TACTICAL COMBAT CASUALTY CARE: TRANSITIONING BATTLEFIELD LESSONS LEARNED TO OTHER AUSTERE ENVIRONMENTS

The Care of Thermally Injured Patients in Operational, Austere, and Mass Casualty Situations

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Burn injury affects a half million people in the United States annually. The severe thermal injury can have long-term debilitating effects. The management of burn patients in austere and operational environments is more complex. Mass casualty incidents can result in a large number of patients with multiple traumatic injuries, which often include burn injury. Appropriate triage of casualties is essential. Severely burned patients should be evacuated to a burn center if possible. Airway management and fluid resuscitation of burn patients present unique challenges. Supplies, resources, and expertise to maintain a definitive airway may not be readily available. Airway adjuncts can be helpful but judicious use of resources is warranted in the austere setting. Traditional resuscitation of severe thermal injury is not practical in the austere environment. Oral resuscitation and in rare cases rectal hydration may be utilized until the patient can be transported to a medical facility. Much has been learned about the management of burn and polytraumatized patients after mass casualty incidents such as the September 11, 2001 terror attacks and the Pope Air Force Base disaster. A well-coordinated emergency preparedness plan is essential. The care of burn patients in austere, operational, and mass casualty situations can tax resources and manpower. The care of these patients will require creativity and ingenuity. Burn patients can be difficult to manage under normal circumstances but the care of these patients under the above situations complicates the management severalfold.

Keywords: burns, austere environment, mass casualty

Introduction

Severe thermal injury can be lethal or result in long-term debilitating effects. According to the Centers for Disease Control (CDC) almost a half million patients sustained thermal injury requiring some sort of medical treatment annually. Of these patients, 40,000 require hospitalization for their injuries (three-fourths of which were admitted to a burn center).¹ In the United States in 2016, 3275 patients died as a result of thermal and/or inhalation injury. There were 123 burn centers in the United States as of 2011. Sixty-five burn centers are

verified by the American Burn Association (ABA) according to 2015 data.² However, many communities are located at great distances from any burn center and several states have no burn center within it. Globally the lack of burn treatment facilities and expertise in burn care is even more pronounced.

Burn care is immensely more complex in austere and operational environments. Severe burn injury (defined as total burn surface area [%TBSA] greater than 20%) is incredibly difficult to manage in these environments. It is imperative that patients with severe thermal injury are evacuated to a higher level of care as soon as possible. Medical evacuation may be delayed and in some cases simply not possible. Alternatives must be devised for airway stabilization, burn resuscitation, and burn wound care. Burn patients who sustain their injuries during mass casualty incidents are much more likely to have concomitant polytraumatic injuries that further complicate their management.

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In a mass casualty event, 20–30% of casualties can have thermal injury.³ Obviously, this proportion increases if incendiary explosives devices are involved. Natural and man-made disasters often result in significant casualties with complex assortment of injuries, which include burn injuries in many cases. Managing casualties in austere, operational, and mass casualty situations have several similarities: resources are usually limited, medical expertise may not be readily available, difficulties in evacuating casualties to an appropriate medical facility, and the need to care for these casualties in suboptimal situations for a prolonged period of time.

Triage and severity of burn injury

The first step in the management of thermally injured patients is to assess the severity of the injury. The amount of body surface area burned, the depth of the injury, presence of inhalation injury, and presence of associated injuries are all factors that determine the severity of burn injury. Patients with burn surface area involvement in excess of 20% may require resuscitation for treatment of their burn injury. The depth of burn and presence of inhalation injury also influence the amount of resuscitation. Both of these factors tend to increase the amount of fluid resuscitation required.⁴

Larger burns (more than 20% TBSA area) are extremely difficult to care for in austere and operational environments. As mentioned above, these patients will require burn resuscitation in many cases. Inadequate fluid management will result in profound hypovolemia, acute kidney injury, and in some cases cardiovascular collapse and eventual death. The risk of burn wound infection is also increased with prolonged exposure of wounds to the environment. Specifically, the inability to cleanse wounds and treat with topical antimicrobial dressings will increase infection risks. Patients with large thermal injuries are also susceptible to hypothermia and must be kept warm and protected from the elements.^{4,5}

Patients with large burns must be evacuated expeditiously, preferably to a burn center. This, of course, is difficult when injuries occur in austere and operational environments. Medical evacuation may require transport across harsh terrain or require rotary or fixed wing transport to traverse great distances. The ability to communicate with the surrounding medical facilities and their ability to rapidly respond and dispatch trained medical teams is important. Even highly trained medical evacuation teams may lack the expertise to care for patients with large burns without specific burn training.

