Guidelines for Burn Care Under Austere Conditions: Introduction to Burn Disaster, Airway and Ventilator Management, and Fluid Resuscitation

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All disasters are local, and a burn mass casualty incident (BMCI) is no different. During the past 150 years, burn disasters have typically been associated with three factors: a fire/explosion in a mass gathering, natural disaster, or act of war/terrorism. Although the incidence of fire/explosion disasters has decreased during the past 50 years, recent natural disasters and acts of war/terrorism highlight the need for ongoing preparedness.[1] The goal of this missive is to provide a background for disaster preparedness and a framework for initial assessment in a burn mass casualty.

Historical Disasters

The Cocoanut Grove Night Club Fire (1942) in Boston, MA, resulting in 492 deaths, is perhaps the seminal BMCI.[2] This entertainment-based mass gathering burn disaster highlighted the need for building code legislation to ensure public safety. Equally important, the study of the events surrounding the Cocoanut Grove disaster provided the foundation for many basic tenants of modern burn treatment, including fluid resuscitation, inhalation injury, posttraumatic stress disorder, and topical burn treatment. These concepts have saved far more lives than were lost in the event. Despite improved technology and building codes, fires involving entertainment-based mass gatherings continue to occur, including the Volendam Café Fire in the Netherlands (2001) the Rhode Island Station Night Club Fire (2003), and the Kiss Night Club Fire (2013) in Santa Maria, Brazil.[3–5] Each of these disasters left >100 dead and burned. Burn disasters are not limited to fires in structures, however. Natural disasters (Haiti Earthquake-2010, Great East Japan Earthquake-2011) and war/terrorism (9/11 attacks-2001, Madrid Train Bombing-2004, and London Subway/Bus Bombings-2005) emphasize the need for broad-based disaster preparedness.[6–13]

Each type of disaster poses particular challenges. Incidents resulting in trauma, burn, or a combination of burn and trauma patients generate competition for scarce resources.[14] Health system infrastructure can be catastrophically destroyed and limit the ability to provide the accepted injury standard of care.[15] The use of thermonuclear explosive devices to intentionally destroy or injure poses the greatest threat to both infrastructure and resources.[16] More than 65 years have passed since thermonuclear weapons injured thousands in Hiroshima and Nagasaki.[17] Today a suitcase-sized highly enriched 5 to 20 kiloton nuclear weapon can produce the same result as the nuclear warhead in 1945. A tactical rocket-based nuclear warhead today has a 475 kiloton to 9 megaton yield; the resulting explosion would dwarf the number of injuries in Nagasaki.[18,19] Efforts and planning associated with disaster preparedness must thus match advances in destructive capability.

RATIONALE: FUNDAMENTALS OF BURN INITIAL ASSESSMENT AND TRIAGE

A BMCI occurs when the number of burn injuries exceeds available burn resources and exceeds the

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capacity of the local burn center to provide optimal care.[15,20,21] Nondisaster medical care criteria are not applicable in such situations. Patient volume and injury burden dictate a different approach. Surge capacity (in a disaster) is the balance of staff, space, and supplies (to include equipment and pharmaceuticals) available to meet the needs of a sudden influx of a large number of patients.[22] Surges of patients result in insufficient resources to serve all; hence, the concept of triage, in which resources are allocated to benefit the greatest number of injured individuals. Triaging patients requires a rapid, stream-lined approach and the willingness to limit care for one to benefit the many. Triage criteria must be easy to implement, especially for personnel unfamiliar with burn care management. For burn disasters, the aim is to reach a surge equilibrium by efficiently distributing patients (based on need) to available appropriate resources (staff, space, supplies, and transportation) in the region.[22] Although current medical standard of care for nondisaster burn management includes treatment at centers designed, staffed, and equipped for burn care within 24 hours of an incident, this is unlikely in a mass casualty situation.[20,21,23]

To appropriately triage patients, centers must be able to assess both capacity and capability. Capacity is typically discussed in terms of available designated burn beds and does not consider burn center capability. Capability encompasses the need for specialized personnel and support staff, operating rooms, supplies, equipment, and other related resources necessary for recovery and rehabilitation. Although sometimes used interchangeably, capacity and capability are not synonymous in terms of disaster operations. Acceptable practice is to consider diverting or providing secondary triage to another burn center once capacity is greater than 50% above traditional occupancy.[15,20,24,25]

An organized process for transporting multiple patients in a BMCI is critical to survivability.[26–29] Protocols and procedures must be in place before an event so that all EMS and health care personnel understand their respective roles and responsibilities. Many local jurisdictions and state EMS agencies already employ some form of a structured methodology based on immediate needs for sorting patients. Typically this is a color-coded system. Two of the more common systems include smart or simple triage and rapid treatment systems.[30,31] While specific parameters may vary slightly, it is universally accepted that the four principle groups with respective color codes denoting patient conditions are red/ immediate, yellow/delayed, green/minor, and black/ expectant.[30,31] This type of triage identifies an order in which care is to be administered, either on scene or on arrival at a surge facility.

BMCI ASSESSMENT AND TRIAGE

A benefit-to-ration triage decision table was developed and revised to provide an objective framework for BMCI treatment decisions (Table 1).[32,33] Patients are classified as 1) outpatient: <10% with no inhalation injury; 2) very high: mortality ≤10%, anticipated length of stay ≤14 to 21 days, 1 to 2 surgical procedures; high: mortality ≤10%, anticipated length of stay ≥14 to 21 days, multiple surgical procedures; medium: mortality 10 to 50%; low: predicted mortality 50 to 90%; and expectant: predicted mortality >90%. The revised triage decision table offers guidance in prioritizing burn patient transfer/treatment.

