

Chapter 26

Burns

Introduction

Burns sustained during conventional military operations constitute 5%-10% of injuries. Even burns to a small surface area can be incapacitating for the casualty and strain the resources of deployed military medical units. It is crucial to remember that burns may represent only one of the casualty's traumatic injuries, particularly when an explosion is the mechanism of injury. Resuscitation of the burn casualty is generally the most challenging aspect of care during the first 48 hours following injury, and optimal care requires a concerted effort on the part of all providers involved during the evacuation and treatment process.

Point-of-Injury Care

Key steps in the initial treatment of burn casualties include:

- **Stop the burning process.** Extinguish flames. Move the patient to a safe location. Remove all burned clothing. Safely separate the patient from the power source related to electrical injury. Remove chemical agents using copious amounts of clean water.
- Provide emergency resuscitative care. Control hemorrhage and protect airway.
- **Remove all constricting articles.** Remove items such as wristwatches, rings, belts, and boots. Remove all contaminated clothing and equipment.
- **Cover the patient.** Do cover the patient with a clean, dry sheet to minimize further contamination during transit. Place saline-soaked dressings over wounds involving *white phosphorus* to prevent ignition of the phosphorus on contact with air.
- **Protect against hypothermia.** Utilize blanket(s) or other warming devices to mitigate hypothermia. Patients with large surface area burns are at increased risk of hypothermia.

- **Establish IV access.** Through unburned skin if possible, through burned skin if necessary, and secure (sew in or staple) IV lines.
- **Begin resuscitation.** Use lactated Ringer (LR) solution or a similar solution, and continue during evacuation. Starting rate: 500 mL/h for adults.

Primary Survey

Do not be distracted by the burn injury itself! The priorities of management for burn casualties are the same as those for other injured patients, with the addition of burn pathophysiology. The burn may not be the most life-threatening injury.

- The primary survey includes hemorrhage control, airway management with protection of the cervical spine as appropriate (based on the mechanism of injury), management of any breathing dysfunction, and rapid circulatory assessment. **In the burn patient, special attention to exposure, removal of materials that may continue to burn the victim, and prevention of hypothermia are very important.**

- **Inhalation injury may be manifested by stridor, hoarseness, cough, carbonaceous sputum, or dyspnea. Airway obstruction may result from plugging of the endotracheal tube and should be suspected if acute changes in pulmonary status occur.**
- **Patients who may have sustained inhalation injury should be closely monitored, without intubation if minimally symptomatic.**
- **Preemptively intubate patients with symptomatic inhalation injury prior to transport.**
- **Endotracheal and nasogastric tubes should be definitively secured with cloth umbilical tape. Securing the endotracheal tube to a premolar tooth using stainless steel wire should be considered in patients with facial burns or other facial trauma.**

- **Airway.**

- Consider cervical spine injury in patients injured in explosions, falls, or by contact with high-voltage electricity.
- Burns are a “distracting injury”; pain secondary to burns, and the treatment of pain with narcotics, may make the clinical diagnosis of spinal injury difficult.

- **Breathing.**

- Inhalation injury occurs in 15% of burned combat casualties. It is more common in patients with extensive cutaneous burns, a history of injury in a closed space (eg, building or vehicle), and facial burns.
- Patients with major burns and/or inhalation injury require supplemental oxygen, pulse oximetry, chest radiography, and arterial blood gas measurement.
- Circumferential **full-thickness** burns of the chest may prevent effective chest motion. In such patients, **perform immediate thoracic escharotomy as a life-saving procedure to permit adequate chest excursion** (Fig. 26-1).
- Definitive diagnosis of lower airway injury requires fiberoptic bronchoscopy.

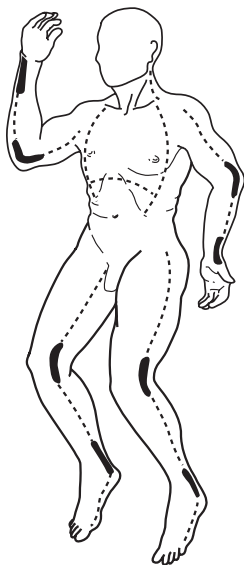


Fig. 26-1. Dashed lines indicate the preferred sites for escharotomy incisions. **Bold lines** indicate the importance of extending the incision over involved major joints. Incisions are made through the burned skin into the underlying subcutaneous fat using a scalpel or electrocautery. For a thoracic escharotomy, begin incision in the midclavicular lines. Continue the incision along the anterior axillary lines down to the level of the costal margin. Extend the incision across the epigastrium as needed. For an extremity escharotomy, make the incision through the eschar along the midmedial or midlateral joint line.