Airway management

Airway management “in the field” can be difficult but even more so in patients with severe thermal injuries. Inhalation injury should always be suspected when a patient is exposed to noxious smoke in a closed space. The patient can present with facial burns, oral/ nasal soot, and carbonaceous sputum and in late stages dyspnea and stridor. The effects of inhalation injury are due to chemical pneumonitis caused by a host of inhaled toxins including carbon monoxide, cyanide, aldehydes, and other poisons. Patient may present with normal respiratory status initially then progress to respiratory failure in 12–48 hours.⁶ It is imperative to obtain airway stabilization before symptoms occur as the patient can decompensate rapidly.

Patients with large burns who do not have inhalation injury are at risk as well. As the burn surface area exceeds 20% the inflammatory response becomes more systemic. This inflammatory response is more pronounced with increasing burn surface area. Burn surface areas that exceed 50% will almost always require stabilization of the airway. Systemic inflammation leads to diffuse swelling and eventual loss of the airway. Airway stabilization is extremely arduous and in some cases near impossible to obtain in large burns after several hours when swelling is maximal. Aggressive resuscitation can accelerate this swelling therefore necessitating earlier airway stabilization.⁷

There are several options for airway stabilization. Most airway adjuncts provide temporary airway support but definitive airway is usually obtained with endotracheal intubation or surgical airway. Definitive airway can be difficult to obtain in the field. Placement of definitive airway will require advanced medical skill and can be resource intensive. These factors must be considered before decision is made to place a definitive airway in a burn patient when in austere conditions.

Burn resuscitation

Burn resuscitation may be required when total burn surface area exceeds 20%. Traditional resuscitation formulas utilize balance salt solutions given intravenously. The most commonly used formulas are derived from the product of percent burn surface area, weight in kilograms, and resuscitation factor (4 mL/kg/%TBSA – Parkland formula; 2 mL/kg/%TBSA – Modified Brooke formula). These formulas require that the total fluid rate be halved at 8 hours and again at 16 hours.⁸ This may be difficult during complex burn resuscitation. The USAISR Burn Center developed a simplified formula that determines the initial fluid rate from the product of the percent burn surface area and a resuscitation factor of 10 (Rule of Tens) (see [Figure 1](#)).⁹ All these formulas

US Army Institute of Surgical Research Rule of Tens⁹

1. Estimate the burn size to the nearest ten.
2. %TBSA X 10 = initial rate for fluid resuscitation (adults 40-80 kg).
3. Every 10 kg above 80 kg the fluid rate should be increased by 100 mL/h.

Example: Calculate the initial fluid rate for a 90 kg male who sustained a 50% TBSA burn in structural fire.

Parkland Formula:	B. $9000/2 = 4500$
A. $4 \times 90 \times 50 = 18,000$ mL	C. $4500/8 = 563$ mL/h
B. $18,000/2 = 9000$	Rule of Tens:
C. $9000/8 = 1,125$ mL/h	A. $5 \times 10 = 500$ mL/h
Modified Brooke formula:	B. Add 100 mL/h for weight –
A. $2 \times 90 \times 50 = 9000$	$500 + 100 = 600$ mL/h

Figure 1. US Army Institute of Surgical Research Rule of Tens.⁹

attempt to replace intravascular fluid loss due to the systemic inflammatory response. There are several metrics of burn resuscitation but hourly urine output is the most common one utilized. Fluid resuscitation requires that several liters of fluid be given in a 24-hour period. This is not practical in austere environments and far forward military operations. Intravenous fluid resuscitation can be delayed or restricted in burns up to 40% TBSA. It is imperative that burn patients who require resuscitation are evacuated expeditiously.