The revised triage decision tables also allow for some modification. Depending on the size and scope of an incident, classifications may be adjusted accordingly. For example, individuals designated as "low" or "expectant" may still be transferred to a burn center if or when a center is able to accommodate such a transfer. Grids also follow a color-coded format similar to other standard triage tag systems, further reinforcing ease of use. Decision tables, however, only address burn risk factors; scoring for concomitant traumatic injury or comorbidities must be taken into account when conducting a full triage assessment.[34]

Initial assessment of a burn patient begins with primary stabilization; maintaining a patent airway, ensuring adequate breathing and circulation, providing analgesia to manage pain and anxiety, assessing level of consciousness, and minimizing the risk of hypothermia.

Estimating extent and depth of a burn wound can be challenging, especially for personnel unfamiliar with this process. A common method to calculate extent of burn is "Rule of Nines"[20] (Figure 1). Estimates in infants and small children using the "Rule of Nines" must be adjusted to account for differences in head-to-body surface ratio in these age groups. Extent may also be estimated by Palmar method[20] (Figure 1). The size of the *patient's* palm, including fingers, represents approximately 1%. Palmar method is especially helpful when estimating scattered burns, is easy to remember, and may be particularly helpful in a disaster situation, where "Rule of Nine" charts may not be readily available. Regardless of which method is employed, only partial thickness or full thickness burns should be included in TBSA calculations.

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Table 1. Resource triage diagram for burn injury in a disaster

Age	0–9.9	10–19.9	20–29.9	30–39.9	40–49.9	50–59.9	60–69.9	70–79.9	80–89.9	≥90
Burn size group, % TBSA all										
0–1.99	Very high	Very high	High	High	High	Medium	Medium	Medium	Low	Low
2–4.99	Outpatient	Very high	High	High	High	Medium	Medium	Medium	Low	Low
5–19.99	Outpatient	Very high	High	High	High	High	Medium	Medium	Low	Low
20–29.99	Outpatient	Very high	High	High	High	Medium	Medium	Medium	Low	Low
30–39.99	Outpatient	Very high	High	High	Medium	Medium	Medium	Low	Low	Expectant
40–49.99	Outpatient	Very high	High	Medium	Medium	Medium	Medium	Low	Low	Expectant
50–59.99	Outpatient	Very high	High	Medium	Medium	Low	Low	Expectant	Expectant	Expectant
60–69.99	Outpatient	High	Medium	Medium	Low	Low	Low	Expectant	Expectant	Expectant
≥70	Very high	Medium	Low	Low	Low	Expectant	Expectant	Expectant	Expectant	Expectant
Burn size group, % TBSA no inhalation injury										
0–1.99	Very high	Very high	High	High	High	High	Medium	Medium	Medium	Medium
2–4.99	Outpatient	Very high	High	High	High	High	High	Medium	Medium	Medium
5–19.99	Outpatient	Very high	High	High	High	High	High	Medium	Medium	Low
20–29.99	Outpatient	Very high	High	High	High	Medium	Medium	Medium	Medium	Low
30–39.99	Outpatient	Very high	High	High	Medium	Medium	Medium	Low	Low	Expectant
40–49.99	Outpatient	Very high	High	High	Medium	Medium	Medium	Low	Low	Expectant
50–59.99	Outpatient	Very high	High	Medium	Medium	Low	Low	Expectant	Expectant	Expectant
60–69.99	Very high	High	Medium	Medium	Low	Low	Expectant	Expectant	Expectant	Expectant
≥70	High	Medium	Medium	Low	Low	Expectant	Expectant	Expectant	Expectant	Expectant
Burn size group, % TBSA with inhalation injury										
0–1.99	High	Medium	Medium	Medium	Medium	Medium	Low	Low	Expectant	Expectant
2–4.99	High	High	High	High	High	Medium	Medium	Medium	Low	Low
5–19.99	High	High	High	High	Medium	Medium	Medium	Medium	Low	Low
20–29.99	Very high	High	High	Medium	Medium	Medium	Medium	Low	Low	Expectant
30–39.99	Very high	High	High	Medium	Medium	Medium	Medium	Low	Low	Expectant
40–49.99	Very high	High	Medium	Medium	Medium	Low	Low	Low	Low	Expectant
50–59.99	High	Medium	Medium	Medium	Medium	Low	Low	Expectant	Expectant	Expectant
60–69.99	Medium	Medium	Medium	Low	Low	Low	Expectant	Expectant	Expectant	Expectant
≥70	Medium	Medium	Low	Low	Expectant	Expectant	Expectant	Expectant	Expectant	Expectant

