

Taylor & Francis
Taylor & Francis Group

Prehospital Emergency Care

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ipec20

Prehospital Trauma Compendium: Management of the Entrapped Patient – a Position Statement and Resource Document of NAEMSP

Nichole Bosson, Benjamin N. Abo, Troy D. Litchfield, Zaffer Qasim, Matthew F. Steenberg, Jake Toy, Antonia Osuna-Garcia & John Lyng

To cite this article: Nichole Bosson, Benjamin N. Abo, Troy D. Litchfield, Zaffer Qasim, Matthew F. Steenberg, Jake Toy, Antonia Osuna-Garcia & John Lyng (24 Oct 2024): Prehospital Trauma Compendium: Management of the Entrapped Patient – a Position Statement and Resource Document of NAEMSP, Prehospital Emergency Care, DOI: 10.1080/10903127.2024.2413876

To link to this article: https://doi.org/10.1080/10903127.2024.2413876

View supplementary material

Published online: 24 Oct 2024.

Submit your article to this journal

Article views: 472

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=ipec20

PREHOSPITAL EMERGENCY CARE
https://doi.org/10.1080/10903127.2024.2413876

Taylor & Francis
Taylor & Francis Group

Check for updates

Prehospital Trauma Compendium: Management of the Entrapped Patient – a Position Statement and Resource Document of NAEMSP

Nichole Bosson[a,b,c], Benjamin N. Abo[d], Troy D. Litchfield[e], Zaffer Qasim[f], Matthew F. Steenberg[g], Jake Toy[a,b,c], Antonia Osuna-Garcia[c], and John Lyng[h]

[a]Los Angeles County EMS Agency, Santa Fe Springs, California; [b]Harbor-UCLA Medical Center Department of Emergency Medicine and the Lundquist Institute for Research, Torrance, California; [c]David Geffen School of Medicine at UCLA, Los Angeles, California; [d]Florida State University College of Medicine, Tallahassee, Florida; [e]Los Angeles County Fire Department, Los Angeles, California; [f]Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania; [g]Rutgers Health NBIMC, Newark, New Jersey; [h]North Memorial Health, Robbinsdale, Minnesota

ABSTRACT

Entrapped patients may be simply entombed or experiencing crush injury or entanglement. Patients with trauma who are entrapped are at higher risk of significant injury than patients not entrapped. Limited access and prolonged scene times further complicate patient management. Although patient entrapment is a significant focus of specialty teams, such as urban search & rescue (US&R) teams that operate as local, regional, and/or national resources in response to complex scenes and disaster scenarios, entrapment is a regular occurrence in routine EMS response. Therefore, all EMS clinicians must have the training and skills to manage entrapped patients and to support medically-directed rescue throughout the extrication process.

NAEMSP RECOMMENDS

- EMS clinicians must perform a timely and thorough primary and secondary assessment and reassessments in parallel with dynamic extrication planning; the environment may require adaption of standard assessment techniques and devices.
- EMS clinicians should establish early, clear, and ongoing communications with rescue personnel to ensure a coordinated patient-centered medically directed approach to extrication. Communication with the patient should be frequent, clear, and reassuring.
- EMS clinicians should immediately take measures to effectively prevent and manage hypothermia.
- EMS clinicians should recognize airway management in the entrapped patient is always challenging. When required, advanced airway placement should be performed by the most experienced operator with proficiency in multiple modalities and alternative techniques in limited access situations.
- In entrapped patients who are experiencing or are at risk for crush syndrome, EMS clinicians should initiate large-volume (i.e., 1–1.5 L/h for adults and 20 mL/kg/h for pediatric patients for the initial 3–4 h) fluid resuscitation with crystalloid, preferably normal saline, as early as possible and prior to extrication.
- In entrapped patients who are experiencing or are at risk for crush syndrome, EMS clinicians should administer medications to mitigate risks of hyperkalemia, infection, and renal failure, early and prior to extrication.
- Tourniquet application should be considered in the setting of the crushed extremity as a potential adjunct to medical optimization before extrication of some patients.
- Patients with prolonged entrapment with the potential for severe injuries require complex resuscitation and may benefit from EMS physician management on scene. EMS systems should consider an early EMS physician response to entrapped patients.

ARTICLE HISTORY
Received 25 September 2024
Accepted 30 September 2024

Introduction

Entrapment is a frequent occurrence encountered by Emergency Medical Services (EMS), commonly due to motor vehicle, industrial, or agricultural accidents (1–3). Entrapped patients may be entombed or experiencing crush injury or entanglement. Patients with trauma who are entrapped are at higher risk of significant injury and have greater mortality than patients not entrapped (3–5). Certain patient and environmental factors can lead to greater risk (5–7). Entrapment has also been associated with complications including the development of acute traumatic coagulopathy, infections, amputations, thromboembolism, and high rates of acute renal injury (8–16).

Up to 20% of deaths after entrapment occur shortly after extrication with rapid deterioration, often termed 'death by rescue' (17). Early field management can prevent a large

CONTACT Nichole Bosson nbosson@dhs.lacounty.gov
Supplemental data for this article can be accessed online at https://doi.org/10.1080/10903127.2024.2413876.
© 2024 National Association of EMS Physicians

proportion of these deaths, mitigate complications, and improve outcomes, particularly for patients with crush syndrome (17–19). Management is complicated by limited access and prolonged scene times, with median extrication times reported to be 30 min, leading to delays to definitive care (1). Confined space hazards, such as toxic and oxygen-deprived environments, may impose additional risks (20).

Large-scale incidents such as earthquakes can result in many entrapped victims leading to delays in care (7, 9, 10, 21). Paradoxically for patients rescued, prolonged entrapment time may not be associated with worse survival, presumably because victims with mild injuries can survive longer without immediate rescue (22). Therefore, rescue efforts for entrapped victims may continue for prolonged periods. While specialty teams, such as urban search & rescue (US&R) teams operating as local, regional, and/or national resources in response to complex scenes and disaster scenarios are particularly equipped to manage entrapped victims, EMS clinicians will be among the first to arrive at the scene.

All EMS clinicians must have the training and skills to assess and treat entrapped patients and must be knowledgeable about medically-directed rescue concepts and practices. We performed a systematic review of the literature to address a series of Patient, Intervention, Control, Outcome (PICO)-structured questions related to EMS care of entrapped patients. Based on a review of the current evidence, we present the National Association of EMS Physicians (NAEMSP) recommendations for optimal entrapped patient management.

Methods

PICO Questions

We identified five PICO questions a priori (Supplemental File Table 1). The questions were developed through initial literature review, collective experience of the investigators, and discussion to achieve consensus on the priorities for evidence-based guidance in managing entrapped patients. These included: (1) What initial assessment should be performed on the entrapped patient?, (2) What is the optimal fluid management for the entrapped patient?, (3) What is the optimal type, timing, and frequency of medications to administer for crush syndrome?, (4) Should tourniquets be applied to crushed limbs?, and (5) Does physician care at the scene improve outcomes for entrapped patients?.

Investigators identified three additional themes on review of the literature, which led to the development of three more PICO questions: (1) What additional interventions are essential for the entrapped patient with prolonged field time (e.g., temperature management)?, (2) How does the medical care integrate with rescue for the extrication of the entrapped victim?, (3) What is the best approach to airway management for the entrapped patient?.

Search Strategy

We performed a structured literature search using guidance developed for the NAEMSP Trauma Compendium. The search strategy was amended to identify literature relevant to EMS, trauma, and entrapped patients (23). We searched PubMed on October 27, 2022, with the assistance of a research librarian (AOG) for all available articles published through that date (Table 1). We searched Google for grey literature using a similar strategy of 'EMS' and 'entrapment' or 'entrapped' or 'crush'. Literature in languages other than English, French, or Spanish were excluded.

Screening of Publications

Articles were uploaded into EndNote, which was used to eliminate duplicates. One investigator (NB) performed an initial review of the title and abstract to exclude those unrelated to the topic, after which full articles were obtained. A single investigator (NB) reviewed the full-text manuscripts for inclusion/exclusion based on applicability to the PICO questions. Articles that addressed one or more of the PICO questions were retained. Publications that were unclear were brought to the group for discussion and consensus, with a general approach to retaining literature that applied directly or indirectly (e.g., evaluation of an intervention applicable to the entrapped patient in another austere environment with delays to definitive care such as military evacuation). The same investigator grouped the retained articles into content areas, according to the eight PICO questions, with articles addressing multiple PICOs included in all relevant content areas.

Evidence Evaluation

The investigators divided the PICO questions to review the relevant literature. One investigator was identified as the lead for each content area. The lead investigator reviewed the full-text articles and identified any relevant references that were missed on the initial search. Those references were referred to NB to screen and to include in the relevant content areas. Each investigator lead prepared a narrative summary of the applicable literature in their content area(s) and presented the summary to the group. The group met five times from January to March 2023 to discuss the summaries of evidence until consensus was reached on the recommendation for each content area based on the available evidence. Once investigators completed recommendations for all content areas, the entire group reviewed the set of recommendations as a whole to ensure universal agreement and consistency.

Results

The search results are provided in Figure 1. The initial search of PubMed yielded 753 articles and 3 additional documents were added from the grey literature resulting in 756 records for screening, of which 581 were excluded on title and abstract review. Of the 175 remaining records, one report was not retrieved. Ninety-one were excluded. Review of the references from the retained records added 18 new articles that were not identified in the literature search. In total, 101 articles were included in the final review and were sorted by topic, with many records addressing more than one PICO.

Table 1. Search strategy.

