA

B. D. Nicholson et al. (eds.), *Manual of Austere and Prehospital Ultrasound*,
https://doi.org/10.1007/978-3-030-64287-7_5

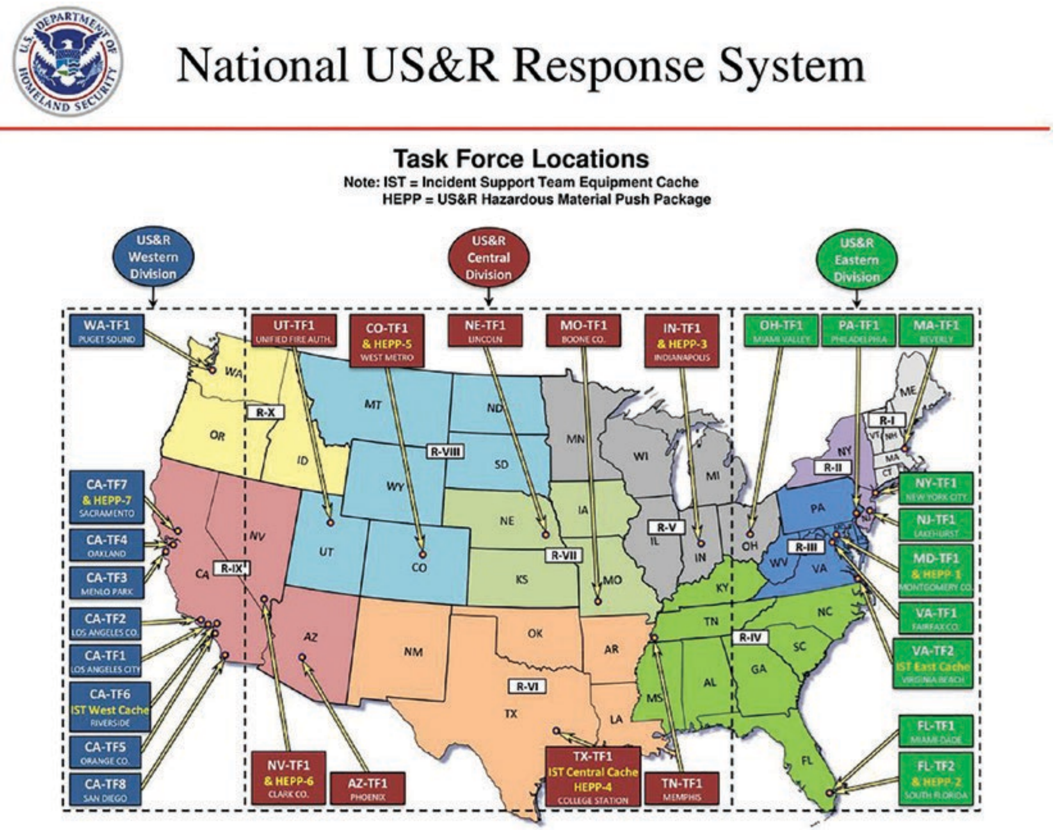

Fig. 1 Locations of FEMA US&R Teams in the United States. (https://www.fema.gov/task-force-locations)

