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Anthony MacIntyre
University of Witwatersrand

Efraim B. Kramer
University of Witwatersrand

Bruno P. Petinaux
George Washington University

Trevor Glass
University of Witwatersrand

Charmaine M. Tate
New Zealand Urban Search and Rescue, Wellington, NZ

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SPECIAL FOCUS

Extreme Measures: Field Amputation on the Living and Dismemberment of the Deceased to Extricate Individuals Entrapped in Collapsed Structures

Anthony Macintyre, MD; Efraim B. Kramer, MD; Bruno Petinaux, MD; Trevor Glass; Charmaine M. Tate, MD

ABSTRACT

Collapsed structures, typically as a result of earthquakes, may result in individuals entrapped by their limbs under heavy structural elements. In addition, access to living persons may be blocked by the deceased. Individuals are often critically ill by the time they are found, and rapid extrication is warranted. This and other factors may necessitate field amputation of an extremity on a living person or dismemberment of the deceased to achieve a rescue. Although case reports have described industrial, mining, and transportation accidents, few discuss this potential in collapsed structures. Also, few specifically outline the indications or the decision process and associated administrative procedures that should be addressed before conducting these procedures. This report presents a review of the literature along with a limited case series. A discussion regarding relevant decision making is provided to encourage the development of protocols. An international consensus statement on these procedures is provided.

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Key Words: field amputations, earthquake, dismemberment, disaster, Urban Search and Rescue, collapsed structure medicine, confined space rescue, INSARAG

The collapse of a structure with entrapment of individuals represents a very dangerous environment for entrapped persons and rescuers alike. Earthquakes are one of the most frequent causes of this type of situation. Although many survivors are extricated through the efforts of bystanders and first responders,¹⁻³ some may be entrapped to such a degree that highly specific expertise and equipment are required to provide safe rescue. The challenges are exponentially increased when the structures involved are reinforced concrete. Urban Search and Rescue efforts have evolved internationally during the past several decades as a distinct discipline to address the medical, search, and rescue techniques required to locate and safely extricate these persons.^{4,5}

It is well documented that some deeply entombed individuals may survive for extended periods in a confined space before being rescued.⁶ Although extreme times to survival have been documented, the majority of entrapped persons are rescued within 5 to 6 days.⁷ Multiple factors contribute to their ability to survive. Access to food (coincidentally located with the person), water (eg, rain), and minimal injuries from the initial collapse have all been documented as contributing factors (among others) to lengthen times to rescue.⁷ Preexisting medical conditions would presumably affect survivability; however, multiple case reports describe successful rescues of persons with co-existing morbidity or those who are young or elderly.⁷

Having early medical care while still entrapped is also cited as a factor contributing to the individual's survival, as there is a high potential for injuries such as crush syndrome, which could cause sudden deterioration or death during extrication.^{8,9} The most critical factor related to survival is the development of a void space (also referred to as "survival space") that is large enough to permit maintenance of vital functions. For this reason, search techniques are, in part, based on identifying potential void spaces in the collapsed structure that could support life.¹⁰

Due to the chaotic fashion in which structures collapse, individuals may become entrapped in such a way that their extremities become pinned under heavy structural elements. In addition, densely populated structures may result in persons becoming entrapped in close proximity to or even entwined with other survivors or the deceased. Both situations create challenges for rescue teams. In the former, great effort may be required to release, breach, or otherwise shore up the structural elements in an effort to remove the individual. Some of these efforts can evolve over many hours, with day-long rescues being common.⁷ In extreme cases, extremity amputation may be necessary to remove the person from the environment. Similarly, when persons are entrapped with the deceased, extreme circumstances may force dismemberment of the deceased to gain access to and remove a living person. These highly sensitive procedures should be ones of last resort and protocol driven.

In this way, appropriate application is assured in the chaotic and dangerous collapsed structure environment, which may also be extremely politically and culturally sensitive. Protocols must address not only technical aspects of the procedures but, perhaps more importantly, administrative ones as well.

This report discusses the relevant literature and provides several case studies to promote effective understanding of amputations and dismemberments in collapsed structures. Also included are technical considerations and administrative approaches for these procedures, which should be considered ones of last resort. Table 1 includes guidance established by an international body.