- Carbon monoxide poisoning causes cardiac and neurological symptoms. Patients with carbon monoxide poisoning require 100% oxygen for at least 3 hours or until symptoms resolve.
- **Circulation.**
 - Secure all IV catheters and lines with suture or surgical staples; tape will not adhere to burned skin, and circumferential wrapping may lead to severe constriction, edema, and possible vascular compromise.
 - Manual blood pressure measurements utilizing a cuff may be inaccurate in patients with burned or edematous extremities; therefore, arterial blood pressure is preferred when possible.

Estimation of Fluid Resuscitation Needs for Adults

Initiate resuscitation with LR based on the patient's burn size. Utilize urine output as the primary index of adequacy of resuscitation (see below). It is equally important to avoid both overresuscitation and underresuscitation.

- **Determine the burn size** based on the Rule of Nines (Fig. 26-2). A patient's hand (palm and fingers) is approximately 1% of the total body surface area (TBSA). Only second and third degree burns are included in burn size calculations.
 - Overestimation is common and may lead to overresuscitation.
- **Estimate initial hourly rate for crystalloid resuscitation utilizing the Rule of Tens** and adjust hourly based on response.

Initial Hourly Rate = %TBSA Burn × 10 mL/h

Example: 40% TBSA Burn

Initial Hourly Rate of Lactated Ringer's = 400 mL/h

- **Any formula-based calculation is only an initial estimate of fluid needs.** Patients weighing more than 80 kg or with inhalation injury, predominantly full-thickness burns, and a delay in resuscitation will have higher fluid requirements. The rate of infusion of LR must be adjusted based on physiological response, primarily urine output. Avoid abrupt

changes in rate of infusion; **avoid bolus infusion of crystalloids.** Increase or decrease infusion rate by approximately 25% of current rate as needed, based on response.

- For patients weighing >80 kg, add 100 mL/h for each 10 kg above 80 kg.
- Remember to adjust based on monitored urine output.
- If LR is not available, use other crystalloids such as normal saline. If crystalloid supplies are severely limited, consider starting colloid as early as 12 hours after injury. Resuscitation requires close monitoring of urine output.

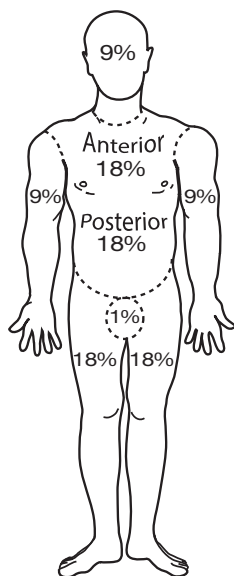


Fig. 26-2. Rule of Nines showing the distribution of body surface area by anatomical part in the adult.

Fluid Resuscitation of Children with Burns

- Fluid resuscitation for pediatric patients with burns involving 20% or more TBSA may be initiated using the modified Brooke formula ($2 \text{ mL/kg} \times \% \text{ TBSA burn} \times \text{weight [kg]}$) administered over 24 hours, with $\frac{1}{2}$ administered in the first 8 hours).
- Adjust LR based on response as measured by glucose-negative urine output, targeted at 1 mL/kg/h. As with adult patients, frequent monitoring and individual titration are essential.
- Peripheral or intraosseous access may suffice initially; however, central venous access is more reliable and usually required for fluid resuscitation.
- Children with burns over 20% TBSA should have a Foley-type catheter placed (size 6 Fr catheter for infants and size 8 Fr catheter for older children); diapers may be weighed to account for urine output if a Foley is not available.

- Children also require a maintenance rate of either D5½NS or D5LR, calculated in the usual fashion, and not titrated during resuscitation.
- Children with burns under 20% TBSA or those presenting for care 24–48 hours after injury may not require fluid resuscitation; rather, fluid should be administered based on clinical need.
- Children may be provided oral nutrition/hydration if they are able to safely tolerate it; however, gastric decompression with a nasogastric tube during the resuscitation phase must also be considered. Stress ulcer prophylaxis is essential.
- Resuscitation targets include an alert sensorium, full peripheral pulses, and warm distal extremities.
- Serum sodium should be monitored every 8 hours during the first 72 hours if burns are >20%. Hypotonic resuscitation fluid should be avoided.