"EMS" Search Terms

	Search Terms	Search String
MESH Terms	Emergency Medical Dispatch	"Emergency Medical Dispatch"[Mesh] OR
	Emergency Medical Services Communication Systems	"Emergency Medical Service Communication Systems"[Mesh] OR
	Emergency Medical Technicians	"Emergency Medical Technicians"[Mesh] OR
	Transportation of Patients	"Transportation of Patients"[Mesh] OR
Text Search	air medical	"air medical"[Title/Abstract] OR
	air medicine	"air medicine"[Title/Abstract] OR
	aeromedical	"aeromedical"[Title/Abstract] OR
	aero-medical	"aero-medical"[Title/Abstract] OR
	aeromedicine	"aeromedicine"[Title/Abstract] OR
	aero-medicine	"aero-medicine"[Title/Abstract] OR
	ambulance*	"ambulance*"[Title/Abstract] OR
	emergency medical service*	"emergency medical service*"[Title/Abstract] OR
	emergency medical technician*	"emergency medical technician*"[Title/Abstract] OR
	emergency services	"emergency services"[Title/Abstract] OR
	ems	"ems"[Title/Abstract] OR
	emt	"emt"[Title/Abstract] OR
	field triage	"field triage"[Title/Abstract] OR
	first responder*	"first responder*"[Title/Abstract] OR
	paramedic*	"paramedic*"[Title/Abstract] OR
	prehospital	"prehospital"[Title/Abstract] OR
	pre-hospital	"pre-hospital"[Title/Abstract]

"Entrapped Patient" Search Terms

	Search Terms	Search String
MESH Terms	Crush Injuries	"Crush Injuries"[MeSH Terms] OR
	Crush Syndrome	"Crush Syndrome"[MeSH Terms] OR
Text Search	collapsed structure	"collapsed structure"[Title/Abstract] OR
	confined space	"confined space"[Title/Abstract] OR
	crush*	"crush*"[Title/Abstract] OR
	entrapped	"entrapped"[Title/Abstract] OR
	extricat*	"extricat*"[Title/Abstract] OR
	limited access	"limited access"[Title/Abstract] OR
	entanglement*	"entanglement*"[Title/Abstract] OR
	amputation*	"amputation*"[Title/Abstract]

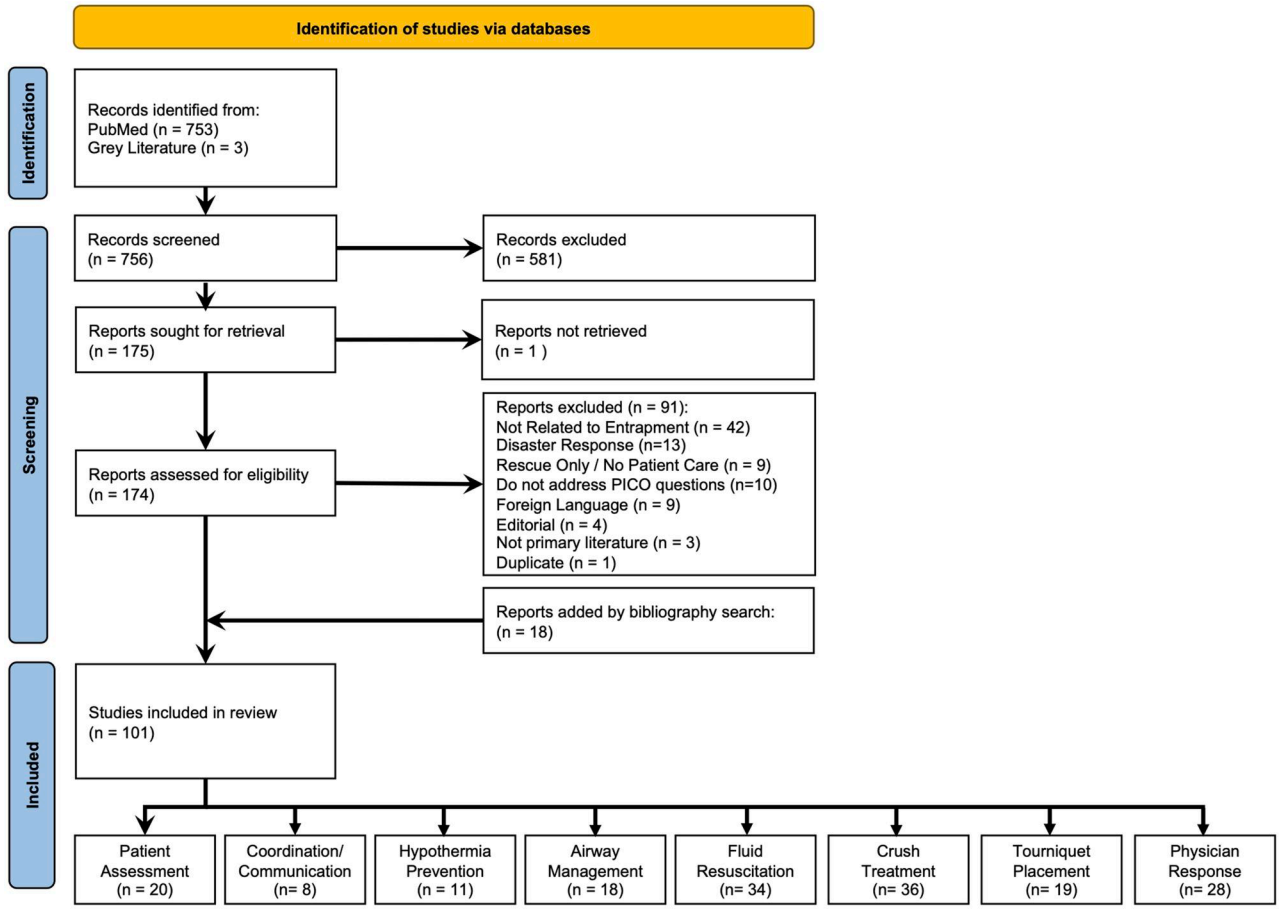


Figure 1. Literature search flow diagram. Studies may contribute to multiple categories.

We developed eight recommendations based on the eight PICO questions. These recommendations addressed patient assessment, team communications, prevention of hypothermia, approach to airway management, fluid administration, treatment of crush injury and crush syndrome, tourniquet application, and the role of physician management on scene.

Discussion

Patient Assessment

EMS Clinicians Must Perform a Timely and Thorough Primary and Secondary Assessment and Reassessments in Parallel with Dynamic Extrication Planning; the Environment May Require Adaption of Standard Assessment Techniques and Devices

Twenty articles discussed assessment of the entrapped victim (Supplemental File Table 2). Entrapped patients have potential for lethal complications, including dysrhythmias due to crush syndrome and shock from hemorrhage and/or fluid losses (24, 25). Multiple authors emphasize the importance of early and ongoing assessments to drive priorities in management and optimize rescue planning (17, 24, 26–30). Guidelines from the International Search and Rescue Advisory Group (INSARAG) and the European Renal Association and the European Dialysis and Transplant Associations emphasize immediate assessment of the victim once contact is established (19, 31). An initial verbal assessment can provide important information such as mental status, complaints, comorbidities, and events leading up to the injury (17). Kotora and colleagues describe use of a camera to allow for early assessment of an entrapped patient in a confined space who could not be accessed, to guide management and rescue efforts (32). Delaying assessment and interventions can increase mortality (33). Furthermore, rapid assessment is important in the triage of multiple victim incidents (34).

Specific assessments recommended include vital signs and electrocardiographic monitoring for dysrhythmias (24, 35, 36), and pulse oximetry (17, 28, 36, 37). However, resources may be constrained due to the environment and/or circumstances (17, 24, 38), and evaluation of the entrapped patient is often challenging with limited space and access (17, 36). The noisy environment, due to extrication efforts, may make assessments such as auscultation difficult if not impossible (28). Some authors describe initiating assessment with limited equipment, relying on mental status, work of breathing, pulse rate, and quality (24). EMS clinicians may need to adapt the equipment to the environment. This can include use of long cables in order to keep the cardiac monitor away from the physically restrained area around the patient (36) or relying on the pulse oximetry as a sign of perfusion and to assess complications from large-volume fluid resuscitation (24). Ultimately, EMS clinicians need to balance the benefits of assessment tools with the complications of managing the patient in a limited space environment.

For prolonged entrapment, ongoing monitoring of fluid status through urine output is recommended (17, 24, 35). Specialty teams may also use point-of-care testing to assess values such as electrolytes and lactate, which can be indicators of developing crush syndrome and direct important management (24, 39). While not currently in common practice, some have explored the role of ultrasound to assess for crush injury in animal models (40). Once priorities of resuscitation are complete, secondary assessment and wound management should be performed to prevent complications including infection (41). Although not discussed in the reviewed literature, given the risk of hypothermia discussed in a later section, we also recommend monitoring the patient's temperature through quantitative or qualitative means. It is important to cover the patient immediately after exposure required to complete assessment (17).

Coordination and Communication

EMS Clinicians Should Establish Early, Clear, and Ongoing Communications With Rescue Personnel to Ensure a Coordinated Patient-Centered Medically Directed Approach to Extrication. Communication with the Patient Should Be Frequent, Clear, and Reassuring

Eight studies addressed the importance of reliable and ongoing communications for the successful rescue of entrapped patients (Supplemental File Table 3). Common themes included an emphasis on the need for coordination between medical and rescue personnel to establish priorities. This coordination requires ongoing communication and a mutual understanding of roles and responsibilities (1, 27–29, 42). Using the Delphi method, a group of experts on extrication of entrapped victims in the United Kingdom (UK), identified 91 consensus statements regarding best practices for extrication and a main theme was patient-focused extrication. Statements in this category addressed various aspects of good patient communication including designating a team member for communication and companionship, referring to the patient by name, and providing ongoing explanations of the process using clear language (30). Establishing good communication with the patient was further emphasized in a qualitative study by Nutbeam et al., in which the authors conducted semi-structured interviews with entrapped victims at least 6 wk after the incident (43). Communication was identified as the main theme, with successful communication reinforcing the patients' sense of well-being, and communications failures leading to distress (43). In addition to physical needs, the patient's psychological needs are an important aspect of the care that should not be overlooked (43, 44). Further, several authors emphasized the importance of communications with the hospital to ensure efficient transfer to definitive care (28, 42). Collectively, these studies demonstrate the importance of clear and continuous communication at all levels both to optimize the efficiency of the extrication and to ensure optimal medical and psychological care of the patient integrated with the rescue efforts.

Hypothermia Prevention

EMS Clinicians Should Immediately Take Measures to Effectively Prevent and Manage Hypothermia

Eleven studies addressed the prevention and/or treatment of hypothermia in entrapped patients (Supplemental File Table 4). Hypothermia increases mortality in patients with

trauma (45–49). This risk may be compounded in entrapped patients. The need for extrication has been associated with increased risk for hypothermia (50), and both entrapment and hypothermia increase risk of coagulopathy, which has been further associated with high mortality (8). Patients with severe hypothermia are at risk for fatal dysrhythmias, which can be triggered by the extrication process (32, 51). Hypothermia can occur in entrapped victims despite relatively high environmental temperatures given their prolonged exposure time (17). Wet environments, wind, and loss of protective skin layer due to injuries such as burns increase risk (32, 50, 52). Once present, hypothermia can be difficult to correct, so it is important to initiate steps to prevent hypothermia immediately (49, 53). Further, patients may be unaware of the cold due to the stress of the event, so EMS clinicians must be proactive in their management (43). Authors suggest taking simple steps such as covering patients immediately after any assessments requiring exposure and having 'hypothermia prevention kits' that can be rapidly deployed to keep the patient warm (27, 28). A case report by Kotora et al., describes use of forced hot air to warm a patient trapped deep in a pipe while extrication efforts were underway and subsequent efforts to keep the patient warm after extrication including staging the decontamination area inside a building, and use of warm blankets, warm fluids, and warm humidified oxygen (32). Henriksson and colleagues evaluated the thermal insulating properties of different blankets and commercial recue bags in simulated environments under different wind conditions (52). The authors found that in low wind conditions, thermal insulation effectiveness correlated with the thickness of the ensembles. However, in moderate or high wind conditions, an outer windproof layer was necessary to preserve the thermal insulation. Use of layered blankets, with an outer metallic foil or plastic covering in higher wind conditions, is practical for EMS clinicians and could meet the need.