Burn resuscitation can occur via the oral route as an alternative to intravenous fluid resuscitation. Oral resuscitation is ideal for burns 10–20% TBSA but can be used effectively in burn up to 40% TBSA. Burns larger than 40% will often be complicated by gastroparesis, which can lead to vomiting and aspiration. Oral replacement fluid can be given by nasogastric tube to mitigate these complications. Oral replacement solutions contain glucose and sodium to enhance the transport of fluid across the enterocytes of the small intestine. The gastrointestinal tract has a large surface area for fluid absorption. The small intestine absorbs 9 L/d normally and up to 20 L/d when challenged. The large intestine absorbs 2 L/d normally and 9 L/d when challenged. Oral burn resuscitation can provide fluid resuscitation until the patient can be evacuated to a medical treatment facility.^{10,11}

Rectal hydration is another method to provide fluid resuscitation to a burned patient. This method involves delivery of replacement fluid via the rectum and large

intestine. This option has limited indications but can be considered when oral and intravenous routes are unavailable. The replacement fluid can be delivered by enema, Foley catheter, red rubber catheter, or standard rectal tube. Common solutions for rectal hydration include sodium chloride or Lactated Ringer's. World Health Organization (WHO) resuscitation fluid may be more readily available and should also be considered. The solution should be 38 to 39°C (100 to 102°F) to prevent hypothermia upon instillation; 700 to 1000 mL (1.5 to 2 pints) can be given every 2 hours (a maximum of 14 L or 30 pints in 24 hours). This delivery method is limited by the ability of the patient to retain fluid in the rectal vault. There is very little data on the use of rectal hydration.^{12,13}

Burn wound management

A central feature of burn care is burn wound management. The ideal burn dressing is simple to apply, contains an antimicrobial with a wide spectrum of activity (possibly antifungal activity as well), is cost effective, and easily portable. Also, the dressing should be versatile enough to use on other wounds besides burn wounds. All of these factors are important but even more so when treating burn patients in austere and operational environments. Another appealing feature is a dressing that can remain intact for several days alleviating the need for daily or twice daily dressing changes. Patients who will be evacuated a short distance and arrive at a medical treatment facility in several hours just need clean and dry dressings to protect open burn wounds. Wet dressings will promote hypothermia especially in patients with large surface area of burn.

Patients who will be evacuated over long distances or arrive at medical treatment after many hours or days will require cleaning of wounds and application of dressing containing a topical antimicrobial to prevent infection. A clean water supply (bottled water) and a mild wound cleanser should be applied to remove superficial debris before burn dressings are placed.¹⁴

There are a multitude of wound care products currently on the market that are used to treat burn wounds. The authors do not endorse any specific product but recognize that some products may be better suited for care in an austere environment. Burn products can be generally divided into 3 categories: topical antimicrobial creams/ topical antimicrobial solutions, dressings that release ionic silver into the wound, and all other products. Topical antimicrobial creams include silver sulfadiazine and mafenide acetate. Mafenide acetate comes in a powder form that can be reconstituted into a solution that can be applied to dressings. The advantage of these dressings is that they penetrate the burn wound effectively and have a good spectrum of antimicrobial activity. The disadvantage of these dressings

is that their application/removal is labor intensive since they require at least daily dressing changes or dressings irrigated several times daily. Silver impregnated products include Acticoat (Smith and Nephew, London), Silverlon (Argentum Medical, Geneva, IL), Silverseal (Alliqua Biomedical, Yardley, PA), and several others. The advantages of using these products are their ease of use and the dressings can remain intact for several days. The main disadvantage of these dressings is their cost.^{15,16} Generally, in the treatment of uncomplicated burn wounds prophylactic antibiotics are not indicated. But antibiotics may be indicated for other open wounds, open fractures, or significant contamination of burn wounds with prolonged time to definitive care. If available prophylactic antibiotics should also be considered for use in the austere environment.¹⁷

Burn care in mass casualty and disaster management

In any mass casualty incident 20 to 30% of casualties are expected to have some degree of thermal injury.³ As stated earlier, triage and care under these conditions resemble care in austere environment due to limited resources and expertise. The challenge is to identify those patients with life-threatening or immediate injuries that would benefit from early evacuation to a medical treatment facility from those patients who are expectant and would not. These decisions are much more complicated when the casualties have a combination of thermal and polytraumatic injuries. Four regional burn centers cared for patients in New York City in the aftermath of the September 11, 2001 terrorist attack. Only two thirds of thermally injured patients were referred to these burn centers. This highlights the difficulty identifying those patients who are injured in a mass casualty incident that will require admission and specialized treatment at a burn center.¹⁸