LITERATURE REVIEW

The literature search was conducted using the terms “amputation” or “dismemberment” in conjunction with numerous different hazards (eg, field, earthquake, accident, train, motor vehicle, industrial, mining) and the search engines PubMed, Ovid, and LexisNexis. The international literature from 1960 to the present was included. Particular attention was paid to indications for field amputations or dismemberments and management issues related to these procedures. Few publications that addressed these infrequent procedures were found. Some provided case reports related to the transportation sector or industry.¹¹⁻¹⁶ Only one directly addressed the procedure performed in the collapsed structure environment.¹⁶ One publication described an amputation conducted by a paramedic under indirect medical supervision.¹⁷ One group tested the ability to use hydraulic cutting tools frequently carried by fire departments to perform the procedure using cadaver legs.¹⁸ They demonstrated minimal tissue damage with use of the tool.

Some of the articles address to varying degrees of specificity team composition, required medical equipment, necessary protective equipment, or protocols.^{11,16,19-22} One author conducted a survey of North American emergency medical service (EMS) systems and found a general lack of protocols for field amputation to extricate victims.²³ Of 143 surveys completed, 13% reported the occurrence of in-field extremity amputation in the preceding 5 years. The majority of respondents (96%) reported a lack of training and preparation for this procedure, and only 2 respondents (<1%) indicated the existence of protocols. Two authors included the issue of informed consent, agreeing that if the person is unconscious, it is most desirable to have 2 physicians document the need for the procedure.^{20,21} One of these authors also addressed other considerations in protocols such as “communications, media interactions, crowd and rescue personnel control, and debriefing of EMS personnel.”²¹

One of the earliest references found that related to field amputation for entrapment was published in 1967.²⁴ This author proposed amputation when the “patient cannot otherwise be extricated in time to save his life.” Another early publication included a case report of a worker trapped by both legs after a partial bridge collapse; bilateral lower extremity amputations

were indicated, in part, out of fear for rescuers’ safety.¹² Only one publication in this review proposed specific indications for field amputation for the entrapped victim.²² Porter proposed that the procedure is indicated when (1) scene characteristics provide immediate threats to the patient or rescuers, (2) the person’s clinical indication is such that the person will die with further delay, and (3) the limb remains minimally attached. In addition, this was the only publication found that specifically mentions dismemberment of a deceased victim. In this case, the author proposed that dismemberment be considered if the deceased is blocking access to potentially live casualties.

CASE STUDIES

Four case studies briefly highlight the complexities involved with field amputations for the living or dismemberment of the deceased. One of the dismemberment cases was *not* conducted to gain access to a living person. All cases occurred in collapsed structures of heavy reinforced concrete as the result of an earthquake within the past decade. The case studies are de-identified by the individual and also by the incident, as these were extreme instances and were covered in media publications. The procedures were carried out by professional Urban Search and Rescue teams. The authors were present, although not necessarily conducting the procedures.

Amputation Case 1

Circumstances of Entrapment

During an earthquake, a 25-year-old woman became trapped at ground level in a 3-story structure that had completely collapsed. The upper floors collapsed toward the street, falling over the woman at a 45° angle and entrapping her under 3 concrete slabs. She was in a void space that was created by a steel door and a large drum. She was prone, with her right arm under the collapsed slabs of concrete, which were supporting the debris field above. Her fingers could be seen from the other side of the slabs. She was originally located by voice call-out.

Reason for Procedure

Efforts to remove the concrete slabs pinning the woman’s arm were judged to be too dangerous. The potential risk of destabilizing the structure and debris field was considered too high, threatening the woman and the rescuers alike.

Administrative Issues Addressed

Representatives from the multidisciplinary on-site Urban Search and Rescue team, which included rescue, safety, medical, and engineering personnel, provided input into the final decision to perform the amputation of her arm. In addition, representatives from 2 other international Urban Search and Rescue teams were consulted. Based on the risks presented, all supported the decision to amputate. The woman had altered sensorium and attempts to explain the procedure to her were futile. No family members were available. Three physicians from the multiple teams present agreed that the procedure was necessary.

TABLE 1

Medical Working Group Clinical Guidance Note: Amputations and Dismemberment

Approved by INSARAG Steering Committee: February 2011

1. Background

1. Amputations (live victims) and dismemberment (deceased) have always generated much discussion in the USAR community and is a complex issue with social, religious, and ethical aspects to be considered. Though there may be rare situations in which these two procedures are indicated as a last resort, the better course of action is to avoid these if at all possible.