Airway Management

EMS Clinicians Should Recognize Airway Management in the Entrapped Patient is Always Challenging. When Required, Advanced Airway Placement Should Be Performed by the Most Experienced Operator with Proficiency in Multiple Modalities and Alternative Techniques in Limited Access Situations

Eighteen articles contributed to the literature on airway management in entrapped patients (Supplemental File Table 5). Entrapped patients are at high risk for respiratory compromise, particularly those entrapped in collapsed structures or industrial and agricultural accidents due to particulate matter in the air leading to dust impaction and pulmonary irritation (17, 33, 36). Additional risks include low-oxygen environments, noxious gases and other potential hazardous materials (17, 36). A mixed-methods study conducted by Pretto and colleagues after a major earthquake identified airway compromise due to inhalation injury and/or obstruction as a main cause of preventable death (33). This was consistent with other reports (29) and a reason authors recommend applying a dust mask early, or at least when particulate matter is high (17). Authors emphasize the challenges of airway management due to environmental factors, including confined space, limited positioning, and low lighting (17, 36). Steps taken to provide spinal motion restriction further complicate airway management (29).

Given the difficulty, some authors feel direct laryngoscopy (DL) is 'impractical' and suggest alternative solutions such as lighted stylets and digital intubation (36). Case reports and cohort studies demonstrate that traditional approaches to airway management are not always feasible, and EMS clinicians must be able to use alternative techniques (4, 37, 54–56). Use of supraglottic airways (SGAs) is increasingly common in EMS. Several case series have demonstrated successful use of SGAs in entrapped patients with some patients subsequently intubated after extrication (54–56). Simulation studies generally found SGAs easier and faster to place in entrapped victims compared with DL or video laryngoscopy (VL) (57–61). While a recent Cochrane Review found VL to be superior to DL in the in-hospital environment (62), data are more limited in the prehospital environment (63). Some manikin studies have found that VL performs better than DL in entrapment scenarios (59, 64), however, this is not consistent across studies and depends upon clinician experience and orientation of access to the patient (65, 66). In one study comparing cricothyroidotomy tools in a confined space simulation, device simplicity was preferred (67).

Ultimately EMS clinicians need to consider the risks of the chosen airway management strategy, including failure to secure the airway after medication administration, or an unrecognized dislodgment of an endotracheal tube during patient movement, along with the potential benefits. Being facile with multiple techniques allows for better optimization of the strategy for the individual circumstances.

Fluid Resuscitation

In Entrapped Patients Who Are Experiencing or Are at Risk for Crush Syndrome, EMS Clinicians Should Initiate Large-Volume (i.e., 1–1.5 L/h for Adults and 20 mL/kg/h for Pediatric Patients for the Initial 3–4 h) Fluid Resuscitation with Crystalloid, Preferably Normal Saline, as Early as Possible and Prior to Extrication

Thirty-three papers were identified that discussed prehospital fluid management in the entrapped patient (Supplemental File Table 6). Published studies consistently stress the importance of early, aggressive fluid management in patients at risk of crush syndrome as well as those with signs of poor perfusion, which should be initiated as soon as is feasible and ideally prior to extrication (4, 17, 19, 28, 35, 36, 41, 68–75). The entrapped patient may suffer both crush injury as well as develop crush syndrome. The latter manifests systemically through traumatic rhabdomyolysis with subsequent release of toxic metabolites into the bloodstream causing metabolic derangement, which, along with sequestration of fluid, external volume losses, and vasodilation, leads to shock (24, 68, 70–72). Almost 50% of those with

crush syndrome will develop acute renal failure as a result of both the massive third-space losses, which may reach 10–18 L/day, as well as direct injury from rhabdomyolysis (68, 72, 74, 75). Further, the sudden release of a crushed body part can result in a potentially lethal reperfusion syndrome (71, 76, 77).

Fluid administration must be sufficient to address these loses and prevent complications. Both the INSARAG Medical Guidelines and the Joint Trauma Clinical Practice Guidelines emphasize that initiating fluid resuscitation prior to extrication is one of the most important actions in entrapped patients with crush (31, 35). Although the preference is to establish intravenous (IV) access, alternate routes can be considered when IV access is not possible, including intraosseous (IO), hypodermoclysis (subcutaneous), and oral routes (19, 35, 77). Authors generally recommend the administration of 1–1.5 L/h of normal saline in the acute phase for adults (17, 19, 24, 35, 68–71, 73, 78–80). Volume resuscitation for pediatric patients was not specifically addressed so we extrapolated an equivalent weight-based volume. After 3–4 h, the rate can be decreased by 50% (19, 68–70). However, Mardones and colleagues recommend continuing the initial rate throughout the rescue phase if the patient does not have comorbidities (79). Urine output measurement can be the best guide to appropriate resuscitation and should be at least 1–2 mL/kg/h (24, 44). Caution should be taken if the patient is elderly, has comorbidities, or is anuric (69). The limited data available suggest entrapped patients may be under-resuscitated in the field (81–83). There may be hesitation to provide aggressive fluid resuscitation due to concern about precipitating bleeding; however, existing literature does not recommend permissive hypotension in this group. There may be a need to balance the possibility of ongoing hemorrhage with the need for fluid resuscitation in entrapped patients at risk of crush syndrome (4, 72, 84). Over-resuscitation in the general trauma patient may be harmful due to the risk of coagulopathy and acidosis (85, 86). Therefore, this recommendation should not be applied beyond the patient at significant risk for crush syndrome and balanced with the other needs of the patient.

There has been a move toward using balanced solutions such as lactated Ringer's (LR) in the resuscitation of the critically ill patient. In the setting of entrapment authors consistently highlighted the importance of avoiding any solution that contains potassium (19, 24, 68, 69, 73, 78, 79). However, there is a lack of data comparing crystalloid solutions or demonstrating harm from LR. Therefore, we feel the benefit of fluid resuscitation outweighs the theoretical risk and EMS clinicians should administer available crystalloid, with a preference for normal saline when available. Excess free water must also be avoided due to the risk of hyponatremia (83). The most common recommendation was for initial boluses of normal saline in the acute phase followed by transition to alternating normal saline and dextrose solutions with the addition of bicarbonate to alkalinize the urine (17, 69, 70, 72, 74, 80). Although not specifically addressed in the literature, given the risk for hypothermia, the authors believe warm fluids should be considered when feasible.

Data on the use of blood products in entrapped patients are limited to case reports (87–92). These patients are at increased risk for traumatic coagulopathy and some authors raise concerns about fluid resuscitation contributing to hemodilution (8, 88). Shackelford and colleagues demonstrated the benefits to blood products on survival in combat casualties, in whom there is also a delay to definitive care (93). Other studies have shown benefits for civilian trauma patients (94–96). Alternative products to improve oxygen-carrying capacity have also been explored in animal models (97). Ultimately, if blood products are available, they should be considered for resuscitation in entrapped patients (30) and administered early to those with signs of hemorrhagic shock (98).

Crush Treatment

In Entrapped Patients Who Are Experiencing or Are at Risk for Crush Syndrome, EMS Clinicians Should Administer Medications to Mitigate Risks of Hyperkalemia, Infection, and Renal Failure, Early and Prior to Extrication

Thirty-six papers addressed the medical management of crush injury and its sequela in the entrapped patient (Supplemental File Table 7). Crush syndrome is common in entrapped victims and has been reported in up to 40% of survivors extricated from collapsed structures, many of whom develop complications including renal failure (17, 36). Crush syndrome, due to ischemic muscle damage, can occur in as little as one hour, with muscle necrosis occurring at four hours (13, 71, 72). Early management, prior to extrication, can prevent these complications (36), whereas lack of treatment prior to extrication may result in sudden cardiac death due to reperfusion of entrapped muscle and sudden hyperkalemia and acidemia (33, 76, 77). The exact timing for medication administration has not been established, however, authors consistently recommend treatment prior to extrication (24, 68, 73, 77, 78, 80, 83).

Fluid resuscitation is paramount, as are treatments to mitigate early and late causes of death are important (80). Table 2 provides a summary of our recommendations based on the literature. The majority of authors discuss the use of sodium bicarbonate as an effective treatment for hyperkalemia and/or for the prevention of renal failure (15, 17, 19, 31, 38, 41, 68–72, 74, 76–80, 82, 84, 88, 99–101). Administration of sodium bicarbonate is recommended prior to extrication in order to prevent early dysrhythmias from hyperkalemia (17, 19, 24, 31, 72, 77, 78, 80). Administration of calcium gluconate or calcium chloride is also generally recommended in this acute phase (13, 17, 19, 31, 35, 68, 69, 72, 77, 78, 99, 100). High doses of the beta-2 agonist albuterol will further lower serum potassium levels by transiently driving it intracellularly (17, 19, 31, 35, 68, 69, 77, 100). However, if operating in a confined space, one must consider the risk of combustion with oxygen infused into the environment. The combined administration of intravenous insulin and glucose will similarly drive potassium into cells (17, 19, 31, 35, 69, 72, 76, 77, 99). Sodium polystyrene (kayexalate) is less commonly recommended,

Table 2. Recommended medications for management of crush injury and crush syndrome.