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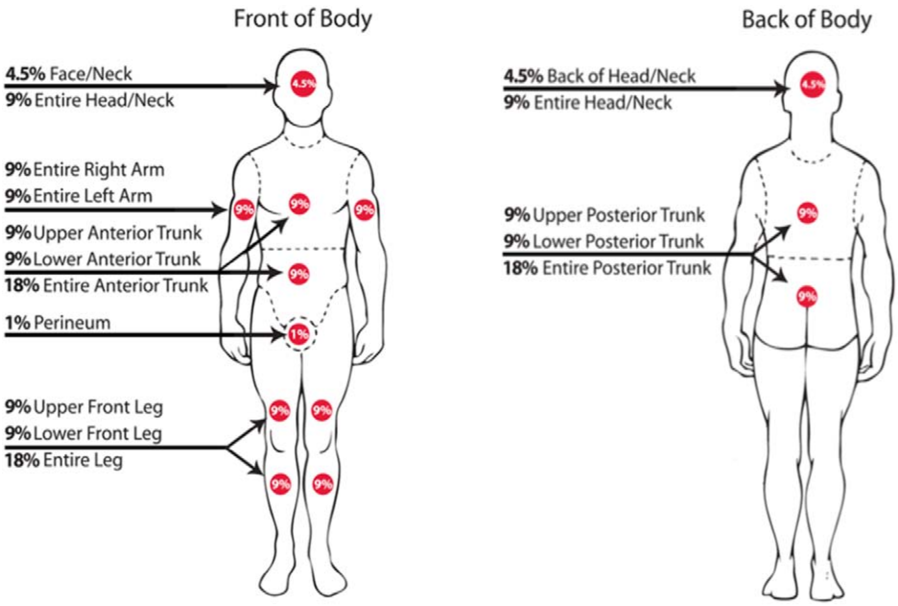

Figure 1. Depiction of the Rule of Nine's and Palmar Method of burn size estimation. For the Rule of Nines, each body region has a surface area in a multiple of nine. In the Palmar Method, the patient's palm represents approximately 1% of that patient's BSA. Reprinted with courtesy from The Burn Center at Saint Barnabas Medical Center, Livingston, New Jersey.

Mechanism of injury may provide valuable insight into potential underlying complications, concomitant trauma, or chemical injury. Other factors to consider include allergies, medications, past medical history, last meal and events/environment related to the injury.[20] If obtaining a tetanus history is unclear, or the most recent tetanus vaccination is more than 5 years and resources allow, consider revaccination.[22] As there is no definitive evidence regarding prophylactic antibiotic use early on in the burn process, antibiotics should not be administered prophylactically in the austere environment.[35,36] Baseline laboratory values such as hematocrit, chemistries, urinalysis, or chest x-ray may be beneficial for burns >15% TBSA.[20] Circumstances will likely limit any ability to perform such testing initially and these too may have to be deferred. Depending on the size and scope of an incident, the number of injured or the available personnel, detailed histories and physical exams may not be possible early on. Once conditions permit a complete head-to-toe assessment should be conducted and recorded for each patient.

Despite the circumstances of a disaster every effort should be made to ensure patients are stabilized, kept warm, and transported to (verified) burn centers. In situations where the number of injured exceeds capability of the local burn center, it may be necessary for patients to be referred to a regional burn center, not necessarily the nearest burn center. Transport arrangements should be coordinated in accordance with established local, regional, or national disaster plans. All available documentation should accompany the patient. Detailed information and extensive medical histories may not be readily available during the initial stages of a BMCI, thus triage tags should be completed as accurately as possible and remain with each patient to ensure continuity of care, as injured personnel are moved from one site to another. Additional detailed information including disaster triage, treatment, and transport of the patient with burn injuries may also be found on the ABA Web site; www.ameriburn.org.

DISCUSSION

Disaster scenarios range from those causing thousands of injuries (such as covert and concealed nuclear detonation or a catastrophic natural disaster) to a fire at a mass gathering. All will tax the American healthcare system. Each offers compelling concerns for how the medical system will respond and will require an altered standard of care taking into consideration the scarcity of supplies and personnel as well as the need for triage skills not typically currently used. Burn care providers are in a unique position to contribute to the disaster response and thus should be familiar with basic disaster principles.

Recommendations

- Sources of a burn disaster range from terrorist nuclear attacks to fires in a mass gathering and natural disruptions such as earthquakes.

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- All medical providers should be familiar with basic disaster tenets and apply these principles in a disaster.
- Disaster triage criteria should be implemented for patients resulting from a mass casualty incident. Centers should distinguish between capacity and capability.
- Burn patients should be stabilized in terms of airway, breathing, circulation, and fluid resuscitation and burn size estimated using Rule of Nines or Palmar method. If possible, transport patients to a (verified) burn center within 24 hours.

GUIDELINES FOR BURN CARE UNDER AUSTERE CONDITIONS: AIRWAY AND VENTILATOR MANAGEMENT

Introduction

Under normal circumstances, burn patients present with unique airway and ventilation challenges: presence of facial burns, distortion of normal upper airway anatomy by debris and edema, and inhalation of toxic gases resulting in lower airway and distal parenchymal damage complicate airway management. In addition, decreased lung compliance resulting from deep thoracic eschar and edema of the chest wall and abdomen make these patients particularly resource-intensive during resuscitation.[37] Even a few of these challenging patients could seem overwhelming to less-experienced providers early in the prehospital setting, into the emergency department, and well into the hospitalization. In the setting of mass casualty incidents, in which the sheer number of casualties may rapidly deplete all available local and regional resources, appropriate care may be daunting to even the most skilled providers.[38]

After the Pope Air Force Base crash in 1994 which resulted in 119 burn casualties, Phillips et al.[39] reported their experience from an anesthesia critical care perspective. They reported that items such as laryngoscopes, endotracheal tubes, and anesthetic agents were quickly depleted. In addition, ventilators were scarce, necessitating the need to "triage" the use of intubation and institution of mechanical ventilation. To achieve this, select providers conducted "airway rounds" to periodically evaluate intubated patients for extubation or to evaluate those at risk for respiratory failure. The lessons learned from this example could apply to similar local catastrophic events. However, a larger scale disaster (>1000 burn casualties) may involve an entirely different set of unforeseen problems. In this review, we anticipate the potential issues that could occur in large-scale mass-casualty situations to assist in optimizing care under austere conditions.