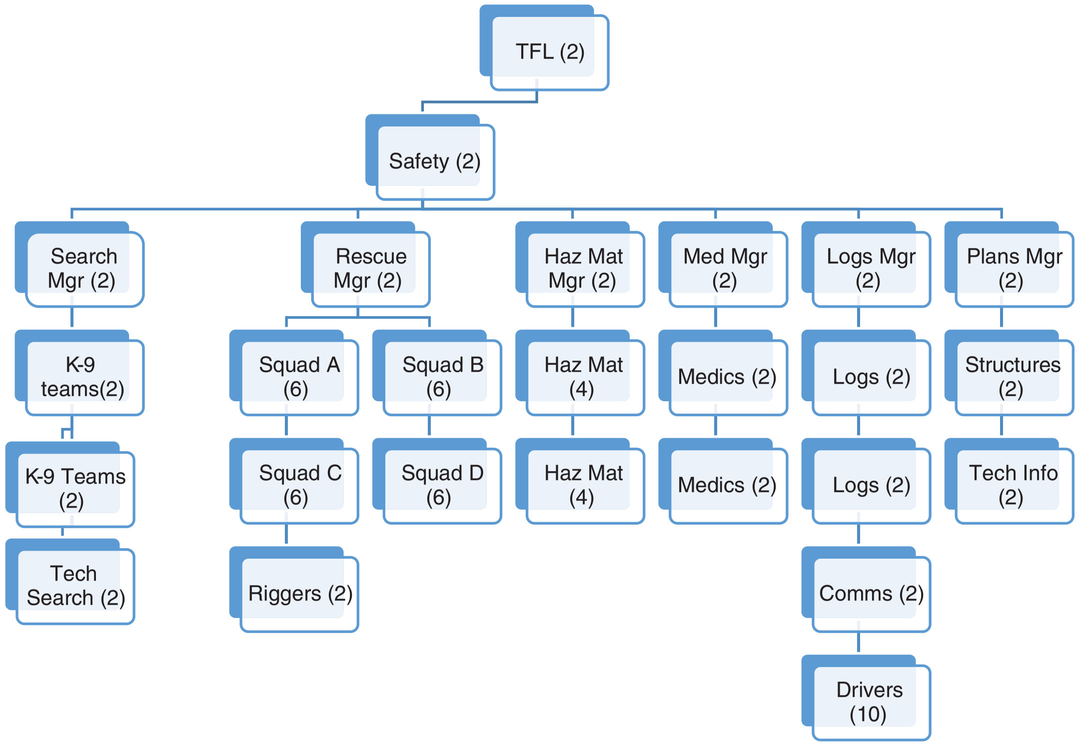

Fig. 2 Typical organizational chart for a FEMS US&R Type 1 team (80 person). TFL Task Force Leader, Med Mgr Medical Manager (Physician)

confined space and management of clinical conditions typically seen as a result of building or structural collapse. While numerous "rescue" incidents can occur on a routine basis in the prehospital environment and readily handled by conventional emergency medical services (EMS) assets, these incidents typically are a result of mechanisms such as a fall, motor vehicle crash or rollover, or entrapment from industrial machinery. Medical care delivered within the USAR environment typically refers to patient care on injuries as a result of "heavy" building collapse which lead to significant entrapment from rubble piles and building materials, prolonged entrapment for up to days and the anticipation that extrication to definitive care will be technically complex and take lengthy periods of time [2, 3]. The technical rescue and extrication process itself can accelerate the pathophysiologic insults to the victim and may cause rapid deterioration and death in an otherwise stable appearing patient who has survived for days of entrapment [2]. Most victims that survive to the point of rescue will likely not have suffered traumatically catastrophic injuries that would likely have required surgical intervention within the "golden hour." Instead, these victims will have clinically significant injures that are survivable if managed but easily aggravated due to the prolonged time they have gone without care, effects of the environment as well as the technical rescue and release from entrapment. In the end, the mechanism of injury due to heavy structural collapse and extended time needed to locate victims and perform extrication all prolong the scene time of these victims resulting in a predictable prolonged field care scenario that requires calculated critical care medicine to stabilize physiologically complex victims as the rescue process is on-going (Fig. 3).

While the victim entrapped from a heavy structural collapse has been the basis for developing the medical capabilities of a USAR task force, recent years have shown an increased change in the typical mission profile for teams. Increased response to hurricanes and floods as well as executing wide-area searches have become commonplace for USAR team deployments. While many of these incidents do not involve significant collapse, medical teams are finding themselves involved with providing urgent care medicine to deployed team members as well as emergency medical care to victims that cannot get to definitive care. In these settings, the medical care has become more typical of that seen in an emergency department, however with less resources. These mission profiles have resulted in teams looking

Fig. 3 An example of the typical USAR patient care environment. Two USAR Medical Specialists are working to secure the airway of a victim still entrapped within the confined space of a rubble pile during a training exercise

for resources and capabilities normally found in an emergency department including bedside ultrasound.

Ultrasound in the USAR Environment

In the past, application of point-of-care ultrasound (POCUS) in the USAR environment has been limited by the technology. Delivery of medical care in the USAR environment typically occurs in confined space settings, greatly limiting the ability to bring everything to the patient. As technology has improved recently, the availability of handheld sized POCUS devices that can offer high resolution images comparable to full size machines found in most hospital have made POCUS in the confined space/USAR environment a reality. Recently, the improvement of ultrasound technology with respect to size, portability and durability, the use of ultrasound in the austere setting for specific indications has steadily increased and described in thee literature [4–6]. Despite the rapid advancement of POCUS technology, the current scope of practice for FEMA USAR medical teams do not include ultrasound training nor is the technology required on the FEMA equipment cache list. At the time of this chapter's publication, most teams that have integrated POCUS into their capabilities have done so on their own and with physicians who have the training and competence of using POCUS as part of their daily clinical practice.