2. Amputations**2.1 Preprocedure****2.1.1 Decision Making**

1. The single most important aspect to consider regarding performing prehospital amputations is the decision-making process as to whether it will be performed.
2. There are numerous potential ethical, moral, cultural, and religious implications as well as the clinical and psychological complications associated with prehospital amputation. This is compounded in situations when the procedure is performed by a medical professional in a foreign country affected by a disaster.
3. There are multiple international limb salvage score criteria. These are intended for use in the controlled environment of the operating theatre with full access to the victim and even these can be questioned retrospectively when applied. It is unrealistic to expect the USAR medical provider to make a determination as to whether a limb is salvageable or not in the collapsed structure environment.
4. Therefore, amputation should be considered a procedure of absolute last resort when:
 - a) The patient's clinical condition is life threatening and requires immediate disentanglement and extrication to facilitate resuscitation
 - b) Hazards present an impending threat to life of the victim or the USAR team members
 - c) Under circumstances when the degree of patient entrapment and entanglement is such that, even after an exhaustive multidisciplinary review of alternative options, amputation provides the only viable means to extricate the patient
5. It is therefore strongly recommended that the USAR team establish and implement a decision-making process with regard to amputations. Ideally, this should include a procedure and equipment checklist to be used in the field. It is also recommended that teams carry minimal equipment and supplies to perform and/or complete a prehospital amputation.
6. Essential persons in the decision-making process should include:
 - a) Treating medical professional
 - b) Patient (if possible/practical)
 - c) Family members (if possible/practical)
 - d) USAR team medical manager
 - e) USAR team leader/deputy team leader
 - f) Representative from LEMA (if possible/practical)
7. It is recognized that in some circumstances it may not be possible or practical to consult with all or any of the persons described above. A recommended practice in this situation should be to consult at least one other medical professional, even if they are a member of another USAR team.
8. Other factors to consider include:
 - a) The available receiving medical facilities and the level of care available to provide the required ongoing management and support to a postamputation patient
 - b) The availability of a suitably qualified medical professional to perform the procedure
 - c) The availability of the appropriate equipment and medication to perform the procedure and postprocedure care

2.1.2 Preparation

1. Once the decision to perform an amputation has been made, the following should be established or conducted:
 - a) A mode of transport to immediately transfer the patient postextrication
 - b) The most appropriate available medical facility to receive the patient
 - c) An individual to assist the primary care provider with the procedure (ideally a health care professional)
 - d) The appropriate equipment and medication for the procedure is available on-site
 - e) Adequate preparation of personal protective equipment e.g., additional gloves; protective garments, goggles, etc.
 - f) A briefing with all rescue personnel directly involved with rescue support during the procedure regarding the medical plan of action
 - g) An equipment assembly point as close to the patient and in the most "sterile" conditions possible
 - h) If possible or practical, document the decision-making process
 - i) Consider environmental constraints imposed by a confined space environment e.g., limited patient access, lighting, and noise

2.1.3 Procedure

1. This guideline focuses on the amputation procedure. The underlying principles consistent with trauma resuscitation apply. For additional information on the provision of medical care in austere environments, refer to the MWG Medical Guidance Note *The Provision of Medical Care in an Austere Environment, Specifically in a Confined Space*.
2. This procedure should only be performed by a suitably trained physician or other medical professional (e.g., paramedic; nurse) under the direct supervision of a physician.

2.1.3.1 Anaesthesia and Analgesia

1. There are well documented methods of providing appropriate and adequate anaesthesia and analgesia in prehospital environments. USAR medical professionals are obligated to ensure adequate anaesthesia and analgesia, during and postprocedure.