Rationale

Airway Management. Burn patient airway management requires a considerable amount of clinical judgment. Often, the establishment of a definitive airway may not be necessary in the prehospital setting if the patient is awake, alert, and able to ventilate and oxygenate on his own—even in the presence of large burns. When resources are limited, as they would be in a mass casualty situation, the decision to intubate is of critical importance. Signs or symptoms that may trigger the decision to intubate include 1) decreased mental status (secondary to direct trauma or to inhalation of toxic gases, such as carbon monoxide or cyanide); 2) facial burns with evidence of thermal injury to the upper airway (characterized by edema of the lips, oral mucosa, hoarseness, or stridor); or 3) evidence of subglottic inhalation injury (soot in the sputum, hypoxemia, and tachypnea).[1] In the absence of symptoms, the mere presence of soot and or singed hairs should not be an immediate trigger for intubation, especially in a resource-constrained environment. Of previously healthy patients with cutaneous burns as their only injury, those with less than 30% TBSA burn seldom require intubation in the collective experience of the authors. For those with burns >30% TBSA, the decision should be based on how the fluid resuscitation is progressing, as the degree of oral and facial edema should drive the decision to intubate. Finally, any burn patient whose anticipated narcotic or sedative requirement for wound care or other procedures such as escharotomies could potentially result in airway compromise warrant consideration for intubation. This is especially true in resource-limited settings, in which expertise in the delivery of light sedation may not be readily available. See Figure 2 for a proposed decision matrix.

Limited availability of advanced airway tools is anticipated in large mass casualty settings. Discussion here will be limited to a few easily stored and readily available items. The laryngoscope is an easily recognized and widely utilized airway instrument and consists of a blade (Miller or Macintosh) and a light source. Typically, the light source is reusable from patient to patient, while the blades require sterilization before each use. During a mass casualty incident, laryngoscope blades may become a limited resource if usual sterilization procedures are followed. It may be necessary for local hospital units

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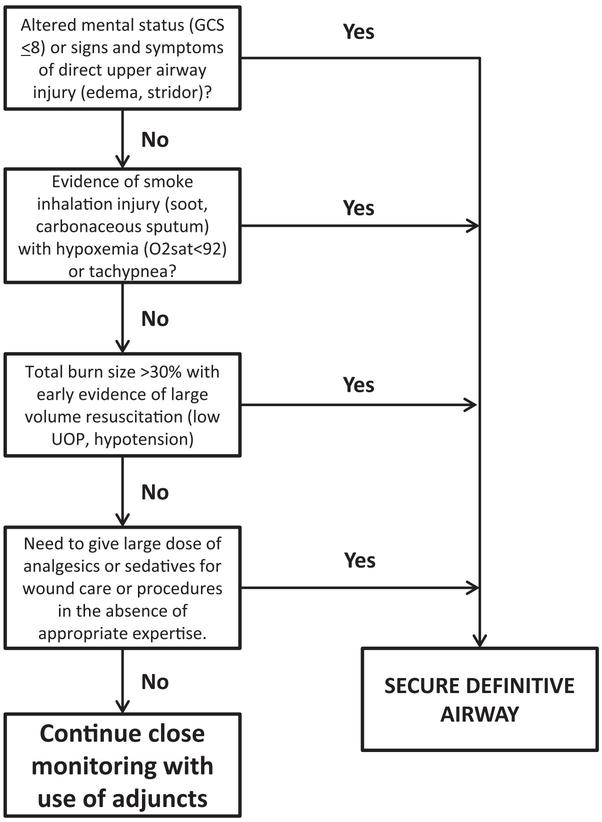

Figure 2. Proposed decision matrix for airway management during burn disasters.

to consolidate all the used blades in a central location and develop a rapid sterilization technique in an effort to be able to turn them around rapidly for use in other patients. Video-guided laryngoscopy (eg, Glide Scope) has become readily available in many hospitals, and can be a great alternate airway management tool. It is easily cleaned for reuse as well. Alternatively, the lighted stylet is an easily packed tool, useful in a variety of circumstances, including patients with limited oral aperture and limited neck extension, or those for whom cervical spine stability must be maintained. The stylet and handle may be cleaned and reused. The principle limitation of this tool is that it is a blind intubation technique, and extensive airway edema makes it less successful. However, in a resource-depleted environment, this technique may be useful. The Airtraq (Prodol Meditec, Ambler, PA), or similar endotracheal-tube-channel optical device, is another example of a low-impact, easily stored device. It provides indirect visualization of the laryngeal structures and is also useful for limited neck extension scenarios. In addition, the channel is also suitable for use with a gum elastic bougie when advancing the endotracheal tube proves difficult. Finally, when only an endotracheal tube is available, the provider may manually elevate the base of the tongue anteriorly with either hand (in some cases, the epiglottis may be reached), using the alternate hand to guide the endotracheal tube along the groove between the index and middle fingers, and through the glottis aperture.