Medication	Recommendation
Sodium Bicarbonate 8.4%, 50mEq slow IV push Calcium Gluconate 10%, 10 mL or Calcium Chloride 10%, 5 mL slow IV push Albuterol Sulfate 2.5 mg/3 mL, 10 mg or Albuterol Sulfate 90 mcg MDI, 16 puffs inhaled	Always administer when feasible prior to release of crushed body part* and/or for signs of hyperkalemia
Insulin Regular 10 units IV AND 50% Dextrose, 50 mL or 10% Dextrose, 250 mL IV	Administer if available prior to release of crushed body part* and/or for signs of hyperkalemia
Mannitol 20%, 1-2 g/kg IV every 4 h	Not routinely recommended; consider for prolonged field care and only if adequate urine output is established and monitored
Polystyrene sulfonate 25-50 grams PO or PR	Not routinely recommended; consider for prolonged field care only
Ertapenem 1 g IV or Cefazolin 1 g IV AND gentamycin 1.5 mg/kg IV	Administer if available, recommended for prolonged field care

Adult dosing provided; weight-based dosing recommended for pediatric patients based on local protocols. Redosing may be necessary based on duration of action and field care duration.

*Risk of crush syndrome is related to the amount of compressive force, involved muscle mass, and duration of compression. The crushed body part should be entrapped for at least 1 or more hours and contain significant muscle mass (typically thigh, pelvis, shoulder girdle) for empiric treatment.

but may be considered for prolonged management (13, 19, 31, 35, 69, 74, 99); although it will lower potassium levels, it is slow in onset and has undesirable side effects including vomiting and diarrhea. Newer medications such as sodium zirconium (Lokelma) have generally replaced kayexalate for in-hospital management but are not addressed in the literature reviewed and are not in common use in the out-of-hospital setting (102).

To the goal of renal protection, authors recommend an infusion of sodium bicarbonate in dextrose 5% in water (D5W), targeting a total of 200 to 300 mEq in the first 24 h, to alkalinize the urine to a pH of 6.5 (13, 68, 70, 72, 73, 99, 101, 103). Mannitol use, though often discussed, is controversial (79, 80, 103). It is recommended as an adjunct for use only after the patient's urine output has been established and can be accurately monitored since it is harmful to a patient who is oliguric or anuric (17, 31, 68, 69, 71–74, 78, 101, 104, 105). Therefore, we believe mannitol should be deferred to hospital management, outside of austere environments with extensive delays to definitive care and where additional monitoring is possible.

Additional considerations are the management of pain and mitigation of complications including sepsis. Analgesics are an important consideration in entrapped patients (43). In addition to commonly used opioids, ketamine is safe and effective and has been used to manage pain in entrapped patients (106, 107). Nonsteroidal anti-inflammatories should be avoided due to nephrotoxicity. Sepsis is a major cause of mortality in patients with crush syndrome (13–15). Given the prolonged field care, early administration of broad-spectrum antibiotics is recommended and can be safely done by EMS clinicians (24, 35, 108–110). In a systematic review, the most common infective organisms following crush injuries were gram-negative bacilli (67%), followed by acinetobacter, pseudomonas, and gram-positive cocci (41). Therefore, broad-spectrum antibiotics such as ertapenem or a cephalosporin in combination with an aminoglycoside are recommended (35, 41, 110).

Tourniquet Placement

Tourniquet Application Should Be Considered in the Setting of the Crushed Extremity as a Potential Adjunct to Medical Optimization before Extrication of Some Patients

Nineteen studies were available that addressed tourniquet placement in the entrapped victim (Supplemental File Table 8). While multiple authors have published case reports and suggested the potential benefit of tourniquet placement to prevent lethal dysrhythmias upon extrication of entrapped patients (77, 111, 112), we found no studies that evaluated the effectiveness of tourniquets applied before extrication to prevent the complications of crush syndrome. Several guidelines in both the civilian and military settings have recommended tourniquet application on crushed extremities at the time of extrication while acknowledging the lack of evidence to support this practice (35, 99). In theory, application could allow for safe extrication followed by medical optimization and controlled release. Multiple review articles discussing the pathophysiology and management of crush injury also recommend this practice (13, 15, 24, 42, 44, 105). However, other authors cite insufficient evidence to routinely support tourniquet placement for this indication (19, 71, 73). The INSARAG guidelines recommend that tourniquet use be reserved for life-threatening bleeding (31).

For the indication of hemorrhage, the safety and effectiveness of tourniquets have been well established. Numerous studies have demonstrated that tourniquets are safe when applied for hemorrhage control in penetrating trauma (113–125). Tourniquets have been associated with a low incidence of renal failure and compartment syndrome (113, 119, 121, 122, 124, 126), and are rarely associated with limb amputation (113–116, 119, 120, 122, 124, 125). Studies of more prolonged tourniquet application, exceeding two hours, in rural or combat settings have demonstrated safety and efficacy, with one case of limb preservation after 16 h (113, 120, 127, 128). Prolonged tourniquet use has been associated with rare complications, including nerve palsies, compartment syndrome, rhabdomyolysis, and thrombosis (125, 129–132). As such, care must be taken to minimize tourniquet use to the shortest duration feasible. Further, it is unclear how much the crush injury to the limb may increase the risk of complications.

Entrapped patients have higher mortality from hemorrhage (25). For hemorrhage control amenable to a tourniquet, we believe tourniquets should be placed. This may include positioning of tourniquets before extrication on entangled limbs that are mangled and at risk for hemorrhage, with the ability to rapidly tighten as needed for hemorrhage control. However, when using tourniquets specifically for the indication of crush, the EMS clinician

should balance the potential risks of placement against the risk of reperfusion with hyperkalemia and acidemia leading to fatal dysrhythmias.

Physician Response

Patients with Prolonged Entrapment with the Potential for Severe Injuries Require Complex Resuscitation and May Benefit from EMS Physician Management on Scene. EMS Systems Should Consider an Early EMS Physician Response to Entrapped Patients

Rapid transport to the trauma center is important for the outcome of patients with severe trauma. However, entrapped patients offer a unique challenge, since they have prolonged scene times and delay to definitive care. Given the risk of early mortality, bringing higher-level care to the patient may be of benefit (103, 133). Twenty-eight articles discussed physician scene care for patients entrapped or in other austere settings with delays to definitive care (Supplemental File Table 9).

Entrapped patients require high-level clinical decision-making and complex resuscitation to manage both medical and trauma complications, integrated with rescue efforts (36). Several reports highlight that, with prolonged scene times or in austere settings, physicians provide benefits due to their ability to adapt protocolized treatment to complex pathophysiology (32, 34, 88, 89, 91, 92, 134, 135). Apodaca and colleagues demonstrated that physician-led teams conferred a survival benefit for patients with moderate and severe trauma in the combat setting (136). Although not specific to entrapped patients, several systematic reviews evaluating the influence of physician presence on-scene for severely injured patients have also found an association between physician care at the scene and lower mortality (137, 138).

Entrapped patients may require procedures that may be beyond the scope of practice of paramedics (104). Reports note a wide range of procedures performed by physicians on scene or during transport including regional anesthesia (88, 139, 140), fracture management (141), transfusion of blood products (89–92), fasciotomies (103), and procedural sedation (141). There are multiple case reports and one observational study of physicians performing amputations on scene (42, 89–91, 142–144). Having the appropriate equipment and technique matters (143, 145–147). Additionally, while it may be possible to train paramedics to perform advanced procedures (145,147,148), physicians on scene offer benefits beyond their procedural skills, including decision-making support and peri-procedural management of analgesia and sedation that may reduce morbidity and mortality (26, 32, 88, 139, 141, 149, 150). Hospital-based and/or specialty teams may also bring resources not always routinely available, such as blood products, to the scene.

Having system protocols and regular training opportunities for physician responders is important (92, 134, 151). However, there is some debate over the background of physician responders. Several studies from European EMS systems, with a long history of physician field response, emphasize the importance of physicians with adequate skills and field training to integrate with EMS clinicians on scene (26, 29, 135). Similarly, Orr et al., highlight the benefits of emergency physicians with adequate experience given the complex situations (34), and Stewart notes responding physicians should be trained specifically in prehospital emergency care (42). One group discussed the use of trauma surgeons given their experience with performing amputations but acknowledged the lack of field experience was a challenge (152). Lack of adequate training and experience in field care in physician responders can inhibit rescue (142). Recognizing that training and experience is more important than the type of clinician (153), the consensus of the authors was that EMS physicians are the most qualified and should be prioritized for the response (154, 155).

Considerations for Implementation

Resource limitations for staffing, equipment, and training may be barriers to the implementation of these recommendations. In particular, systems may not have readily available EMS physicians for field response. Although not addressed in the literature specific to this population, telemedicine is increasingly used in EMS and may be an alternative method to provide clinical guidance though this will not address scope of practice limitations. Ensuring primary education and ongoing training opportunities for EMS clinicians in the care of the entrapped patient is important for successful implementation. Establishing partnerships with local Urban Search & Rescue teams, as well as other specialized EMS teams and agencies that focus on medically-directed rescue may offer opportunities for hands on training. In our experience, this has been an effective method for collaborative training with EMS clinicians, alongside physicians and nurses who may assist with field response.

Limitations

These recommendations must be considered in the context of their limitations. The literature search was performed on a single database with one investigator (NB) screening the articles for inclusion. We did not use Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) methodology or perform risk of bias assessments. While there was literature available for each of the identified content areas, much of the available evidence was based on descriptive literature on disaster events, case reports, and small retrospective or simulation studies. Given the gaps in the literature, investigators pulled from their collective experience in addition to the evidence available. In particular, there is a lack of data demonstrating the optimal dose and timing of medications for crush. There remains the potential for harm due to the administration of unnecessary medications as EMS clinicians attempt to assess the risk of crush syndrome. Therefore, the role of education and training is paramount. Further, the role of the EMS physician and EMS clinicians' scope of practice and integration of technologies continue to evolve. All EMS systems must

consider the scope of practice of the EMS clinicians and the practice environment when operationalizing these recommendations. Resource limitations may impact the implementation of these recommendations, and in particular, the ability to deploy certain technologies and personnel including EMS physicians to the scene.

This position statement and resource document were developed based on the evidence available at the time of the literature review. It should be reviewed and updated five years after its publication, or earlier if substantial relevant new literature is identified. The review process should include a search and synthesis of new and relevant evidence since publication, with consideration for modifications or new recommendations as needed.

Conclusion

All EMS clinicians must have the training and skills to manage entrapped patients. Best practices include performing a timely thorough assessment with the use of remote assessment strategies when necessary, establishing clear communications among the team and with the patient, taking measures to prevent and treat hypothermia, optimizing airway management strategies, initiating large-volume fluid resuscitation and medications in patients at risk for crush syndrome, and considering tourniquet placement and physician field response.

Acknowledgments

The authors are grateful to Claudia Del Toro for her administrative support of this project. The authors are further grateful to Dr. Christian Martin-Gill for his guidance on the methodology and literature search strategy.