2.1.3.2 Technique

1. The World Health Organization (WHO) has established practice guidelines on amputations in disaster situations, refer to *Best Practise Guidelines on Emergency Surgical Care in Disaster Situations, Section 12, Amputations*, pages 15-17.
2. In the confined space environment, the following points must be considered:
 - a) Consider the administration of an appropriate broad-spectrum antibiotic, if available, as soon as possible
 - b) Consider the administration of tetanus prophylaxis, if available, as soon as possible
 - c) Attempt to conduct the procedure with the most "sterile" technique possible; surgical site preparation should still be considered within the restrictions of the confined space environment whenever possible or practical
 - d) Proximal control of haemorrhage is paramount pre and postprocedure
 - e) A guillotine amputation performed as distally as possible on the affected limb/s is the preferred method
 - f) It is recommended that use is made of a wire saw e.g., Gigli saw, rather than a fixed-blade saw, as it is more suitable in a confined space environment
 - g) Make a note on the patient's limb as to the time of the amputation
 - h) Maintain vigilant of the risks posed by surgical instruments, bone fragments, and body fluids during the procedure
 - i) Apply antiseptic agent to the amputated stump if available and dress the wound appropriately
 - j) If a tourniquet has been applied, leave the tourniquet in situ until the patient is handed over to the most appropriate medical facility available

(continued)

TABLE 1

Medical Working Group Clinical Guidance Note: Amputations and Dismemberment (continued)

Approved by INSARAG Steering Committee: February 2011

2. Amputations

2.1.4 Postprocedure

- a) Maintain adequate levels of anaesthesia and analgesia during the extrication process
- b) Maintain haemorrhage control and ensure that it will remain effective during the extrication process
- c) Ensure adequate covering of the amputation part that remains in the rubble. This is to reduce the risk of physical exposure or injury as well as the potential detrimental psychological effects
- d) Attempt to forewarn the receiving medical facility of the patient's clinical condition and arrival
- e) Ensure completion of appropriate documentation as time permits
- f) Due to the potential adverse psychological impacts of performing this procedure, adequate debriefing for all personnel involved is recommended
- g) Notify all the relevant parties as to the procedure undertaken e.g., OSOCC; LEMA

3. Dismemberment

1. As with prehospital amputation, the single most important aspect to consider regarding performing dismemberment is the decision-making process. In fact, dismemberment in some countries may be illegal. The decision-making process, personnel involved, and procedure are similar to those for prehospital amputation as described above. However, the reasons for this procedure differ e.g.:
 - a) It's the only way to gain access to a live victim
 - b) To remove a risk to USAR personnel
2. There are critical issues to be considered with regard to handling and recovering the deceased that are applicable to performing dismemberment. Refer to MWG Medical Guidance Note *Recovery of Deceased During USAR Operations*.

Last revised: January 2011. Abbreviations: INSARAG, International Search and Rescue Advisory Group; LEMA, Local Emergency Management Authority; MWG, Medical Working Group (INSARAG); OSOCC, On-site Operations Coordination Centre (UN); USAR, Urban Search and Rescue.

Patient Outcome

The procedure was performed after the patient was administered midazolam and ketamine. The entire procedure took less than 5 minutes. She was subsequently rapidly extricated and transported to a field hospital. She was discharged from this facility in ambulatory condition 3 days later.

Amputation Case 2*Circumstances of Entrapment*

An approximately 50-year-old man became entrapped on the ground level of a large multistory structure, which collapsed during an earthquake. He had been located by voice call-out and was in a relatively large empty space (permitting 2 rescuers to gain access to him simultaneously), but both his legs were crushed by a large structural beam. The left leg was pinned at the knee and the right at the level of the mid-tibia. No access to the feet was possible.

Reason for Procedure

By the time access was gained (>48 hours after the earthquake), the man was in a severe condition, with signs of shock and an altered mental status that persisted in spite of resuscitation efforts and treatment for crush syndrome. Given the potential time duration until multiple floors above the beam could be removed and with no possibility of undermining the floor, 2 different international Urban Search and Rescue teams agreed that amputation of both his lower extremities was necessary to facilitate rapid extrication before he died.

Administrative Issues Addressed

The decision to amputate was agreed to by 1 physician on each team. No family was available, and the man had an altered sensorium. Owing to his critical condition, an evacuation process was established before conducting the procedure; this included having a helicopter basket lift from a nearby clearing with an attendant on the line.

Patient Outcome

It was determined that the man's airway required control, and rapid-sequence intubation was done while he was still entrapped. A small monitor was used to monitor his vital signs. Treatment for crush and anesthesia/analgesia were administered. Bilateral amputations were performed (above the knee on the left and mid-tibia-fibula amputation on the right). The man was airlifted to definitive care. He died 3 days after extrication.

Dismemberment Case 1*Circumstances of Entrapment*

An indeterminate-aged adult man was trapped on the first floor of a large multistory structure that had completely collapsed as a result of an earthquake. The man was dead on initial encounter and was positioned so that his body blocked access to a woman who was alive and trapped in a small void space.