Oxygen in Burn Disasters

Oxygen is a typically abundant resource that may be become limited in a large-scale disaster. In the United States, this may become an issue in protracted disasters, such as continued flooding, hurricane, or a nuclear event. In 2011, in Japan, an earthquake and resultant tsunami caused 16,000 immediate deaths and increased the need for oxygen therapy in the hospital and outpatient settings.[40,41] In Sarajevo in 1993 to 1994, oxygen therapy was scarce during the medical humanitarian effort to treat the civilian trauma patients.[42] In Joplin Missouri in 2011, tornados interrupted the hospital's oxygen system, and critically ill patients died as a result.[43]

The 2007 Task Force for Mass Critical Care listed that most countries do not have sufficient supplies or oxygen therapy to treat a surge of patients.[44] In the United States, only 65% of urban hospitals and 47% of all hospitals reported that oxygen supplies in their emergency departments were at or above capacity.[44] The Federal Emergency Management Agency and the Centers for Disease Control provide supplies during U.S. domestic disasters. However, neither provide oxygen supplies or therapy.[43] The Strategic National Stockpile provides a "12-hour push pack" with medical supplies, but does not include oxygen therapy or supplies.[43]

Available Forms of Oxygen Therapy. Hospitals primarily have liquid oxygen (LOX) because many liters of oxygen can be stored in a small space. Portable oxygen cylinders are also used. H cylinders are the largest (6900 L of gas). E cylinders are small (679 L of gas) and are used when transporting patients. The cylinders have a high internal pressure and are a risk to patients if they are damaged or mishandled.[45] Thus, the larger cylinders should be stored away from direct patient care areas. The National Fire Protection Association has specific guidelines on their storage.[46]

Hospital accreditation bodies such as The Joint Commission and Det Norske Veritas accreditation requires hospitals to have contingency plans for disasters. The contingency plan should include an approach to providing oxygen therapy, including determining how much oxygen is provided daily at the hospital, and how many days the hospital can provide oxygen without being serviced. Create different

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scenarios of events when performing disaster planning exercises. When tornados struck the hospital in Joplin, their LOX system, emergency back-fill lines, and connector lines through the building were all damaged in one event. The H cylinders are often used for backup when the LOX system is down or damaged. H cylinders provide sustained oxygen supply; however, they are not allowed in patient rooms.[43]

During a disaster, patients may be placed in alternate sites (cafeteria, conference room, and hallways). If oxygen is provided to these areas from the main LOX system, depressurization could occur and render the ventilators inoperable. Conserving oxygen use in the hospital and creating a mix of high- and low-oxygen-requiring patients in the alternate areas may avert depressurization. To preserve the available supplemental oxygen, reduce passive oxygen consumption in the hospital, reduce acceptable pulse oximeter thresholds to less than 90 to 92%, decrease the low-flow oxygen into the carbon dioxide absorbers in the operating rooms, and shut off the passive flow oxygen in the flowmeters in the neonatal intensive care and post anesthesia-care units.[43,47] In addition, oxygen can be withheld for patients in whom the focus of care has been transitioned to comfort measures only.

Treatment of Carbon Monoxide Toxicity When Oxygen Is Limited. In a large-scale burn disaster, large numbers of patients may present with carbon monoxide toxicity. For mild toxicity, symptoms are headache, lethargy, and dizziness. Effects of moderate toxicity are sedation, vomiting, syncope, and chest pain. Severe effects are coma, seizures, focal neurologic deficits, and acidosis.[48] Most patients with carbon monoxide exposure or toxicity require only a full exam and evaluation and treatment with oxygen. Given that oxygen therapy may be a limited resource, oxygen may need to be rationed and utilized judiciously when this scenario is present. Patients with exposure (no clinical effects) or mild effects (headache and dizziness) could be managed on room air alone or reduced, low-flow oxygen. High-flow oxygen could be reserved for patients with at least moderate effects. Oxygen should be administered in those with carbon monoxide levels greater than 10% with symptoms until the carbon monoxide level is undetectable. Anticipated time of therapy should be considered. The half-life of carbon monoxide is 4 to 5 hours on room air, 1 hour on 100% oxygen (eg, nonrebreather mask).[49] Thus, in most patients, oxygen therapy can be discontinued relatively quickly. Clinicians should keep this in mind and be sure to discontinue oxygen therapy in those that no longer need it in an effort to conserve oxygen for those who will.

Treatment of Cyanide Toxicity When Oxygen Is Limited. Patients involved in mass burn disasters may also be exposed to cyanide.[45] Cyanide is produced from combustion of synthetic and natural products. Cyanide primarily inhibits the cellular electron transport chain by binding cytochrome aa3 and induces cellular hypoxia. Mild symptoms of inhaled cyanide include dizziness, headache, and vomiting.[46] Moderate and severe symptoms include lactic acidosis, tachycardia, depressed mental status and then coma, apnea, hypotension, seizures, and cardiac arrest.[50,51] Oxygen should be administered to all patients with clinical symptoms. Oxygen alone may be sufficient for very mild toxicity, in particular when there is limited antidote available.[52] Indications for antidote therapy include decreased mental status, hypotension, apnea, lactic acidosis, or signs of myocardial ischemia. Two available antidotes are hydroxocobalamin, and sodium nitrite with sodium thiosulfate.[46] They can be administered intravenously (IV) or intraosseously, but not intramuscularly.[53] Sodium nitrite and sodium thiosulfate together are effective.[54] Sodium nitrite causes methemoglobinemia and hypotension. Sodium thiosulfate has a few adverse effects; however, in one recent study of cyanide-induced hypotension, sodium thiosulfate was ineffective when administered alone.[55] Hydroxocobalamin is also effective for cyanide toxicity. It does not cause hypotension or methemoglobinemia, but adds a red hue to body fluids (ie, urine) and the skin which interferes with some laboratory test methods.[56]