Authors Contributions

NB, AOG, and JL developed the plan for literature review and evidence extraction. All authors assume full responsibility for the collection and integrity of the data. NB, BA, TL, ZQ, MS, JT, and JL participated in the evidence extraction, data analysis, development of the clinical practice guideline. NB wrote the initial draft of the manuscript, all authors participated in editing. All authors assume full responsibility for the entire content of the manuscript.

Declaration of Generative AI in Scientific Writing

The authors did not use a generative artificial intelligence (AI) tool or service to assist with preparation or editing of this work. The author(s) take full responsibility for the content of this publication.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

External Review

This document was created solely by NAEMSP and was not subject to review by external parties.

Funding

This document was developed by NAEMSP without external funding.

Updating Procedure

Pursuant to NAEMSP Standards & Clinical Practices Committee procedures and practices, this position statement and resource document will be reviewed and updated five years after its publication. Applicable NAEMSP review and revision practices that are current as of the time of the review will be followed. At a minimum the review process should include a search and synthesis of any new and relevant evidence that is published since the printing of this document.

ORCID

Nichole Bosson http://orcid.org/0000-0001-8356-0772
Benjamin N. Abo http://orcid.org/0000-0003-0680-298X
Troy D. Litchfield http://orcid.org/0000-0002-7390-2852
Zaffer Qasim http://orcid.org/0000-0002-9633-9206
Matthew F. Steenberg http://orcid.org/0000-0002-8052-5303
Jake Toy http://orcid.org/0000-0002-0089-5495
Antonia Osuna-Garcia http://orcid.org/0000-0002-6825-8580
John Lyng http://orcid.org/0000-0001-5191-5700

References

1. Nutbeam T, Fenwick R, Hobson C, Holland V, Palmer M. The stages of extrication: a prospective study. Emerg Med J. 2014; 31(12):1006–8. doi:10.1136/emermed-2013-202668.
2. Nour MM, Cheng YH, Field WE, Sheldon E, Ni JQ. Summary of known U.S. Injuries and fatalities involving livestock waste storage, handling, and transport operations: 1975–2019. J Agric Saf Health. 2022;28(1):65–81. doi:10.13031/jash.14615.
3. Nutbeam T, Fenwick R, Smith J, Bouamra O, Wallis L, Stassen W. A comparison of the demographics, injury patterns and outcome data for patients injured in motor vehicle collisions who are trapped compared to those patients who are not trapped. Scand J Trauma Resusc Emerg Med. 2021;29(1):17. doi:10.1186/s13049-020-00818-6.
4. Sanson G, Di Bartolomeo S, Nardi G, Albanese P, Diani A, Raffin L, Filippetto C, Cattarossi A, Scian E, Rizzi L. Road traffic accidents with vehicular entrapment: incidence of major injuries and need for advanced life support. Eur J Emerg Med. 1999;6(4):285–91. doi:10.1097/00063110-199912000-00002.
5. Nutbeam T, Kehoe A, Fenwick R, Smith J, Bouamra O, Wallis L, Stassen W. Do entrapment, injuries, outcomes and potential for self-extrication vary with age? A pre-specified analysis of the UK trauma registry (tarn). Scand J Trauma Resusc Emerg Med. 2022;30(1):14. doi:10.1186/s13049-021-00989-w.
6. Nutbeam T, Weekes L, Heidari S, Fenwick R, Bouamra O, Smith J, Stassen W. Sex-disaggregated analysis of the injury patterns, outcome data and trapped status of major trauma patients injured in motor vehicle collisions: a prespecified analysis of the UK trauma registry (tarn). BMJ Open. 2022;12(5): e061076. doi:10.1136/bmjopen-2022-061076.
7. Pan ST, Cheng YY, Wu CL, Chang RH, Chiu C, Foo NP, Chen PT, Wang TY, Chen LH, Chen CJ, et al. Association of injury pattern and entrapment location inside damaged buildings in the 2016 Taiwan earthquake. J Formos Med Assoc. 2019;118(1): 311–23. doi:10.1016/j.jfma.2018.05.012.
8. Mitra B, Cameron PA, Mori A, Maini A, Fitzgerald M, Paul E, Street A. Early prediction of acute traumatic coagulopathy. Resuscitation. 2011;82(9):1208–13. doi:10.1016/j.resuscitation.2011.04.007.
9. Eknoyan G. The armenian earthquake of 1988: a milestone in the evolution of nephrology. Adv Ren Replace Ther. 2003;10(2): 87–92. doi:10.1053/jarr.2003.50013.

10. Kantarci G, Vanholder R, Tuglular S, Akin H, Koç M, Ozener C, Akoglu E. Acute renal failure due to crush syndrome during marmara earthquake. Am J Kidney Dis. 2002;40(4):682–9. doi:10.1053/ajkd.2002.35673.
11. Roy N, Shah H, Patel V, Bagalkote H. Surgical and psychosocial outcomes in the rural injured-a follow-up study of the 2001 earthquake victims. Injury. 2005;36(8):927–34. doi:10.1016/j.injury.2005.02.017.
12. Sever MS, Erek E, Vanholder R, Akoğlu E, Yavuz M, Ergin H, Tekçe M, Korular D, Tülbek MY, Keven K, et al. The marmara earthquake: epidemiological analysis of the victims with nephrological problems. Kidney Int. 2001;60(3):1114–23. doi:10.1046/j.1523-1755.2001.0600031114.x.
13. Jagodzinski NA, Weerasinghe C, Porter K. Crush injuries and crush syndrome – a review. Part 1: the systemic injury. Trauma. 2010;12(2):69–88. doi:10.1177/1460408610372440.
14. Wen J, Shi YK, Li YP, Wang L, Cheng L, Gao Z, Li L. Risk factors of earthquake inpatient death: a case control study. Crit Care. 2009;13(1):R24. doi:10.1186/cc7729.
15. Stewart IP. Major crush injury. Br Med J (Clin Res Ed). 1987;294(6576):854–5. doi:10.1136/bmj.294.6576.854.
16. Rogers FB, Hammaker SJ, Miller JA, Lee JC, Chandler R, Edavettal MM, Sakorafas LU, Wu D, Evans T, Horn LA, et al. Does prehospital prolonged extrication (entrapment) place trauma patients at higher risk for venous thromboembolism? Am J Surg. 2011;202(4):382–6. doi:10.1016/j.amjsurg.2010.10.013.
17. Ashkenazi I, Isakovich B, Kluger Y, Alfici R, Kessel B, Better OS. Prehospital management of earthquake casualties buried under rubble. Prehosp Disaster Med. 2005;20(2):122–33. doi:10.1017/s1049023x00002302.
18. Liu S, He C. Related factors associated with earthquake inpatient mortality. Disaster Med Public Health Prep. 2022;16(1):65–70. doi:10.1017/dmp.2020.125.
19. Sever MS, Vanholder R. Recommendation for the management of crush victims in mass disasters. Nephrol Dial Transplant. 2012;27 Suppl 1(Suppl 1):i1–67. doi:10.1093/ndt/gfs156.
20. Wilson MP, Madison HN, Healy SB. Confined space emergency response: assessing employer and fire department practices. J Occup Environ Hyg. 2012;9(2):120–8. doi:10.1080/15459624.2011.646644.
21. Najafi I, Safari S, Sharifi A, Sanadgol H, Hosseini M, Rashid-Farokhi F, Seirafian S, Mooraki A, Samimagham H, Osare S, et al. Practical strategies to reduce morbidity and mortality of natural catastrophes: a retrospective study based on bam earthquake experience. Arch Iran Med. 2009;12(4):347–52.
22. Sever MS, Erek E, Vanholder R, Ozener C, Yavuz M, Kayacan SM, Ergin H, Apaydin S, Cobanoglu M, Donmez O, et al. Lessons learned from the marmara disaster: time period under the rubble. Crit Care Med. 2002;30(11):2443–9. doi:10.1097/00003246-200211000-00007.
23. Martin-Gill C, Lyng JW. Methodology for evidence evaluation and reporting of the naemsp trauma compendium position statements. Prehosp Emerg Care. 2024;28(4):660–5.
24. Anderson JL, Cole M, Pannell D. Management of severe crush injuries in austere environments: a special operations perspective. J Spec Oper Med. 2022;22(2):43–7. doi:10.55460/2Y7A-IGK7.
25. Dias ARN, Abib SdCV, Poli-de-Figueiredo LF, Perfeito JAJ. Entrapped victims in motor vehicle collisions: characteristics and prehospital care in the city of são paulo, brazil. Clinics (Sao Paulo). 2011;66(1):21–5. doi:10.1590/s1807-59322011000100005.
26. Wilmink AB, Samra GS, Watson LM, Wilson AW. Vehicle entrapment rescue and pre-hospital trauma care. Injury. 1996;27(1):21–5. doi:10.1016/0020-1383(95)00162-X.
27. Hallinan B. Untangling metal. The EMT's & paramedic's role in vehicle extrication. JEMS. 2015;40(6):30–4.
28. Augustine JJ. Priorities in extrication. Emerg Med Serv. 1994;23(6):53.
29. Mahoney PF, Carney CJ. Entrapment, extrication and immobilization. Eur J Emerg Med. 1996;3(4):244–6. doi:10.1097/00063110-199612000-00005.
30. Nutbeam T, Fenwick R, Smith JE, Dayson M, Carlin B, Wilson M, Wallis L, Stassen W. A Delphi study of rescue and clinical subject matter experts on the extrication of patients following a motor vehicle collision. Scand J Trauma Resusc Emerg Med. 2022;30(1):41. doi:10.1186/s13049-022-01029-x.
31. International search and rescue advisory group. The medical management of the entrapped patient with crush syndrome. 2023 Mar [accessed 2024 Oct 14]. https://www.insarag.org/wp-content/uploads/2023/05/Attachment-C2-MWG-The-Medical-Management-of-the-Entrapped-Patient-with-Crush-Syndrome-March-2023.pdf
32. Kotora JG, Westrol MS, Merlin MA. Use of a fiber optic camera to perform a trauma assessment during a confined space rescue. Am J Disaster Med. 2014;9(2):151–6. doi:10.5055/ajdm.2014.0151.
33. Pretto EA, Angus DC, Abrams JI, Shen B, Bissell R, Ruiz Castro VM, Sawyers R, Watoh Y, Ceciliano N, Ricci E. An analysis of prehospital mortality in an earthquake. Prehosp. Disaster Med. 1994;9(2):107–17. doi:10.1017/S1049023X00041005.
34. Orr SM, Robinson WA. The Hyatt regency skywalk collapse: an EMS-based disaster response. Ann Emerg Med. 1983;12(10):601–5. doi:10.1016/s0196-0644(83)80203-0.
35. Walters T, Powell D, Penny A, Stewart I, Chung K, Keenan S, Shackelford S. Joint trauma system clinical practice guidelines. Crush syndrome - prolonged field care (cpg id:58). 2016. [Accessed 2022 Apr 20]. https://jts.amedd.army.mil/assets/docs/cpgs/crush_syndrome_pfc_28_dec_2016_id58.pdf.
36. Barbera JA, Macintyre A. Urban search and rescue. Emerg Med Clin North Am. 1996;14(2):399–412. doi:10.1016/S0733-8627(05)70258-3.
37. Augustine JJ. Extraordinary extrication. A confined area poses challenges for ems when a man falls through his front porch. Emerg Med Serv. 2007;36(22):24–5.
38. Yoshimura N, Nakayama S, Nakagiri K, Azami T, Ataka K, Ishii N. Profile of chest injuries arising from the 1995 southern hyogo prefecture earthquake. Chest. 1996;110(3):759–61. doi:10.1378/chest.110.3.759.
39. Kubota M, Ishida H, Kojima Y, Fukuda A, Mizushima Y, Mizobata Y, Matsuoka T, Yokota J. Impact of mobile clinical analyzers on disaster medicine: a lesson from crush syndrome in the 1995 hanshin-awaji earthquake. Biomed Instrum Technol. 2003;37(4):259–62. doi:10.2345/0899-8205(2003)37[259:IOMCAO.[PMC]2.0.CO;2]
40. Zhang CD, Lv FQ, Li QY, Zhang Y, Shi XQ, Li XY, Tang J. Application of contrast-enhanced ultrasonography in the diagnosis of skeletal muscle crush injury in rabbits. Br J Radiol. 2014;87(1041):20140421. doi:10.1259/bjr.20140421.
41. Wuthisuthimethawee P, Lindquist SJ, Sandler N, Clavisi O, Korin S, Watters D, Gruen RL. Wound management in disaster settings. World J Surg. 2015;39(4):842–53. doi:10.1007/s00268-014-2663-3.
42. Stewart RD, Young JC, Kenney DA, Hirschberg JM. Field surgical intervention: an unusual case. J Trauma. 1979;19(10):780–3. doi:10.1097/00005373-197910000-00012.
43. Nutbeam T, Brandling J, Wallis LA, Stassen W. Understanding people's experiences of extrication while being trapped in motor vehicles: a qualitative interview study. BMJ Open. 2022;12(9):e063798. doi:10.1136/bmjopen-2022-063798.
44. Julien H. [current organization of disaster medicine]. Bull Acad Natl Med. 2013;197(9):1727–37. discussion 1737–9.
45. Tsuei BJ, Kearney PA. Hypothermia in the trauma patient. Injury. 2004;35(1):7–15. doi:10.1016/s0020-1383(03)00309-7.
46. Jurkovich GJ, Greiser WB, Luterman A, Curreri PW. Hypothermia in trauma victims: an ominous predictor of survival. J Trauma. 1987;27(9):1019–24. doi:10.1097/00005373-198709000-00011.
47. Shafi S, Elliott AC, Gentilello L. Is hypothermia simply a marker of shock and injury severity or an independent risk factor for mortality in trauma patients? Analysis of a large national