Reason for Procedure

The large volume of debris (multistory) limited access to both people through a single passageway that was tunneled under the foundation of the structure. The collapse pattern prohibited any further breaching, delayering, shoring, or other activity that could improve access. The deceased man, whose left lower extremity was pinned between 2 large concrete slabs, blocked access to the woman. Verbal contact with the living person revealed a state of confusion.

Administrative Issues Addressed

The Urban Search and Rescue team decided to conduct a dismemberment of the man to gain timely access to the woman. An individual at the site was confirmed to be a family member of the deceased man. The team members explained to him the recommended approach to rescue the living woman. After the family member consulted with other nearby members of the family, he granted permission for the dismemberment to occur.

Field Amputations

Patient Outcome

The man was removed after dismemberment of the lower extremity. The woman was rescued after another approximately 6 hours and transferred to a field hospital; she survived her injuries.

Dismemberment Case 2

Circumstances of Entrapment

A middle-aged adult man was trapped under a large slab of unstable sloping concrete on the third floor of a multistory structure that had undergone a pancake collapse as a result of an earthquake. The man was alive on initial encounter but soon died from his injuries. Although easily accessible, the area around the man was extremely dangerous, as the structure was unstable and the large concrete slab could not be moved without threatening total structural collapse.

Reason for Procedure

The deceased had been initially conscious and able to *confirm his identity*. All surviving victims had been recovered from the collapsed structure, and a cautious deconstruction process ensued using heavy machinery to retrieve the remaining deceased. Due to the instability of the structure and associated safety risks, a complete collapse might result from the process. If this were to occur, the ability to recover other deceased victims intact or in an identifiable state might be compromised. Because the exposed, deceased man was positively identified, a decision was made to retrieve his body before the deconstruction of the collapsed building. The man's right arm from the high shoulder and his complete right hind quarter were pinned under the large sloping concrete slab.

Administrative Issues Addressed

The engineering team managing the deconstruction process was consulted to determine the risks associated with conducting dismemberment and to verify the need for the procedure (ie, potential for blocking retrieval of other deceased). After concurrence from the coroner's office, the Urban Search and Rescue team decided to conduct the dismemberment.

Patient Outcome

The man was removed after dismemberment of the upper extremity and lower hind quarter. His body was transferred to the local coroner.

COMMENT

It is often difficult to extricate people entrapped in collapsed structures. Rescue can be complicated by both the entrapment of limbs and obstructions posed by deceased individuals blocking access to survivors. Amputation of the living person's limb(s) or dismemberment of a deceased person's limbs to retrieve the living should be considered procedures of last resort. As unsettling a topic as this might be, the need for these procedures is real, although infrequent, as highlighted in the cited case studies.

All planning must account for the unique environmental considerations in collapsed structures. Multiple hazards may pose a

risk to the entrapped person and the rescuer alike. The collapsed structure environment may be made hazardous by the presence of inhalational contaminants, other chemical hazards, unsecured utilities, or environmental extremes. In many instances, these hazards may be mitigated before rescue attempts are made; in some cases, they cannot. Collapsed structures themselves are a significant risk, as they are often unstable and at risk of secondary collapse (with or without aftershock). Even if the main structure is stable in its collapsed position, significant risk may be posed by unstable overhanging hazards.

Extrication planning should consider parameters specific to the person caught in the collapsed structure. The physical space where these individuals are entrapped is often very small, allowing limited access. In many instances, only 1 provider/rescuer can gain access to the person at any one time. In some cases, the rescuer may need to back out and change position to achieve a different orientation before re-entering the confined space to perform the required task. Also, the presenting body part of the entrapped person may be at odd angles and/or below or above the rescuer. Full access to the individual's body is rare, and adequate room for large equipment or monitors even rarer. All of these considerations can make the simplest procedure challenging. When considering more complex procedures such as amputation, evaluation of the capability to even perform this procedure must occur first.