In a resource-limited setting, sufficient antidotes may not be available and oxygen resources may be threatened. Thus, it is important to ration both cyanide therapies as well as oxygen. Those with no clinical symptoms may only require observation without oxygen. Those with mild symptoms may benefit from low-flow oxygen. Antidotes should be reserved for those patients who continue to have persistent lactic acidosis and hypotension despite adequate resuscitation and oxygen therapy.

Ventilator Allocation. The most valuable but limited resource after a large-scale burn disaster may be the availability of mechanical ventilators. While the Strategic National Stockpile does include mechanical ventilators, disaster medical assistance team (DMAT) caches do and many hospitals can expect to have delivery of these limited items within short time frame.[43] However, it is not difficult to imagine that in many large-scale disaster scenarios, these supply lines may be disrupted, leaving local providers to make do with what they already have. As with any other life-saving or life-sustaining therapy, there

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must be a shift in priority from addressing the needs of individual patients to doing the "greatest good for the greatest number." This shift is often very difficult and requires a significant amount of predisaster education and training. Even then, it is recognized that a team-based approach to addressing these ethical decision is optimal.[57] Thus, careful and deliberate ventilator allocation by a separate "ventilator triage team" consisting of individuals experienced in the management of critical care patients has been advocated.[58] Ideally, this team would be tasked with performing airway and ventilator rounds at regular intervals to optimize ventilator resource allocation.

It is important to emphasize that patients will present with varying degrees of need for ventilator support, from those who only need airway protection and supplemental oxygen, to those who develop significant ventilation and oxygenation abnormalities requiring maximum ventilator support. In the former situation, decoupling the need for a protected airway with the need for mechanical ventilation may be necessary. As such, in these patients, a simple t-piece device delivering blow-by oxygen attached directly to the endotracheal tube may be sufficient. In others, noninvasive ventilation may be utilized. In those with definitive airways with minimal ventilator needs, any available transport ventilator may be adequate. In situations in which ventilators are no longer available and the patient requires ventilatory assistance, the "walking wounded" could be recruited for assistance with bag-mask ventilation, freeing up valuable health care provider assets. In the right group of patients who require similar levels of ventilator support, the option of connection multiple patients to one ventilator has previously been described and should be considered.[59]

CONCLUSIONS

The principles of care after disasters and mass casualty incidents are centered on "doing the greatest good for the greatest number." From an airway and ventilation perspective, we have presented the issues that are likely to be encountered in a large-scale burn disaster. We must remain vigilant in our preparation for such events. Prior preparation and training can have a substantial impact and save lives.[60] The alternative (apathy, denial, and lack of preparation) will only have a compounding effect on the disaster.

Recommendations

- Critically evaluate the need for a definitive airway in a resource-constrained environment.
- Reuse disposable airway adjuncts if necessary (with proper disinfection).
- Develop procedures to ration oxygen when supplies are limited.
- Treat CO and CN toxicity in only those patients with symptoms.
- Employ a deliberate system of ventilator allocation, if needed, aided by a separate 'ventilator triage' team.

GUIDELINES FOR BURN CARE UNDER AUSTERE CONDITIONS: FLUID RESUSCITATION

Introduction

Burn shock is a condition characterized by inadequate oxygen delivery to organs and insufficient elimination of tissue metabolites following thermal injury to the skin. After burn injury patients become dehydrated and can develop shock due to fluid loss through the burn. If untreated, burn shock—along with smoke inhalation injury—is the most common cause of death after burns. Before the initiation of resuscitation regimens, the LD50 burn size (burn size in which half the people died) was ~30% TBSA. Major burn wounds, defined as >20% TBSA, will require significant fluid administration, particularly in the first 24 hours post injury. After the first day, fluid requirements decrease, but are still above baseline due to evaporative losses through the burn wound. Hence, plans for resuscitation need to consider the prolonged need for fluids, both IV and oral, for weeks to months after the initial event. The purpose of this article is to provide options for resuscitation of the burn injured patient after a burn mass casualty event. The method used will depend on local resources and specifics of the situation.

Rationale

Intravenous Resuscitation. Prevention and treatment of burn shock can be accomplished by the IV administration of electrolyte solutions, such as lactated Ringer's or Hartmann's solution. Initial fluid requirements can be estimated by the Parkland formula: 2 to 4 ml/kg/% burn of lactated ringers solution over 24 hours, half in the first 8 hours and the remainder in the next 16 hours.[1,61] This formula, however, is just an estimate. Ideally, fluids should be adjusted to maintain a urine output of approximately 0.5 ml/kg/hr in adults and 1 ml/kg/hr in children <12 years. Typically, fluids are increased or decreased by 10 to 20% to maintain urine output in that range. Note that burn size and patient weight need to be

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recorded. Burn size can be estimated by the Rule of Nines or the Palmar method (patient's palm and fingers represent 1% of their BSA). Weight is often difficult to directly measure, but driver's license or ID cards frequently have weight, and Breslow tapes can be helpful for children. A more detailed description for estimating burn size can be found in the wound section of the austere guidelines.