Figure 3 is a triage tool for a mass casualty incident in which many of the casualties have sustained thermal injury. The tool divides patients into 5 triage categories: outpatient, high, medium, low, and expectant, which is based on their probability of survival. It also dictates the priority for evacuation to medical treatment facilities and burn centers. The patients triaged to “outpatient” or “high” have less severe injury and their evacuation can be delayed and their injuries may be treated on an outpatient basis or at local medical treatment centers. They are less likely to require care at a burn center. The casualties triaged to the “low” and “expectant” categories have very severe injury and/or advanced age and they are not likely to survive. Evacuation of patients in this category should be delayed to allow the evacuation of patients with a greater chance of survival. The focus of care (especially the expectant group) should be palliative. The “medium” triage category represents the

group in which most of the stabilization and evacuation efforts should be directed. This group also will most likely require specialized care at a burn center.¹⁹

Since 9/11 there have been tremendous improvements in the nation’s ability to respond to mass casualty incidents. Disaster response is currently coordinated at the local, state, and national levels in numerous cities and principalities. Burn centers are incorporated at each level and this is coordinated by the American Burn Association (ABA) and the US Department of Health and Human Services (HHS). The Federal Emergency Management Agency (FEMA) is an integral part of this relationship. Civil and military response is also coordinated at the national level and special military teams train and remain on alert to respond to civilian disasters and mass casualty incidents (see Figure 2).^{20,21} The Special MEDCOM Response Capability – Burn (SMRC-B) or Burn Flight Team (BFT) is composed of members of the USAISR Burn Center. The BFT’s primary mission is to go “anywhere at any time” to evacuate military beneficiaries (and in some cases nonmilitary-affiliated civilians) with burn injury. The majority of recent mission have been to Germany to evacuate burn casualties injured in overseas contingency operations in the Middle East. BFT could be available to support a response to a civilian disaster if directed by the Department of Defense (DoD). The BFT has historically supported humanitarian missions internationally. BFT missions require close coordination with the US Air Force and BFT can be augmented by personnel of the US Air Force Critical Care Air Transport Teams (CCAT) as needed.²²

The Pope Air Force Base (AFB) Green ramp incident is an example of a response to a mass casualty incident involving burn patients. On March 23, 1994, an F-16 fighter jet collided into a C-130 cargo plane and then

Figure 2. US Northern Command (USNORTHCOM), Department of Defense (DoD), and Federal Emergency Management Agency (FEMA) Support of Burn Disasters.²¹

Age/ years	Burn Size (%TBSA)									
	0 – 10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91+%
0-1.99	High	High	Medium	Medium	Medium	Medium	Low	Low	Low	Expectant
2-4.99	Outpatient	High	High	Medium	Medium	Medium	Medium	Low	Low	Low
5-19.9	Outpatient	High	High	High	Medium	Medium	Medium	Medium	Medium	Low
20-29.9	Outpatient	High	High	High	Medium	Medium	Medium	Medium	Low	Low
30-39.9	Outpatient	High	High	Medium	Medium	Medium	Medium	Medium	Low	Low
40-49.9	Outpatient	High	High	Medium	Medium	Medium	Medium	Low	Low	Low
50-59.9	Outpatient	High	High	Medium	Medium	Medium	Low	Low	Expectant	Expectant
60-69.9	High	High	Medium	Medium	Medium	Low	Low	Low	Expectant	Expectant
70+	High	Medium	Medium	Low	Low	Expectant	Expectant	Expectant	Expectant	Expectant

Figure 3. Triage and Burn Survival Grid.¹⁹

struck a C-141 cargo plane full of soldiers preparing for a parachuting exercise. The C-141 exploded and 23 patients died immediately while another 80 patients were injured. The occupants of the cargo plane escaped uninjured. Most patients were evacuated to Womack Army Hospital, Fort Bragg, North Carolina, but some patients were evacuated to 6 area hospitals. Most survivors (43 casualties) were eventually evacuated to the USAISR Burn Center and 7 of the most critical patients were transported to Jaycee Burn Center in Central North Carolina.²³

In conclusion, the management of patients with burn injury in austere, operational, and mass casualty circumstances is incredibly difficult. Providers must be able to perform airway management, burn resuscitation, and burn wound care in less than optimum conditions in patients who are likely to have polytraumatic injuries as well as burns. Limited resources and lack of expertise further complicate patient management. Providers must be able to adapt and render care despite these obstacles. Care of burn patients in mass casualty incidents resembles care in austere situations in that resources are limited and expertise may not be readily available. Care of these patients in during combat operations is especially difficult as terrain and tactical considerations must be taken into account.