Finally, the multiple medical conditions that people in these situations have play a large role. Airway compromise and hypoxia are possible, although, if severe, the patient probably will have died before the rescuer gains access. More commonly, severe volume depletion with metabolic derangements can present life-threatening situations. Traumatic injuries that remain untreated for a prolonged period can increase the chance of a person being in critical condition. For example, sepsis associated with penetrating wounds and open fractures become life-threatening. Crush syndrome, referred to in the rescue literature as "smiling death" or the "grateful dead" syndrome, is an ever-present concern in which a person's condition may suddenly deteriorate as compressive forces are removed from muscle mass. The individual's condition suddenly deteriorates from third-space sequestration of fluids or the release of anaerobic metabolites or potassium into the general circulation from the damaged muscle. These and numerous other reasons increase the imperative to treat the entrapped person as soon as access permits and achieve extrication in an efficient manner; otherwise, the individual may die before extrication.

Few published reports have clearly articulated indications for amputations to free entrapped persons.²² No publication was found that addresses the decision process and associated relevant administrative activities. The indications for amputation are proposed, which differ slightly than those proposed by Porter:

- The person's clinical condition is such that any delay in extrication could cause loss of that individual's life.

- The environment poses such a high-level risk to person AND rescuer such that it cannot be ameliorated and is immediately life-threatening.
- The individual's degree of entanglement or entrapment is such that extrication is not possible without amputation.

This last indication is the most difficult to ascertain of the 3 and ideally should be determined after input from a multidisciplinary team including rescuers, medical personnel, structural engineers, and other relevant persons.

As noted, Porter includes a fourth indication for amputation: when the limb is horrifically mangled and minimally attached to the body.²² This indication may be better placed in a different category of "completion of an amputation." Osmond-Clarke proposes the application of various limb-salvage scoring criteria.²⁴ Unfortunately, many of these criteria have been developed for the sterile environment of the surgical suite, where full access to the person is available. It is unrealistic to apply these criteria in collapsed structures. A recent publication by Jasper questions the application of these scoring criteria in the military arena as they often do not account for the heavily contaminated wounds seen in conflicts and (by these authors' estimation) this extends to the collapsed structure environment.²⁵

Important managerial considerations influence the decision process and relate to the medical indications. All of the following questions should be answered before amputation is considered.

- Does it need to be done? Careful review of the medical indications should occur. In a chaotic environment, decisions may become pressured and finalized in a rapid fashion. Evaluation of the indications should preferably be conducted by 2 medical providers and documented, if possible. Consultation with other disciplinary experts should occur for the third indication (ie, degree of entanglement), which can be the most challenging to definitively discern.

Alternatives may often be found that are not immediately self-evident, especially to the medical provider. Undermining, breaching from a different position, or angling the extremity in a different fashion may permit rescue without amputation. One author (A.G.M.) has participated in 2 rescue scenarios in which amputations were considered but not needed because repositioning of the extremity (and the person), with appropriate analgesia, ultimately permitted release. Consultation with experts in other disciplines also provides the element of "exploring all possible alternatives with the view to saving the limb," which may be relevant if issues arise afterward. Finally, photographs of the entrapment may be considered for documentation purposes.

- Can it be done? The physical ability to perform the procedure should be evaluated. As noted, performance of the procedure can be difficult, if not impossible, in the space available. Even with additional delayering, space may not be adequate. It may be difficult to obtain anesthesia and analgesia or, likewise, to support the entrapped person's airway adequately. Also, appropriate equipment may not be immediately available. It is the opin-

ion of the authors of this report that rescue equipment such as saws and cutters are not viable alternatives to surgical equipment, and space constraints may preclude the use of these bulkier devices. A medical provider who is not only trained in the procedure but who is familiar with the hazards and challenges posed by collapsed structures is preferable. These considerations should be factored into the final decision-making.

- Does the patient want it to be done (if conscious)? If the patient is conscious, consent should be sought before performing the procedure. The practicality of this may seem challenging, but is necessary nonetheless. Consent may not need the degree of detail that exists in health care facilities (ie, documented informed consent), but witnessed verbal agreement from an awake and alert patient is minimally sufficient. The case for implied consent in an unconscious person can be argued, although any situation can be challenged in retrospect (even with good outcomes). As proposed in the literature, having 2 concurring, on-scene physicians is ideal but not always practical.
- Does the patient's family (if available) want it to be done? In the case of minors or incapacitated persons, seeking out the family to obtain consent may be feasible, if expedited. At a minimum, involving the patient's family in decision-making and keeping them informed is a good practice, as with all medical interventions.
- Do local culture and authorities permit it to be done? In some countries, the cultural stigma associated with amputees is significant, particularly those associated with field amputations to perform extrication.²⁶ Interaction with local authorities should occur if the rescue team is not local to inform the authorities of the imminent procedure and its indications. Situations may arise in which local authorities will not permit such a procedure (eg, by people from another country) or in which religious considerations play a role.
- Can it be done safely? The hazards cited here should be considered. In addition, other factors can contribute to an unsafe environment, such as a combative person, the release of body fluids, or presence of large crowds. In most cases, these can be addressed prospectively.