trauma registry. J Trauma. 2005;59(5):1081–5. doi:10.1097/01.ta.0000188647.03665.fd.
48. Martin RS, Kilgo PD, Miller PR, Hoth JJ, Meredith JW, Chang MC. Injury-associated hypothermia: an analysis of the 2004 national trauma data bank. Shock. 2005;24(2):114–8. doi:10.1097/01.shk.0000169726.25189.b1.
49. Peng RY, Bongard FS. Hypothermia in trauma patients. J Am Coll Surg. 1999;188(6):685–96. doi:10.1016/s1072-7515(99)00035-6.
50. Weaver MD, Rittenberger JC, Patterson PD, McEntire SJ, Corcos AC, Ziembicki JA, Hostler D. Risk factors for hypothermia in ems-treated burn patients. Prehosp Emerg Care. 2014;18(3):335–41. doi:10.3109/10903127.2013.864354.
51. Hohlrieder M, Kroesslhuber F, Voelckel W, Lutz M, Mair P. Experience with helicopter rescue missions for crevasse accidents. High Alt Med Biol. 2010;11(4):375–9. doi:10.1089/ham.2010.1027.
52. Henriksson O, Lundgren JP, Kuklane K, Holmér I, Bjornstig U. Protection against cold in prehospital care-thermal insulation properties of blankets and rescue bags in different wind conditions. Prehosp Disaster Med. 2009;24(5):408–15. doi:10.1017/S1049023X00007238.
53. Stroop R, Schoene C, Grau T. Efficacy of an infrared radiator for hypothermia prevention in a simulated setup of entrapped vehicle accident victims. Injury. 2021;52(9):2491–501. doi:10.1016/j.injury.2021.06.003.
54. Castle N, Naguran S. Reflection: on the use of the ilma in an entrapped patient. Emerg Med J. 2014;31(12):1014–5. doi:10.1136/emermed-2013-202366.
55. Greene MK, Roden R, Hinchley G. The laryngeal mask airway. Two Cases of Prehospital Trauma Care. Anaesthesia. 1992;47(8):688–9. doi:10.1111/j.1365-2044.1992.tb02392.x.
56. Hulme J, Perkins GD. Critically injured patients, inaccessible airways, and laryngeal mask airways. Emerg Med J. 2005;22(10):742–4. doi:10.1136/emj.2005.026443.
57. Gaszynska E, Samsel P, Stankiewicz-Rudnicki M, Wieczorek A, Gaszynski T. Intubation by paramedics using the ilma or airtraq, kingvision, and macintosh laryngoscopes in vehicle-entrapped patients: a manikin study. Eur J Emerg Med. 2014;21(1):61–4. doi:10.1097/MEJ.0b013e3283632fb6.
58. Gupta A, Kabi A, Gaur D. Assessment of success and ease of insertion of proseal™ laryngeal mask airway versus i-gel™ insertion by paramedics in simulated difficult airway using cervical collar in different positions in manikins. Anesth Essays Res. 2020;14(4):627–31. doi:10.4103/aer.AER_72_20.
59. Martin AB, Lingg J, Lubin JS. Comparison of airway management methods in entrapped patients: a manikin study. Prehosp Emerg Care. 2016;20(5):657–61. doi:10.3109/10903127.2016.1139218.
60. Steinmann D, Ahne T, Heringhaus C, Goebel U. Comparison of airway management techniques for different access in a simulated motor vehicle entrapment scenario. Eur J Emerg Med. 2016;23(4):279–85. doi:10.1097/MEJ.0000000000000254.
61. Wetsch WA, Schneider A, Schier R, Spelten O, Hellmich M, Hinkelbein J. In a difficult access scenario, supraglottic airway devices improve success and time to ventilation. Eur J Emerg Med. 2015;22(5):374–6. doi:10.1097/MEJ.0000000000000230.
62. Hansel J, Rogers AM, Lewis SR, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adults undergoing tracheal intubation. Cochrane Database Syst Rev. 2022;4(4):CD011136. doi:10.1002/14651858.CD011136.pub3.
63. Kent ME, Sciavolino BM, Blickley ZJ, Pasichow SH. Video laryngoscopy versus direct laryngoscopy for orotracheal intubation in the out-of-hospital environment: a systematic review and meta-analysis. Prehosp Emerg Care. 2024;28(2):221–30. doi:10.1080/10903127.2023.2219727.
64. Nakstad AR, Sandberg M. The glidescope ranger video laryngoscope can be useful in airway management of entrapped patients. Acta Anaesthesiol Scand. 2009;53(10):1257–61. doi:10.1111/j.1399-6576.2009.02094.x.
65. Pap R, van Loggerenberg C. A comparison of airway management devices in simulated entrapment-trauma: a prospective manikin study. Int J Emerg Med. 2019;12(1):15. doi:10.1186/s12245-019-0233-z.
66. Schober P, Krage R, van Groeningen D, Loer SA, Schwarte LA. Inverse intubation in entrapped trauma casualties: a simulator based, randomised cross-over comparison of direct, indirect and video laryngoscopy. Emerg Med J. 2014;31(12):959–63. doi:10.1136/emermed-2012-202064.
67. Givens GC, Shelton SL, Brown EA. Emergency cricothyrotomy in confined space airway emergencies: a comparison. Prehosp Disaster Med. 2011;26(4):259–61. doi:10.1017/S1049023X11006352.
68. Abassi ZA, Hoffman A, Better OS. Acute renal failure complicating muscle crush injury. Semin Nephrol. 1998;18:558–65.
69. Alpert EA, Pachys G. EMS confined space care. Statpearls. Treasure Island (FL): StatPearls Publishing; 2022.
70. Better OS. Rescue and salvage of casualties suffering from the crush syndrome after mass disasters. Mil Med. 1999;164(5):366–9. doi:10.1093/milmed/164.5.366.
71. Genthon A, Wilcox SR. Crush syndrome: a case report and review of the literature. J Emerg Med. 2014;46(2):313–9. doi:10.1016/j.jemermed.2013.08.052.
72. Gonzalez D. Crush syndrome. Crit Care Med. 2005;33(1 Suppl):S34–S41. doi:10.1097/01.ccm.0000151065.13564.6f.
73. Greaves I, Porter K, Smith JE, Voluntary Aid S. Consensus statement on the early management of crush injury and prevention of crush syndrome. J R Army Med Corps. 2003;149(4):255–9. doi:10.1136/jramc-149-04-02.
74. Sever MS, Vanholder R, Lameire N. Management of crush-related injuries after disasters. N Engl J Med. 2006;354(10):1052–63. doi:10.1056/NEJMra054329.
75. Vanholder R, Stuard S, Bonomini M, Sever MS. Renal disaster relief in europe: the experience at l'aquila, italy, in april 2009. Nephrol Dial Transplant. 2009;24(10):3251–5. doi:10.1093/ndt/gfp335.
76. Allister C. Cardiac arrest after crush injury. Br Med J (Clin Res Ed). 1983;287(6391):531–2. doi:10.1136/bmj.287.6391.531-a.
77. Whiffin ANH, Spangler JD, Dhir K, Zhang R, Ferguson JD. Bathroom entrapment leading to cardiac arrest from crush syndrome. Prehosp Emerg Care. 2019;23(1):90–3. doi:10.1080/10903127.2018.1471558.
78. Burns K, Cone DC, Portereiko JV. Complex extrication and crush injury. Prehosp Emerg Care. 2010;14(2):240–4. doi:10.3109/10903120903564498.
79. Mardones A, Arellano P, Rojas C, Gutierrez R, Oliver N, Borgna V. Prevention of crush syndrome through aggressive early resuscitation: clinical case in a buried worker. Prehosp Disaster Med. 2016;31(3):340–2. doi:10.1017/S1049023X16000327.
80. Smith J, Greaves I. Crush injury and crush syndrome: a review. J Trauma. 2003;54(5 Suppl):S226–S30. doi:10.1097/01.TA.0000047203.00084.94.
81. Macke C, Sarakintsis M, Winkelmann M, Mommsen P, Omar M, Schröter C, Krettek C, Zeckey C. Influence of entrapment on prehospital management and the hospital course in polytrauma patients: a retrospective analysis in air rescue. J Emerg Med. 2018;54(6):827–34. doi:10.1016/j.jemermed.2018.02.030.
82. Sever MS, Erek E, Vanholder R, Akoglu E, Yavuz M, Ergin H, Turkmen F, Korular D, Yenicesu M, Erbilgin D, et al. Clinical findings in the renal victims of a catastrophic disaster: the marmara earthquake. Nephrol Dial Transplant. 2002;17(11):1942–9. doi:10.1093/ndt/17.11.1942.
83. Zhang L, Fu P, Wang L, Cai G, Zhang L, Chen D, Guo D, Sun X, Chen F, Bi W, et al. Hyponatraemia in patients with crush syndrome during the Wenchuan earthquake. Emerg Med J. 2013;30(9):745–8. doi:10.1136/emermed-2012-201563.
84. Greaves I, Porter KM, Revell MP. Fluid resuscitation in prehospital trauma care: a consensus view. J R Coll Surg Edinb. 2002;47:451–7.
85. Geeraedts LMG, Jr, Pothof LAH, Caldwell E, de Lange-de Klerk ESM, D'Amours SK. Prehospital fluid resuscitation in hypotensive trauma patients: do we need a tailored approach? Injury. 2015;46(1):4–9. doi:10.1016/j.injury.2014.08.001.