Monitoring the Burn Patient

- Two IV catheters, a Foley catheter, continuous ECG, pulse oximetry, a core thermometer, and a nasogastric tube are needed for ICU care of a patient with burns of 20% TBSA or greater.
- Vital signs and fluid input/output should be accurately recorded hourly on a flow sheet.
- Nasogastric decompression is essential for all patients with burns over 20% TBSA, due to potential gastric ileus.
- Placement of a Foley-type catheter is an essential part of the resuscitation process. Burns to the penis should not prevent intubation of the urinary meatus. Debridement of eschar and use of a small hemostat may be necessary to facilitate urinary catheter placement. Suprapubic catheter placement is rarely necessary and should be avoided.

Secondary Survey

- Perform a thorough head-to-toe secondary survey, looking for non-thermal injuries, including fractures, dislocations, corneal abrasions, and/or tympanic membrane rupture.
- Ocular examination for corneal laceration and/or globe trauma should be performed early before resuscitation-related edema makes examination more difficult.

- If there is a question of intraabdominal injury, diagnostic peritoneal aspiration, through burned skin if necessary, is appropriate.

Burn Resuscitation—First 24 Hours

Continuously reassess the patient's hourly urine output, which is the single most reliable indicator of the adequacy of resuscitation.

- Target a urine output of 30–50 mL/h in adults or 1 mL/kg/h in children. If urine output is less than the target for 1–2 consecutive hours, increase the LR infusion rate by about 25%; if the response is greater than the target, decrease rate by about 25%.
- Avoid overresuscitation, which may lead to edema-related complications (eg, compartment syndrome or pulmonary edema).
- Other indices of effective resuscitation include a decreasing lactate, improving base deficit, improved tachycardia (a heart rate of 100–130 is normal in adult burn patients), and an improving or normal mental status.
- The use of diuretics is rarely, if ever, indicated in the treatment of burn shock, except when gross pigmenturia is present (see below).
- Glycosuria is common following severe thermal injury and may cause hypovolemia secondary to osmotic diuresis. Check the urine for glucose and treat hyperglycemia with IV insulin as needed.

Burn Resuscitation—Second 24 Hours

At the end of the first 24 hours postburn, decrease use of crystalloid LR and implement use of 5% albumin in normal saline.

- Calculation of 24-hour albumin volume is as follows:

$$\begin{aligned} \text{5\% albumin volume} &= (*\text{mL}) \times (\%\text{TBSA burned}) \\ &\quad \times (\text{preburn weight, kg}) \end{aligned}$$

%TBSA burn	30–49	50–69	70+
*mL	0.3	0.4	0.5

For example, in a burn of approximately 40% in an 80-kg patient:

$$\begin{aligned}\text{Albumin volume} &= (*\text{mL}) \times (40\%) \times (80 \text{ kg}) \\ &= (0.3) \times (3,200) \\ &= 960 \text{ mL}/24 \text{ h} \\ &= \mathbf{40 \text{ mL/h.}}\end{aligned}$$

- Burns <30% TBSA generally do not require infusion of colloid solution.
- It is rarely necessary to adjust the colloid infusion rate.
- If albumin is not available, fresh frozen plasma or synthetic colloid can be used at the same rate used for 5% albumin. If none of these are available, continue utilizing LR while monitoring urine output.
- **Monitor electrolytes.** Burn resuscitation is usually complete by 48 hours after burn injury. However, evaporative water loss replacement is required. **Be watchful for both hypo- or hypernatremia!**
- **Document and communicate.** Accurately document all fluid volumes administered to the patient and communicate this information to providers as the patient is transferred between levels of care. Utilization of the Joint Theater Trauma System (JTTS) Burn Resuscitation Flowsheet is strongly encouraged and demonstrated to improve outcomes following severe burns. Early communication with the burn center is also encouraged.

Burn Wound Care

- The burn wound itself is not immediately life-threatening. However, adequate wound care reduces the risk of infection, which remains the primary complication in burn casualties. Early care of the burn wound should be performed in a clean and warm environment where adequate sedation and analgesia are available.

Early burn wound care includes adequate IV pain management, removal of foreign materials, debridement, cleansing with antibacterial soap, and application of a topical antimicrobial dressing.