Due to reasons described in previous sections of this chapter, the typical USAR confined space patient will inherently have delays which prolong scene time as well as time to definitive care. POCUS for emergency medical providers have been helpful in making rapid decisions based on specific findings on specific types of exams. However, given the USAR working environment constraints, the value of POCUS may not be in a rapid transition to definitive care after recognition of occult hemorrhage. Rather, the value of POCUS in the USAR prolonged field care environment is the ability to perform higher sensitivity serial exams to look for clinical change over time. Studies have looked at the value of integrating ultrasound into mass casualty triage processes in order to help identify those patients who may benefit from higher triage category after identification of hemoperitoneum during prehospital FAST examinations. Most have shown limited change in clinical management based on positive FAST exams [7–11]. Walcher et al. noted a change in clinical management for 30% of patients based on a positive prehospital FAST exam with high sensitivity and specificity for hemoperitoneum [7]. Chart analysis from another study described how approximately 10% of patients triaged as "yellow" using the START algorithm had positive FAST findings with very few having any change to their clinical course of action with at a level I trauma center [10].

For the USAR medical team, positive trauma ultrasound findings provide additional data to help guide management of the confined space victim. Negative findings can help rule out presumptive diagnoses on the differential and allow the medical team to avoid unnecessary interventions while addressing other clinical possibilities not yet ruled out. Positive ultrasound findings may help the USAR medical team better triage patient treatment priorities if multiple victims are encountered. With environmental limitations in the confined space setting such as low lighting, high noise due to active heavy rescue operations and limited access to patient anatomy, the use of ultrasound offers additional clinical data that can be obtained without the use of traditional diagnostic tools such as stethoscopes. It also offers clinical information comparable to other traditional diagnostic tools such as chest radiography in a smaller, compact unit that can be brought to the entrapped patient's bedside.

Clinical Indications: Undifferentiated Shock

It can be expected that after a major building collapse, the usual patient that USAR medical teams will encounter may have suffered significant traumatic forces. While the usual mechanism of injury will consist of crushing or blunt force trauma, other injuries as a direct result from blast overpressure if any explosions were involved as well as penetrating trauma as a result of blast injuries can be expected. The challenge with these patients is that the situational predicament tends to result in entrapment and prolonged extrication. It also results in limited access and assessment of victims. Due to expected delays in reaching still live victims as well as expected prolonged extrication times, many of these patients will be volume deplete even before any hemorrhage has occurred. If exsanguinating hemorrhage has occurred, it is unlikely these victims will survive. Rather, many victims encountered by USAR medical teams have not suffered life-threatening hemorrhage. Instead, the hemorrhage process has been tamponaded by some compressive force or the blood loss in insidious. Being able to apply eFAST protocols will help the medical team differentiate the type of volume loss a victim is experiencing. Use of ultrasound in abdominal trauma can help guide management and improve outcomes [7, 8]. The information of knowing whether a victim's shock is due to intra-abdominal blood loss versus overall low volume due to a decompressed inferior vena cava (IVC) during patient care in a confined space would be added value to the decision-making process on patient acuity, immediate volume needs and whether other anatomical locations of blood loss need to be considered.

Clinical Indications: Renal Perfusion and Crush Syndrome

The clinical condition of most concern to USAR medical teams as a result of massive compressive forces to large amounts is the crush syndrome. Described in detail at the outset of the London Bombings in 1941, it was becoming apparent to rescuers and medical providers that casualties buried under rubble for days would suddenly be freed only to succumb to death from their injuries immediately upon release or later on in the hospital as a result of acute renal failure (ARF). This "crush syndrome" is the direct result muscle tissue compression and necrosis. Compressive times required to develop crush syndrome are typically hours with as little as 2 hours of compression. Crush syndrome results in a characteristic syndrome of rhabdomyolysis, inducing myoglobinuric ARF, also known as traumatic rhabdomyolysis [12]. Crush kills in a few ways. Immediately upon release from compressive forces, there is massive shifting of remaining blood volume into previously tamponaded third spaces. If the victim is not adequately volume resuscitated prior to entrapment release, their blood pressure will be sure to bottom out the moment these forces are released. Crush syndrome also kills during the release of entrapment when otherwise damaged muscle cells are re-perfused, resulting in return circulation of cardiotoxic potassium and calcium shifts. The destruction of muscle tissue and the influx of myoglobin, potassium, and phosphorus into the circulation results in the classic picture of traumatic rhabdomyolysis/crush syndrome. The syndrome is characterized by hypovolemic shock and hyperkalemia [12]. Finally, crush syndrome can ultimately kill a victim later in their clinical course in a predictable manner if myoglobin is not adequately cleared from the plasma and ARF ensues.