86. Ley EJ, Clond MA, Srour MK, Barnajian M, Mirocha J, Margulies DR, Salim A. Emergency department crystalloid resuscitation of 1.5l or more is associated with increased mortality in elderly and nonelderly trauma patients. J Trauma. 2011;70(2):398–400. doi:10.1097/TA.0b013e318208f99b.
87. Mapp JG, Manifold CA, Garcia AM, Aguilar JL, Stringfellow ML, Winckler CJ. Prehospital blunt traumatic arrest resuscitation augmented by whole blood: a case report. Transfusion. 2020;60(5):1104–7. doi:10.1111/trf.15740.
88. Meyer P, Lamour O, Caussanel JM, Marland J, Moreau F. [crush injury of the lower limbs. Use of anti-shock trousers]. Ann Fr Anesth Reanim. 1988;7(5):412–4. doi:10.1016/s0750-7658(88)80059-5.
89. Chiapuzio C, Dang T, Meagher S, Woodward B, Neeki M. The effect of physician-led enhanced care teams in prehospital trauma resuscitation. Cureus. 2020;12(9):e10405. doi:10.7759/cureus.10405.
90. Bunyasaranand JC, Espino E, Rummings KA, Christiansen GM. Management of an entrapped patient with a field amputation. J Emerg Med. 2018;54(1):90–5. doi:10.1016/j.jemermed.2017.08.097.
91. Ebraheim NA, Elgafy H. Bilateral below-knee amputation surgery at the scene: case report. J Trauma. 2000;49(4):758–9. doi:10.1097/00005373-200010000-00028.
92. Howie W, Scott-Herring M, Pollak AN, Galvagno SM, Jr. Advanced prehospital trauma resuscitation with a physician and certified registered nurse anesthetist: the shock trauma "go-team". Air Med J. 2020;39(1):51–5. doi:10.1016/j.amj.2019.09.004.
93. Shackelford SA, Del Junco DJ, Powell-Dunford N, Mazuchowski EL, Howard JT, Kotwal RS, Gurney J, Butler FK, Jr., Gross K, Stockinger ZT. Association of prehospital blood product transfusion during medical evacuation of combat casualties in Afghanistan with acute and 30-day survival. Jama. 2017;318(16):1581–91. doi:10.1001/jama.2017.15097.
94. Brown JB, Cohen MJ, Minei JP, Maier RV, West MA, Billiar TR, Peitzman AB, Moore EE, Cuschieri J, Sperry JL. Pretrauma center red blood cell transfusion is associated with reduced mortality and coagulopathy in severely injured patients with blunt trauma. Ann Surg. 2015;261(5):997–1005. doi:10.1097/SLA.0000000000000674.
95. Brown JB, Sperry JL, Fombona A, Billiar TR, Peitzman AB, Guyette FX. Pre-trauma center red blood cell transfusion is associated with improved early outcomes in air medical trauma patients. J Am Coll Surg. 2015;220(5):797–808. doi:10.1016/j.jamcollsurg.2015.01.006.
96. Guyette FX, Sperry JL, Peitzman AB, Billiar TR, Daley BJ, Miller RS, Harbrecht BG, Claridge JA, Putnam T, Duane TM, et al. Prehospital blood product and crystalloid resuscitation in the severely injured patient: a secondary analysis of the prehospital air medical plasma trial. Ann Surg. 2021;273:358–64. doi:10.1097/SLA.0000000000003324.
97. Philbin N, Rice J, Gurney J, McGwin G, Arnaud F, Dong F, Johnson T, Flournoy WS, Ahlers S, Pearce LB, et al. A hemoglobin-based oxygen carrier, bovine polymerized hemoglobin (HBOC-201) versus hetastarch (Hex) in a moderate severity hemorrhagic shock swine model with delayed evacuation. Resuscitation. 2005;66(3):367–78. doi:10.1016/j.resuscitation.2005.03.019.
98. Berry C, Gallagher JM, Goodloe JM, Dorlac WC, Dodd J, Fischer PE. Prehospital hemorrhage control and treatment by clinicians: a joint position statement. Prehosp Emerg Care. 2023;27(5):544–51.
99. American college of emergency physicians. Crush injury and crush syndrome; 2009.
100. Anderson PB. A comparative analysis of the emergency medical services and rescue responses to eight airliner crashes in the United States, 1987–1991. Prehosp Disaster Med. 1995;10(3):142–53. doi:10.1017/s1049023x00041923.
101. Bartels SA, VanRooyen MJ. Medical complications associated with earthquakes. Lancet. 2012;379(9817):748–57. doi:10.1016/S0140-6736(11)60887-8.
102. Chaitman M, Dixit D, Bridgeman MB. Potassium-binding agents for the clinical management of hyperkalemia. P T. 2016;41(1):43–50.
103. Li W, Qian J, Liu X, Zhang Q, Wang L, Chen D, Lin Z. Management of severe crush injury in a front-line tent icu after 2008 wenchuan earthquake in China: an experience with 32 cases. Crit Care. 2009;13(6):R178. doi:10.1186/cc8160.
104. Anderson TE, Rose WD, Leicht MJ. Physician-staffed helicopter scene response from a rural trauma center. Ann Emerg Med. 1987;16(1):58–61. doi:10.1016/s0196-0644(87)80288-3.
105. Jagodzinski NA, Weerasinghe C, Porter K. Crush injuries and crush syndrome – a review. Part 2: the local injury. Trauma. 2010;12(3):133–48. doi:10.1177/1460408610372441.
106. Porter K. Ketamine in prehospital care. Emerg Med J. 2004;21:351–4. doi:10.1136/emj.2003.010843.
107. Fernandez AR, Bourn SS, Crowe RP, Bronsky ES, Scheppke KA, Antevy P, Myers JB. Out-of-hospital ketamine: indications for use, patient outcomes, and associated mortality. Ann Emerg Med. 2021;78(1):123–31. doi:10.1016/j.annemergmed.2021.02.020.
108. Lack W, Seymour R, Bickers A, Studnek J, Karunakar M. Prehospital antibiotic prophylaxis for open fractures: practicality and safety. Prehosp Emerg Care. 2019;23(3):385–8. doi:10.1080/10903127.2018.1514089.
109. Sandean D. Open fractures - what is the evidence, and how can we improve? Arch Bone Jt Surg. 2021;9:559–66. doi:10.22038/abjs.2020.53120.2637.
110. Yang C, Wang HY, Zhong HJ, Zhou L, Jiang DM, Du DY, Hu P, Jiang JX. The epidemiological analyses of trauma patients in Chongqing teaching hospitals following the Wenchuan earthquake. Injury. 2009;40(5):488–92. doi:10.1016/j.injury.2009.01.102.
111. Zhang X, Bai X, Zhou Q. First-aid treatments of crush injuries after earthquake: 2 special cases. Am J Emerg Med. 2014;32(7):817.e3–817.e4. doi:10.1016/j.ajem.2013.12.062.
112. Schwartz DS, Weisner Z, Badar J. Immediate lower extremity tourniquet application to delay onset of reperfusion injury after prolonged crush injury. Prehosp Emerg Care. 2015;19(4):544–7. doi:10.3109/10903127.2015.1005264.
113. Bedri H, Ayoub H, Engelbart JM, Lilienthal M, Galet C, Skeete DA. Tourniquet application for bleeding control in a rural trauma system: outcomes and implications for prehospital providers. Prehosp Emerg Care. 2022;26(2):246–54. doi:10.1080/10903127.2020.1868635.
114. Henry R, Matsushima K, Ghafil C, Henry RN, Theeuwen H, Golden AC, Abramson TM, Inaba K. Increased use of prehospital tourniquet and patient survival: Los Angeles countywide study. J Am Coll Surg. 2021;233(2):233–9.e2. doi:10.1016/j.jamcollsurg.2021.03.023.
115. Inaba K, Siboni S, Resnick S, Zhu J, Wong MD, Haltmeier T, Benjamin E, Demetriades D. Tourniquet use for civilian extremity trauma. J Trauma Acute Care Surg. 2015;79(2):232–7. quiz 332-3. doi:10.1097/TA.0000000000000747.
116. Kragh JF, Jr., Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, Holcomb JB. Survival with emergency tourniquet use to stop bleeding in major limb trauma. Ann Surg. 2009;249(1):1–7. doi:10.1097/SLA.0b013e31818842ba.
117. Kragh JF, Jr., O'Neill ML, Beebe DF, Fox CJ, Beekley AC, Cain JS, Parsons DL, Mabry RL, Blackbourne LH. Survey of the indications for use of emergency tourniquets. J Spec Oper Med. 2011;11(1):30–4. doi:10.55460/36SQ-1UQU.
118. Kragh JF, Jr., O'Neill ML, Walters TJ, Jones JA, Baer DG, Gershman LK, Wade CE, Holcomb JB. Minor morbidity with emergency tourniquet use to stop bleeding in severe limb trauma: research, history, and reconciling advocates and abolitionists. Mil Med. 2011;176(7):817–23. doi:10.7205/milmed-d-10-00417.
119. Legare T, Schroll R, Hunt JP, Duchesne J, Marr A, Schoen J, Greiffenstein P, Stuke L, Smith A. Prehospital tourniquets placed on limbs without major vascular injuries, has the pendulum swung too far? Am Surg. 2022;88(9):2103–7. doi:10.1177/00031348221088968.