- Adequate wound care requires adequate pain control. Small, intermittent boluses of IV morphine or fentanyl are effective for basal pain control. Ketamine is effective for painful wound care (start with an analgesic dose of 0.25 mg/kg IV).
- Prophylactic antibiotics are generally not recommended for burn wounds alone. However, other wounds—such as open fractures, facial injuries, or intraabdominal injuries—may justify use of IV antibiotics and are not contraindicated by the presence of the burn injury.
- Apply a topical antimicrobial agent once or twice daily after thorough cleansing with a surgical detergent such as chlorhexidine gluconate (Hibiclens).
- Use of silver nylon dressings:
 - Burns may be dressed in pliable silver nylon dressings, which provide effective antimicrobial coverage by releasing silver ions. They require a slightly moist environment to remain effective. They should be wrapped with a layer of sterile gauze (eg, Kerlix) and moistened with water to maintain a damp environment. Avoid oversaturation leading to possible hypothermia.
 - Silver nylon dressings may be left in place for extended periods (72 hours), which may offer an advantage during transport.
- Use of topical antimicrobial solution or creams:
 - Aqueous mafenide acetate (Sulfamylon) 5% solution may be prepared and used to moisten sterile gauze and wrapped or laid on burn wounds. Sulfamylon 5% solution should be applied to the dressings approximately every 8 hours to maintain moisture in the dressings.
 - 1% silver sulfadiazine (Silvadene), and/or 8.5% mafenide acetate (Sulfamylon) burn creams may be used. They are applied as a thick layer ($\frac{1}{16}$ to $\frac{1}{8}$ inch thick) on the burn and wrapped with sterile gauze. One 400-g jar covers 20% TBSA.
 - During the period of active wound exudation, it is helpful to place bulky dressings beneath the burned parts to absorb the exudate.
 - Burn cream should be reapplied to open burns as often as needed to keep them covered.

Burn patients must be adequately immunized against tetanus.

- Definitive burn surgery in the combat zone is not advised for patients who can be evacuated to a definitive burn care facility.
- Prevent thermal stress by keeping the environment as warm as possible (>85°F).
- Corneal abrasions in burn patients can lead to full-thickness ulceration and blindness, and require aggressive treatment with antibiotic ointments, preferably gentamicin or a quinolone every 4 hours, alternating with erythromycin every 4 hours.
- Ear burns are prone to chondritis. Avoid placing ties across the ears and apply Sulfamylon cream to burns involving the ear because it will provide better cartilage penetration.
- It is common for patients to develop a sterile chemical cellulitis, manifested by an erythematous rim of normal tissue extending ~1 cm around the wound margin. **Erythema extending beyond this margin, with other clinical evidence of infection, likely represents gram-positive cellulitis (beta-hemolytic streptococcus or staphylococcus).** Consider early use of vancomycin. Treat with appropriate IV antibiotics.
- Invasive gram-negative burn wound infection is heralded by striking changes in the color of the burn wound and a clinical course consistent with sepsis.
 - Antibiotic treatment with an aminoglycoside and a carbapenem is recommended. Apply Sulfamylon cream BID and plan urgent evacuation, if available.
 - If evacuation is not possible, perform surgical excision to fascia.

Daily inspection of the burn wound by a surgeon is essential to identify early infection complications.

Extremity Care

- Carefully monitor the extremities throughout the resuscitation period. Management of the burned extremity can be summarized as follows:

- Elevate.
- Exercise burned extremities hourly.
- Evaluate pulses and neurological status hourly.
- Perform escharotomy as indicated.
- **In extremities with full-thickness, circumferential burns, edema formation beneath the inelastic eschar may gradually constrict the venous outflow and, ultimately, arterial inflow.** Adequate perfusion must be assessed hourly during resuscitation.

Progressive diminution of audible arterial flow by Doppler is a primary indication for escharotomy. Doppler flow should be sought in the palmar arch, not the wrist.

- Pulses may be difficult to palpate in edematous, burned extremities. However, **in the absence of a Doppler flowmeter, and in the appropriate clinical setting, loss of palpable pulses may indicate a need for escharotomy.**
- Patients requiring escharotomy often present with a tight and edematous extremity. They may have progressive neurological dysfunction, such as unrelenting deep tissue pain or paresthesias, and/or distal cyanosis.
- Prior to prolonged transport, strongly consider prophylactic escharotomy.
- Note that loss of the palmar arch Doppler signal, in the presence of adequate radial and ulnar pulses, is an indication for dorsal hand escharotomies. These are performed over the second and fourth metacarpals. Digital escharotomies may be useful in some cases.
- **Following escharotomy, document restoration of normal pulses and continue to monitor the patient.** If the procedure fails to restore pulses, reassess the depth and extent of the incisions, and look for other causes for poor perfusion.
- After escharotomy, cover wounds, including the escharotomy incisions, in burn cream.
- The patient may still develop a true intramuscular, subfascial compartment syndrome requiring fasciotomy.

- Fractures associated with thermal injury are ideally treated with external fixation to permit exposure of the burns and their treatment with topical antimicrobial agents. Plaster, if used, should be bivalved immediately to permit access for wound care and to accommodate edema of the burned limb.