Of note, IV resuscitation may be difficult in a resource-constrained environment for several reasons. First, IV fluids and supplies (such as IV catheters, tubing, pumps, and alcohol swabs) may be limited or inadequate in the event of a mass casualty event. Traditional IV resuscitation also often requires prodigious amounts of IV fluids. For example, a 40% burn in a 70 kg male will require approximately 11,200 ml in the first 24 hours. IV fluids and/or supplies needed for fluid administration could easily be depleted, particularly in facilities that do not routinely treat trauma or burns. In addition to the first 24 hours, fluid losses continue until wounds are closed. The estimated daily fluid requirement in milliliters can be estimated by the formula: (25 + %TBSA burn) × BSA burned plus normal fluid maintenance requirements; hence, the need for large volumes of IV fluid for weeks after burn injury. Fluids will need to be thoughtfully administered and monitored. Patients requiring massive volumes may need to be critically evaluated with respect to limiting resuscitative efforts. In the event that lactated ringers is not available, available isotonic fluids should be used. Second, as mentioned above, IV resuscitation requires frequent monitoring of urine output and IV fluid rate adjustment, which may not be possible with an overwhelming number of casualties. Finally, the reliability of BSA estimates in a disaster are not known, which could lead to either over- or underestimation of burn size and resuscitation.

Oral Resuscitation. Because the resources for administering large volumes of IV fluids may be lacking in an austere environment, practitioners should develop an alternative plan for oral fluid resuscitation. The gastrointestinal tract has the ability to absorb large amounts of fluid, up to 20 L per day.[62] The intestine retains its capacity for fluid absorption even in the presence of burns of up to 40% TBSA.[63] Oral rehydration therapy (ORT) is a well-established technique for preventing dehydration caused by diarrhea, particularly in developing countries.[64,65] Quite simply, ORT is the technique of giving patients adequate amounts of a solution containing glucose and electrolytes p.o. ORT can be delivered by local health care workers or family members at acceptably low cost. In 2001, it was estimated that a child with diarrhea could be rehydrated using ORT at a cost of only US $0.50.[66]

Since 1975, the World Health Organization and the United Nations Children's Fund (UNICEF) have provided packets of glucose and salts to be used in ORT for infectious diarrhea. The original formulation contained glucose, sodium chloride, potassium chloride, and trisodium citrate, with a resulting total osmolarity of 311 mOsm/L. In 2003, the formula was modified. Current recommendations are for use of reduced osmolarity oral rehydration solution (ORS) to reduce stool output from diarrhea[66,67] (Table 2). Free water is toxic to patients recovering from burn shock. Allowing patients to drink free water creates deadly hyponatremia, leading to cerebral edema and death.[69] Thus, sodium is an absolute requisite for the electrolyte composition of ORS for burn resuscitation. Nutrient-independent salt-absorption exchange mechanisms are present in enterocytes (Na/H and Cl/HCO_3), but the sodium-glucose cotransporter (SGLT1) moves a significant portion of sodium from the gut. Two sodium ions are transported for every molecule of glucose.[68] The osmolality of ORS can be increased and transport of sodium facilitated by addition of glucose polymers, rice powders, or other simple carbohydrates.

Although insufficiently tested in prospective, randomized clinical trials, expert opinion is that ORT can be used successfully to resuscitate patients from burn shock, provided that the burn size does not exceed 40% of the BSA and that there are no other injuries or illnesses that would preclude safe oral intake.[63,69,70]

An additional approach that may be of value in remote or rural settings is rectal infusion therapy (proctoclysis).[71] First introduced by John Benjamin Murphy in the early 20th century to treat patients in shock from peritonitis, it was used for treatment of battlefield injuries in both World Wars. Rectal infusions of either tap water or saline have been tolerated at rates up to 400 ml/hr.[72]

Resuscitation Options

Up to 20% TBSA can be resuscitated with ORT. Some patients with burns up to 40% TBSA can also be resuscitated successfully with ORT. In the hospital, up to 15% of the total resuscitation fluids can be given orally. If urine output is satisfactory, IV fluid can be diminished as long as ORT can be continued. In the field, the decision is made by the availability (or lack) of IV fluids and cannulas. Additional fluids and electrolytes can be given by proctolysis if oral intake is restricted. Unlike burn resuscitation

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Table 2. Composition of oral glucose-electrolyte solutions and clear liquids (based on 62–64, 66–68)

Solution	Na^+	K^+	Cl^-	Base	Glucose	Osmolality
Rehydration						
WHO-UNICEF ORS salts	90	20	80	10 (citrate)	111 (20 g/L)	310
WHO-UNICEF reduced osmolarity ORS salts	75	20	65	10 (citrate)	75 mmol/L	245
Meyer's solution	85	0	63	29 (citrate)	0	160
Rehydralyte®	75	20	65	30	139 (25 g/L)	325
Infalyte® or Ricelyte® liquid, oral	50	25	45	36 (citrate)	30 g/L as rice syrup solids	270
Lytren®	50	25	45	10 (citrate)	111 (20 g/L)	290
Pedialyte®	45	20	35	10 (citrate)	140 (25 g/L)	250
Resol®	50	20	50	11 (citrate)	111 (20 g/L)	270
Gatorade®	20	3	20	3	250 (35 g/L)	280
Cola	2	0.1	2	13 (HCO_3)	730	750
Ginger ale	3	1	2	4 (HCO_3)	500	540
Apple juice	3	28	30	0	690	730
Chicken broth	250	8	250	0	0	450
Tea	0	0	0	0	0	5