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References

- Centers for Disease Control and Prevention, National Center for Health Statistics (NCHS). National vital statistics system (1998). Available at: <https://www.cdc.gov/nchs/nvss/>. Accessed July 25, 2016.
- American Burn Association. Burn Incidence and Treatment in the US: 2001 Fact Sheet. Available at: www.ameriburn.org. Accessed July 25, 2016.
- Barillo DJ. Burn disasters and mass casualty incidents. *J Burn Care Res.* 2005;26:107–108.
- Frieburg C, Ignieri P, Sartorelli K, et al. Effects of differences in percent total body surface area estimation on fluid resuscitation of transferred burn patients. *J Burn Care Res.* 2001;28:42–48.
- White CE, Renz EM. Advances in the surgical care: management of severe burn injury. *Crit Care Med.* 2008;36(7 suppl):S318–S324.
- Cancio LC. Airway management and smoke inhalation in the burn patient. *Clin Plastic Surg.* 2009;36(2009):555–567.
- Micak RP, Suman OE, Herndon DN. Respiratory management of inhalation injury. *Burns.* 2007;33:2–13.
- Pham TN, Cancio LC, Gibran NS. American Burn Association practice guidelines burn shock resuscitation. *J Burn Care Res.* 2008;28:257–266.
- Chung KK, Salinas J, Renz EM, et al. Simple derivation of the initial fluid rate for the resuscitation of severely burned adult combat casualties: in silico validation of the rule of 10. *J Trauma.* 2010;69(suppl 1):S49–S54.
- Cancio LC, Kramer GC, Hoskins SL. Gastrointestinal fluid resuscitation of thermally injured patients. *J Burn Care Res.* 2006;27:561–569.
- Michell MW, Oliveira HM, Kinsky MP, et al. Enteral resuscitation of burn shock using world health organization oral rehydration solution: a potential solution for mass casualty care. *J Burn Care Res.* 2008;27:819–825.
- Needham D. Proctoclysis for hydration. *Lancet.* 1995;345(8949):596.
- Tremayne V. Emergency rectal infusion of fluid in rural or remote settings. *Emerg Nurse.* 2010;17:26–28. quiz 29.
- D'Avignon LC, Saffle JR, Chung KK, Cancio LC. Prevention and management of infections associated with burns in the combat casualty. *J Trauma.* 2008;64:S277–S286.
- Monafo WW, Freedman B. Topical therapy for burns. *Surg Clin Nor Am.* 1987;76:133–145.

16. Aziz Z, Abu SF, Chong NJ. A systematic review of silver-containing dressings and topical silver agents (used with dressings) for burn wounds. *Burns*. 2012;38:307–318.
17. Avni T, Levcovich A, Ad-El DD, Leibovici L, Paul M. Prophylactic antibiotics for burn patients: systemic review and meta-analysis. *BMJ*. 2010;340:c241.
18. Yurt RW, Bessy PQ, Bauer GJ, et al. A regional burn center's response to a disaster: September 11, 2001 and the days beyond. *J Burn Care Rehab*. 2005;26:117–124.
19. ABA Board of Trustees, Committee on Organization and Delivery of Burn Care, Disaster Management and the ABA Plan. *J Burn Care and Rehab*. 2005;26:102–106.
20. Jeng J, Gibran N, Peck M. Burn care in disaster and other austere settings. *Surg Clin N Am*. 2014;94:833–907.
21. Jordan MH, Mozingo DW, Gibran NS, Barillo DJ, Purdue GF. Plenary Session II: American Burn Association disaster readiness plan. *J Burn Care Rehabil*. 2005;26:183–191.
22. Renz EM, Cancio LC, Barillo DJ, White CE et al. Long range transport of war-related burn casualties. *J Trauma*. 2008;64(2 suppl):S136–S144.
23. Mozingo DW, Barillo DJ, Holcomb JB. The Pope air force base aircraft crash and burn disaster. *J Burn Care Rehabil*. 2005;26:132–140.