Technical considerations for amputation in collapsed structures are summarized in Table 2. It is beyond the scope of this publication to review the detailed procedure further, but important considerations occur in situations of a confined space (as opposed to a hospital).

In many ways, dismemberment of a deceased individual parallels the amputation process. The authors of this report believe that the only absolute indication is to permit access to a living person requiring rescue. Other indications that are less absolute are, for example, described in dismemberment case 2. In these instances, documenting the decision process and involving other available on-site specialty experts become even more important. Other than rescuing a living person, indications for dismemberment could include the following:

- Dismemberment of the individual provides the only safe means for rescuers to remove the deceased.

Field Amputations

- A deceased individual is pinned in a very public fashion and removal of the body can only occur expeditiously with dismemberment.
- Dismemberment can prevent further structural collapse that could cause difficulties such as identification of other deceased individuals in the collapsed structure.

As uncomfortable as it is to consider such a procedure, important administrative considerations for it parallel field amputations. For example, on-site family members should be consulted about the procedure and, if possible, provide permission (cf, dismemberment case 1). Local authorities and, if possible, medical examiners or disaster victim identification teams, should be included in the decision process as well. Other considerations include the following:

- Dismemberment in any situation should be limited to a limb of the deceased (in most instances, this is enough to remove

the individual). Other surgical procedures, such as hemi-corpectomy, are generally not indicated, potentially dangerous (eg, increasing chance for exposure to body fluid), difficult to perform in the collapsed structure environment, and emotionally challenging to the operator.

- Only a medical provider with appropriate training in collapsed structure situations and with the appropriate equipment should perform the procedure. Individuals not trained in anatomy or with inappropriate equipment (eg, rescue equipment) can encounter difficulties and actually make the procedure more difficult.
- Disposition of the body should be arranged before conducting the procedure.
- When possible, limbs that remain entrapped should be marked as matched to the deceased. If the limbs are subsequently recovered, they may be more easily reunited with the remains through more formal means of disaster victim identification.

TABLE 2

Technical Considerations for Field Amputations in the Collapsed Structure Environment