120. Leonard J, Zietlow J, Morris D, Berns K, Eyer S, Martinson K, Jenkins D, Zietlow S. A multi-institutional study of hemostatic gauze and tourniquets in rural civilian trauma. J Trauma Acute Care Surg. 2016;81(3):441–4. doi:10.1097/TA.0000000000001115.
121. McNickle AG, Fraser DR, Chestovich PJ, Kuhls DA, Fildes JJ. Effect of prehospital tourniquets on resuscitation in extremity arterial trauma. Trauma Surg Acute Care Open. 2019;4(1): e000267. doi:10.1136/tsaco-2018-000267.
122. Scerbo MH, Mumm JP, Gates K, Love JD, Wade CE, Holcomb JB, Cotton BA. Safety and appropriateness of tourniquets in 105 civilians. Prehosp Emerg Care. 2016;20(6):712–22. doi:10.1080/10903127.2016.1182606.
123. Scerbo MH, Holcomb JB, Taub E, Gates K, Love JD, Wade CE, Cotton BA. The trauma center is too late: major limb trauma without a pre-hospital tourniquet has increased death from hemorrhagic shock. J Trauma Acute Care Surg. 2017;83(6): 1165–72. doi:10.1097/TA.0000000000001666.
124. Schroll R, Smith A, McSwain NE, Jr., Myers J, Rocchi K, Inaba K, Siboni S, Vercruysse GA, Ibrahim-Zada I, Sperry JL, et al. A multi-institutional analysis of prehospital tourniquet use. J Trauma Acute Care Surg. 2015;79(1):10–4. discussion 14. doi: 10.1097/TA.0000000000000689.
125. Teixeira PGR, Brown CVR, Emigh B, Long M, Foreman M, Eastridge B, Gale S, Truitt MS, Dissanaike S, Duane T, et al. Civilian prehospital tourniquet use is associated with improved survival in patients with peripheral vascular injury. J Am Coll Surg. 2018;226(5):769–76.e1. doi:10.1016/j.jamcollsurg.2018.01.047.
126. BenÍtez CY, Ottolino P, Pereira BM, Lima DS, Guemes A, Khan M, Ribeiro Junior MAF. Tourniquet use for civilian extremity hemorrhage: systematic review of the literature. Rev Col Bras Cir. 2021;48:e20202783. doi:10.1590/0100-6991e-20202783.
127. Tien HC, Jung V, Rizoli SB, Acharya SV, MacDonald JC. An evaluation of tactical combat casualty care interventions in a combat environment. J Am Coll Surg. 2008;207(2):174–8. doi: 10.1016/j.jamcollsurg.2008.01.065.
128. Kragh JF, Jr., Baer DG, Walters TJ. Extended (16-hour) tourniquet application after combat wounds: a case report and review of the current literature. J Orthop Trauma. 2007;21(4):274–8. doi:10.1097/BOT.0b013e3180437dd9.
129. Mikdad S, Mokhtari AK, Luckhurst CM, Breen KA, Liu B, Kaafarani HMA, Velmahos G, Mendoza AE, Bloemers FW, Saillant N. Implications of the national stop the bleed campaign: the swinging pendulum of prehospital tourniquet application in civilian limb trauma. J Trauma Acute Care Surg. 2021;91(2):352–60. doi:10.1097/TA.0000000000003247.
130. Pillgram-Larsen J, Mellesmo S. [Not a tourniquet, but compressive dressing. Experience from 68 traumatic amputations after injuries from mines]. Tidsskr Nor Laegeforen. 1992;112(17):2188–90.
131. Sabate-Ferris A, Pfister G, Boddaert G, Daban JL, de Rudnicki S, Caubere A, Demoures T, Travers S, Rongieras F, Mathieu L. Prolonged tactical tourniquet application for extremity combat injuries during war against terrorism in the Sahelian strip. Eur J Trauma Emerg Surg. 2022;48(5):3847–54. doi:10.1007/s00068-021-01828-4.
132. Tatebe LC, Schlanser V, Hampton D, Chang G, Hanson I, Doherty J, Issa N, Ghandour H, Kingsley S, Stewart A, et al. The tight rope act: a multicenter regional experience of tourniquets in acute trauma resuscitation. J Trauma Acute Care Surg. 2022;92(5):890–6. doi:10.1097/TA.0000000000003491.
133. Holcomb JB. Transport time and preoperating room hemostatic interventions are important: Improving outcomes after severe truncal injury. Crit Care Med. 2018;46(3):447–53. doi:10.1097/CCM.0000000000002915.
134. Cone DC, Wydro GC, Mininger CM. Physician field response: a national survey. Prehosp Emerg Care. 2000;4(3):217–21. doi: 10.1080/10903120090941227.
135. Pietsch U, Strapazzon G, Ambühl D, Lischke V, Rauch S, Knapp J. Challenges of helicopter mountain rescue missions by human external cargo: need for physicians onsite and comprehensive training. Scand J Trauma Resusc Emerg Med. 2019; 27(1):17. doi:10.1186/s13049-019-0598-2.
136. Apodaca A, Olson CM, Jr., Bailey J, Butler F, Eastridge BJ, Kuncir E. Performance improvement evaluation of forward aeromedical evacuation platforms in operation enduring freedom. J Trauma Acute Care Surg. 2013;75(2):S157–S163. doi:10.1097/TA.0b013e318299da3e.
137. Wilson SL, Gangathimmaiah V. Does prehospital management by doctors affect outcome in major trauma? A systematic review. J Trauma Acute Care Surg. 2017;83(5):965–74. doi:10.1097/TA.0000000000001559.
138. Knapp J, Häske D, Böttiger BW, Limacher A, Stalder O, Schmid A, Schulz S, Bernhard M. Influence of prehospital physician presence on survival after severe trauma: systematic review and meta-analysis. J Trauma Acute Care Surg. 2019; 87(4):978–89. doi:10.1097/TA.0000000000002444.
139. Carness JM, Wilson MA, Lenart MJ, Smith DE, Dukes SF. Experiences with regional anesthesia for analgesia during prolonged aeromedical evacuation. Aerosp Med Hum Perform. 2017;88(8):768–72. doi:10.3357/AMHP.4760.2017.
140. Lopez S, Gros T, Deblock N, Capdevila X, Eledjam JJ. [Multitruncular block at the elbow for a major hand trauma for prehospital care]. Ann Fr Anesth Reanim. 2002;21:816–9.
141. Chesters A, Webb T. Ketamine for procedural sedation by a doctor-paramedic prehospital care team: a 4-year description of practice. Eur J Emerg Med. 2015;22(6):401–6. doi:10.1097/MEJ.0000000000000241.
142. Maningas PA, Robison M, Mallonee S. The ems response to the Oklahoma City bombing. Prehosp Disaster Med. 1997;12(2):9–14. doi:10.1017/S1049023X0003733X.
143. Porter KM. Prehospital amputation. Emerg Med J. 2010;27:940–2. doi:10.1136/emj.2009.074500.
144. Kampen KE, Krohmer JR, Jones JS, Dougherty JM, Bonness RK. In-field extremity amputation: prevalence and protocols in emergency medical services. Prehosp Disaster Med. 1996;11(1): 63–6. doi:10.1017/s1049023x00042370.
145. Emmerich BW, Stilley JAW, Sampson CS, Horn BG, Pollock KE, Stilley JD. Prehospital amputation: an experimental comparison of techniques. Am J Emerg Med. 2020;38(7):1305–9. doi:10.1016/j.ajem.2019.09.002.
146. Jakob DA, Minneti M, Benjamin ER, Lam L, Schellenberg M, Matsushima K, Demetriades D, Inaba K. Practical assessment of different saw types for field amputation: a cadaver-based study. Am J Emerg Med. 2021;45:11–6. doi:10.1016/j.ajem.2021.02.034.
147. Leech C, Porter K. Man or machine? An experimental study of prehospital emergency amputation. Emerg Med J. 2016;33(9): 641–4. doi:10.1136/emermed-2015-204881.
148. Kelly JB, Thompson AS, 3rd, Gervin AA. Field leg amputation by a paramedic. Prehosp Emerg Care. 1999;3(1):77.
149. Lockey D. Pre-hospital critical care at major incidents. Br J Anaesth. 2022;128(2):e82–e85. doi:10.1016/j.bja.2021.10.002.
150. Bounes V, Concina F, Lecoules N, Olivier M, Lauque D, Ducasse JL. [physician staffed ambulances are better for patients' analgesia on arrival at the emergency department]. Ann Fr Anesth Reanim. 2010;29:699–703. doi:10.1016/j.annfar.2010.06.018.
151. Scott C, Putnam B, Bricker S, Schneider L, Raby S, Koenig W, Gausche-Hill M. The development and implementation of a Hospital Emergency Response Team (HERT) for out-of-hospital surgical care. Prehosp Disaster Med. 2012;27(3):267–71. doi:10.1017/S1049023X12000660.
152. Sharp CF, Mangram AJ, Lorenzo M, Dunn EL. A major metropolitan "field amputation" team: a call to arms and legs. J Trauma. 2009;67:1158–61.
153. Ummenhofer W, Scheidegger D. Role of the physician in prehospital management of trauma: european perspective. Curr Opin Crit Care. 2002;8(6):559–65. doi:10.1097/00075198-200212000-00013.
154. EMS physician-performed clinical interventions in the field. Prehosp Emerg Care. 2018;22:390–1.
155. EMS physician-performed clinical interventions in the field. Prehospital Emergency Care. 2018;22:390–1.