The mainstay of treatment for crush syndrome patients has focused on early intravenous fluid resuscitation prior to entrapment release to minimize the effects of hypovolemic shock due to excessive volume shifts, administration of intravenous alkalinizing agents such as sodium bicarbonate to improve the excretion of myoglobin from the body and management of life-threatening arrhythmias due to the effects of potassium, calcium and phosphorus [12]. Use of ultrasound imaging for the evaluation of renal injury as well as its perfusion has been described in the literature [13, 14]. The utility of these applications while more beneficial in the hospital setting, may have limited use in the confined space austere environment. It is unclear whether surrogate ultrasound measures of renal perfusion have any value added to the management of these patients in the acute phase of care. Clinical markers currently used, such as level of mentation, hemodynamic markers, urine output continue to offer valuable clinical data in the absence of reliable renal ultrasound techniques in the austere environment. Additionally, use of ultrasound in major earthquake events described in the literature focused more on the utility of FAST examinations as part of a larger triage methodology to identify patients a t higher risk for surgical intervention rather than in applications related specifically to crush syndrome pathology or renal function [14–16].

Clinical Indications: Undifferentiated Dyspnea

The differential diagnosis for dyspnea in patients within the confined space environment is broad and can range from minor to life threatening. By far, one of the most common causes of dyspnea in the confined space patient is dust impaction. Confined space case reviews have described the dyspnea described by patients due to the suspension of dust particles and debris within the atmosphere of the environment [3]. This is due to the particles released during both the initial collapse and destruction of building materials as well as during the rescue phase in which rescuers utilize machinery to gain patient access through the same pile of debris. These particles pose a health and occupational hazard to both victim and rescuer. They also serve as triggers for any underlying pulmonary disease such as asthma or other reactive airway diseases. The usual treatment is supportive, with mechanical cleansing of the oral and nasal passages of dust, respiratory protective equipment and supplemental oxygen. Where ultrasound comes into use is the ability to differentiate other life-threatening diseases entities as a result of collapse such as development of blast lung due to blast over-pressure exposure or primary pulmonary trauma such as tension pneumothorax or hemothorax. Use of ultrasound during eFAST for identification of tension pneumothorax as evidenced by absence of lung sliding "comet" tail artifacts is easily recognized by the POCUS operation and can also be used as a serial exam during re-assessment of decompensating patients. Looking for other ultrasound findings to identify pulmonary edema in the dyspneic patient may be helpful as the delayed onset of primary blast lung injuries in exposed patients begin to develop. Ultrasound has been shown to offer utility in differentiating specific findings in the pulmonary windows to help differentiate these clinical entities and may have benefit as an adjunct to more traditional physical examination methods of assessing the lung given auscultation may not always be accurate or possible in the confined space environment [17–19].

Conclusions

Prehospital application of POCUS in the USAR environment is promising. While not currently a standard part of medical team training or capabilities, the major advances of POCUS technology have allowed USAR physicians to consider the use of this technology given its ability to identify specific conditions as it relates to trauma. With the sensory and physical constraints of a confined space environment, use of ultrasound gives the USAR medical team a rapid and reliable answer to ruling out life-threatening conditions such as abdominal trauma, pulmonary edema due to blast injury, tension pneumothorax as well as general volume status. While the ultimate determining factor of scene time for confined space patients is based on length of extrication time, useful information in eFAST and other POCUS protocols can give the medical team managers more information that can assist the rescue team managers and task force leaders with accurate and timely information on patient clinical conditions which could then determine further technical rescue decisions. Ultrasound thus becomes an extension of the medical team's diagnostic capabilities in patient assessment and determination of clinical status rather than a simple point-of-care test used to make "yes/no" decisions about disposition. Ultrasound is integrated as part of the patient re-assessments during prolong field care and used similar to other diagnostic tools to help identify and monitor life-threatening conditions, as well as guide therapy and interventions in the absence of more sensitive diagnostic tools found in the hospital setting. Additionally, as USAR teams find themselves engaged in other types of search and rescue missions unrelated to building collapse, most medical teams can integrate POCUS into their sick call/urgent care operations similar to how POCUS is currently used in many emergency departments. This has included missions such as wide area searches, hurricane response, swift water and surface water rescues. In missions where local medical resources become limited, the USAR medical teams will provide day-to-day urgent care services to team members and first responders. US applications commonly used in the emergency department such as procedural applications, soft tissue and musculoskeletal applications including fracture or foreign body identification can be utilized in the field. As the ultrasound technology makes bringing it into the field more feasible, so will the increase of its use in the USAR environment.