Process	Steps
Patient preparation	<ul style="list-style-type: none"> • Patient size: Ensure that extrication equipment and route are adequate for removal of patient once procedure is completed (eg, curves or corners in extrication route may dictate use of a half-back extrication device) • Preprocedure antibiotics: The environment prohibits a sterile field, and broad-spectrum antibiotics should be considered for either intravenous or intramuscular administration, depending on available agent • Airway management: Rapid-sequence intubation should not be considered mandatory. If not done, consider taking into confined space appropriate equipment for potential patient deterioration such as rescue airway devices. Note: oxygen in the confined space can be difficult to administer (device, access, limited supply) and can increase environmental risks such as fire or explosion • Patient monitoring: Confined spaces often preclude large monitors. Finger-pulse oximeters may be helpful if available. Monitoring chest excursions and pulse are the easiest parameters in this situation • Intravenous/intraosseous access: Almost always obtainable; if there is enough space to conduct amputation, then generally, there is enough space to initiate • Analgesia, anesthesia: Choice dictated in part by ability to control airway. In our experience, ketamine proved to be an excellent anesthetic in such a setting. Nerve blocks using local anesthetics (maintaining caution about total permissible dosages) may be considered • Blood-borne exposure protection can be difficult in this austere environment and may require unusual adaptations such as heavy plastic sheeting to provide barriers on rough, uneven surfaces
Preparation of limb	<ul style="list-style-type: none"> • Exposure of extremity: Remove debris and clothing as much as possible and as distal as possible. If possible, ensure space to move operator's arms to perform procedure • Wash: Brief irrigation of area with water (sterile if available) to remove fine debris • Antiseptic: Apply povidone-iodine or similar agent liberally to operative site (pour) • Tourniquet: Place tourniquet at least 2 in (5 cm) proximal to incision site (too close may interfere with procedure). Do not tighten until ready to conduct procedure. In our experience, both improvised and commercial tourniquets performed acceptably, but commercial may be easier and faster to apply
Amputation	<ul style="list-style-type: none"> • Administer anesthesia/analgesia: Titrate to achieve effect. Monitor parameters discussed here closely • Tourniquet: Tighten and secure in fixed position to prevent dislodging during procedure or extrication • Choose incision site: Incise as distally as possible. Assess space for adequate room to conduct procedure (eg, saw will fit, operator's hands will have room to move in the space) • Incise: Incise skin using large scalpel blade. Expect to use multiple scalpels as they may break or dull in this unusual environment (debris in wound, unusual angle for procedure). Having an accessory device (eg, Magill forceps) can help in removing broken blades from the field. Incise neurovascular bundles last, if possible, to avoid bleeding that cannot be seen or may be difficult to control. Guillotine amputation is preferred (stump can be revised later when patient is at a location for more definitive care) • Periosteum: Scrape bone to remove periosteum using scalpel if nothing else available • Bone: Cut the bone using available surgical tool. In our experience, gigli (flexible wire) saws are easier to use than fixed-handle saws due to space confinement. Attempt perpendicular cut; space limitation may require angled cut • Assess: Evaluate quickly for bleeding. (Note: bleeding may occur from distal limb as a result of back-bleeding.) Clamp excessively bleeding vessels (in most situations, suture ties are not practical) • Dressing: Apply large, bulky (compressive) dressing
Postprocedure	<ul style="list-style-type: none"> • Reassessments: Constant reassessment of person's overall status is important throughout extrication process. If lengthy, stop patient movement and reassess. Monitor status of tourniquet to ensure it's still in place and functioning throughout extrication • Anesthesia/analgesia: When person is outside the structure, more aggressive anesthesia and analgesia can be considered, including rapid-sequence intubation to protect airway, if not already done • Retrieval of amputated limb: Porter describes retrieval of the amputated limb (if possible) as a potential source for donor tissue/skin to aid in healing of the amputated stump.²² This should only be attempted if practical and safe

Amputation of a living individual's limb and dismemberment of a deceased individual's limb are serious but real prospects in collapsed structures. Consequently, an international organizing body has published its own recommendations regarding this topic. The International Search and Rescue Advisory Group (INSARAG) is an organizing body under the Office for Coordination of Humanitarian Affairs (OCHA)/Field Coordination Support Section (FCSS) within the United Nations. The Medical Working Group has been in operation for approximately 5 years within INSARAG, providing advice and protocols related to the medical aspects of international operations in the collapsed structure environment. Representation from multiple countries includes the Americas, Europe, the Middle East, Africa, the Pacific, and Asia. The group's efforts have resulted in the protocol included in the Table 1. These recommendations parallel those made in this report.

The concepts described herein apply to collapsed structures (usually reinforced concrete). Other situations also occur in which individuals become entrapped (eg, transportation sector accidents). Application of these recommendations may be helpful but should factor in the relevant parameters in those scenarios (eg, ease in which changes may be made to permit removal of a limb or of the deceased).

CONCLUSION

Desperate times may call for extreme measures. Collapsed structures may occur for a variety of reasons including earthquakes, bombings, and poor construction. In these environments, individuals may become entrapped such that the amputation of a limb may be necessary to allow their rescue. In addition, a deceased individual's limb may require amputation to permit access to a survivor. These measures should be considered extreme; very few situations in medicine parallel the decision-making process and necessary administrative procedures. For this reason, any organization that could potentially participate in such a procedure in response to collapsed structures or other incidents should establish prospectively protocols that outline necessary steps before and while conducting such a procedure. Having these in place can ensure that the right decision is made for the right situation.

Author Affiliations: Division of Emergency Medicine, Faculty of Health Sciences, University of Witwatersrand, Johannesburg, South Africa (Dr Kramer and Mr Glass); Division of Emergency Medicine, The George Washington University, Washington, DC (Dr Petinaux); New Zealand Urban Search and Rescue, New Zealand Defence Force, Wellington (Dr Tate).

Correspondence: Anthony Macintyre, MD, Professor of Emergency Medicine, The George Washington University, 2120 L St NW, Ste 450, Washington, DC 20037 (e-mail: amacintyre@mfa.gwu.edu).

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