ORS, oral rehydration solution. Manufacturer information: Rehydralyte: Abbott Pharmaceutical Company, Abbott Park, IL; Infalyte: Mead Johnson and Company, Glenview IL; Ricelyte: Mead Johnson and Company, Glenview, IL; Lytren: Mead Johnson and Company, Glenview, IL; Pedialyte: Abbott Pharmaceutical Company, Abbott Park, IL; Gatorade: Gatorade Company, Chicago, IL.

with IV fluids, there are no established guidelines that relate the size of burn to the amount of desired fluid intake. It is reasonable to assume that the patient should be encouraged to take as much oral fluid as can be tolerated. Monitoring of efficacy of ORT should include commonly used parameters of adequate circulation, including urine output and mental status. Patients with burn injury >20% have a hypermetabolic state, resulting in a baseline elevation in heart rate. Hence, tachycardia alone is not an accurate measure of hydration. Changes in heart rate may be useful.

Adults and children greater than the age of 2 years should be allowed to take sips from a cup frequently, with the goal of consuming approximately 8 to 10 ounces every 10 to 15 minutes. Very young children less than the age of 2 years should be given a teaspoon of fluid every 1 to 2 minutes. ORT is unlikely to result in complications from overresuscitation, such as fluid overload; the usual complication from excessively rapid consumption of fluid is nausea and vomiting. If vomiting occurs, a few minutes should be given to allow symptoms to subside before resuming intake. Even if the patient vomits, there may still be significant absorption of fluids from the gastrointestinal tract.

There are many options for ORT: ORS can be made with 1 L of clean water, one teaspoon of table salt (3 g), and three tablespoons of sugar (36 g or 9 sugar cubes); it can also be purchased as commercially available packets. Clean water can be obtained by boiling the water, or by adding potassium alum, chlorine drops, or iodine tablets. As an alternative to table salt, sodium bicarbonate (baking soda) can be used as a source of sodium. A worldwide list of manufacturers and distributors of ORS products can be found at http://rehydrate.org/resources/suppliers.htm. If the quantity of added salt cannot be measured, the solution should have the taste of tears. Molasses and other forms of raw sugar can be substituted for white table sugar. (Note—both brown sugar and molasses add additional potassium.) If it is necessary to boil the water, do so before adding ingredients. If chemicals are being used to clean the water, warm the water before adding salt and sugar. Patients should drink sips every 5 minutes; wait 10 minutes after an episode of vomiting. At least 4 cups (1 L) per hour should be taken in orally. Keep the solution cool if possible; discard after 24 hours and make new batch.

Other local solutions for ORT include rice water (congee) with salt, fresh lime water with salt and sugar, vegetable or chicken soup with salt, lassi (yogurt drink with salt and sugar), sugarcane juice with lemon, black pepper, and salt, sports drink (eg, Gatorade® or Powerade®) with ¼ teaspoon salt and ¼ teaspoon baking soda for each quart, carrot soup, and gruel (cooked cereal diluted with water). Because of the risk of osmotic diuresis, drinks to be avoided include soft drinks, fruit drinks with high sugar content, sweet tea or coffee, or herbal teas that contain diuretics.

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Proctolysis can be performed by 1) boiling water to reduce risk of infection or allergic reaction; 2) warming the water to body temperature; formulating a balanced rehydration solution by the addition of salt and bicarbonate as described above; 3) inserting a urethral catheter into the rectum; 4) attaching a reservoir (such as 50 ml syringe with plunger removed) to the catheter; and 5) infusing fluids at a rate comfortable to the patient and consistent with clinical signs.[71]

Recommendations

1. Patients with burns less than 20% BSA can be effectively resuscitated from burn shock using oral solutions; many patients with burns up to 40% BSA can also be safely resuscitated.
2. For patients with burns >20%, IV resuscitation, if supplies permit, should be utilized using the Parkland formula. In resource-constrained environments, IV resuscitation may need to be restricted to survivable burns >40%.
3. There are many formulas for oral rehydration solutions, but all include clean water, glucose, and electrolytes.
4. Oral fluids should be given in amounts tolerated by the patient, accepting the occasional episode of nausea and vomiting as inevitable but not a reason to discontinue oral therapy.

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APPENDIX

This article was authored by a team of burn care providers dedicated to disaster preparedness with sponsorship from the American Burn Association. Each person has volunteered their time and effort to author this publication. The authors for each publication are listed below.

1. Guidelines for burn care under austere conditions: an introduction to burn disaster management principles (authors: Randy D. Kearns, DHA, MSA, CEM; Kathe M. Conlon, BSN, RN, MSHS; Annette F. Matherly, RN, CCRN).
2. Guidelines for burn care under austere conditions: airway and ventilator management (authors: Kevin K. Chung, MD; Vikhyat S. Bebarta, MD; Jacob J. Hansen, DO; Leopoldo C. Cancio, MD)
3. Guidelines for burn care under austere conditions: fluid resuscitation (authors: Michael Peck, MD, ScD, FACS)

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