References

1. Bea K. Urban search and rescue task forces: facts and issues. CRS Report for Congress. Updated 24 Apr 2006.
2. Barbera JA, Macintyre A. Urban search and rescue. Emerg Med Clin North Am. 1996;14:399–412.
3. Petinaux B, Macintyre A, Barbera J. Confined space medicine and the medical management of complex rescues: a case series. Disaster Med Public Health 190-197. Preparedness. 2014;8:20–9.
4. Nelson B, Melnick E, Li J. Portable ultrasound for remote environments, part 1: feasibility of field deployment. J Emerg Med. 2011;40:190–7. https://doi.org/10.1016/j.jemermed.2009.09.006.
5. Nelson B, Melnick E, Li J. Portable ultrasound for remote environments, part 2: clinical indications. J Emerg Med. 2011;40:313–21. https://doi.org/10.1016/j.jemermed.2009.11.028.
6. Zahran T, El-Sayed M. Prehospital ultrasound in trauma: a review of current and potential future clinical applications. J Emerg Trauma Shock. 2018;11:4–9. https://doi.org/10.4103/JETS.JETS_117_17:10.4103/JETS.JETS_117_17.
7. Walcher F, Weinlich M, Conrad G, et al. Prehospital ultrasound imaging improves management of abdominal trauma. Br J Surg. 2006;93:238–42.
8. Jørgensen H, Jensen C, Dirks J. Does prehospital ultrasound improve treatment of the trauma patient? A systematic review. Eur J Emerg Med. 2010;17:249–53.
9. Stawicki S, Howard J, Pryor J, et al. Portable ultrasonography in mass casualty incidents: the CAVEAT examination. World J Orthop. 2010;1:10–9.
10. Sztajnkrycer M, Baez A, Luke A. FAST ultrasound as an adjunct to triage using the START mass casualty triage system: a preliminary descriptive study. Prehosp Emerg Care. 2006;10:96–102.
11. Ma O, Norvell J, Subramanian S. Ultrasound applications in mass casualties and extreme environments. Crit Care Med. 2007;35:S275–9.
12. Gonzalez D. Crush syndrome. Crit Care Med. 2005;33:s34–41.
13. Keven K, Ates K, Yagmurlu B, et al. Renal doppler ultrasonographic findings in earthquake victims with crush injury. J Ultrasound Med. 2001;20:675–9.
14. Sarkisian A, Khondrkarian R, Amirbekian N, et al. Sonographic screening of mass casualties for abdominal trauma and renal injuries following the 1988 Armenian earthquake. J Trauma. 1991;31:247–50.
15. Dan D, Mingson L, Jie T, et al. Ultrasonographic applications after mass casualty incident caused by Wenchuan earthquake. J Trauma. 2010;68:1417–20.
16. Mulvey JM, Awan SU, Qadri AA, Maqsood MA. Profile of injuries arising from the 2005 Kashmir earthquake: the first 72 hours. Injury, Int J Care Injured. 2008;39:554–60.
17. Noble VE, Lamhaut L, Capp R, et al. Evaluation of a thoracic ultrasound training module for the detection of pneumothorax and pulmonary edema by prehospital physician care providers. BMC Med Ed. 2009;9:3.
18. Zechner P, Aichinger G, Rigaud M, et al. Prehospital lung ultrasound in the distinction between pulmonary edema and exacerbation of chronic obstructive pulmonary disease. Am J Emerg Med. 2010;389:e1–2.
19. Brun P, Bessereau J, Levy D, et al. Prehospital ultrasound thoracic examination to improve decision making, triage, and care in blunt trauma. Am J Emerg Med. 2014;32:817e1–2.