Other Considerations

- After 24-48 hours postburn, patients will develop a hypermetabolic state, with hyperthermia, tachycardia, and hypercatabolism. These changes are proportional to burn size, and may be difficult to distinguish from early sepsis.
- Stress ulcer prophylaxis with IV medication is crucial during the early phases of treatment following severe burns.
- Implement early enteral nutrition once the patient is hemodynamically stable, generally by 24 hours postburn.
- Respiratory care.
 - Soon after injury, patients with subglottic inhalation injury may develop casts composed of fibrinous exudate, blood, mucus, and debris. Inhaled heparin sodium, at a dose of 10,000 units, should be given by nebulization every 6 hours to prevent the formation of casts and help prevent potentially life-threatening obstruction of endotracheal tubes.
 - **Subglottic inhalation injury may persist longer than clinically evident. Extubation must be performed with caution after adequate airway assessment.**
- Patients with large burns are at risk of abdominal compartment syndrome, which is best avoided by keeping the infused volume < 250 mL/kg during the first 24 hours postburn.

Electrical Injury

- High-voltage electrical injury (>1,000 volts) causes muscular damage that often is much greater in extent than the overlying cutaneous injury.
- Examine the extremities for compartment syndrome and perform urgent fasciotomy as needed.
- Gross pigmenturia (myoglobinuria) may result, and fluid resuscitation must be modified to protect against renal injury.
 - Pigmenturia is diagnosed by reddish-brownish urine, with a dipstick test that is positive for blood, but with insignificant numbers of red blood cells on microscopy.

- Elevated blood levels of creatine phosphokinase (CPK) > 5,000 IU/L may assist in trending the severity of myoglobinuria.
- Increase the hourly LR rate until a urine output of 100 mL/h is achieved.
- If increasing hydration fails to result in a progressive clearing of the urinary pigmenturia over a period of 3–4 hours, add 12.5 g mannitol to each liter of LR infused.
- Infusion of sodium bicarbonate in water (150 mEq/L) to alkalinize the urine may be useful.
- Hyperkalemia may occur as a result of rhabdomyolysis, and must be carefully assessed and treated with calcium gluconate infusion, insulin, and glucose.
- Surgical debridement of nonviable muscle is the definitive treatment of persistent myoglobinuria.

High-voltage electric injury requires consideration of deep muscle injury, with resultant rhabdomyolysis, hyperkalemia, acute renal failure, and compartment syndrome. Cardiac monitoring, aggressive fluid and electrolyte management, fasciotomy, and debridement are often required.

- Patients with electrical injuries are at increased risk for multiple fractures, including spinal fractures.

Chemical Burns

- Initial treatment requires immediate removal of the offending agent.
 - Brush any dry materials off the skin surface before implementing lavage with copious amounts of water.
 - In the case of alkali burns, lavage may need to be continued for several hours.
 - Resuscitate and manage chemical burns just as you would a thermal burn.

White Phosphorus Burns

- Most of the cutaneous injury resulting from phosphorus burns is due to the ignition of clothing and is treated as a conventional burn.

- Fragments of this metal, which ignite on contact with the air, may be driven into the soft tissues.
- First-aid treatment of casualties with imbedded phosphorus particles includes **copious water irrigation and placement of a saline-soaked dressing that must be kept continuously wet.**
- Profound hypocalcemia and hyperphosphatemia may result from white phosphorus injury. Check the ECG for prolonged QT interval. Treat with IV calcium and monitor closely.
- Rapid surgical removal of the identifiable particles should be performed; a UV (Wood's) lamp can be used to help locate particles.
 - A dilute (1%), freshly mixed solution of copper sulfate has been used to help identify white phosphorus particles. However, this is no longer recommended because, if the solution is absorbed, it can cause severe hemolysis. If it is used, immediately wash it off with copious saline irrigation; do not apply it as a wet dressing.
- Liberally apply topical antimicrobial burn creams postoperatively.

Triage Considerations

Application of optimal care currently results in survival of approximately 50% of young adults whose burns involve 80% or more of the TBSA. However, treatment options in a battlefield triage situation may be less than optimal, and expectant care may be considered for patients with burns that exceed 80% TBSA when resources are limited. Expectant status (comfort care) should not be implemented based solely on the severity of injury alone, and resuscitation should be implemented for all burn patients, provided resources are available for progressive care, including evacuation to definitive care. Care can be delayed for those patients with burns of 20% or less who are otherwise hemodynamically stable.

Care of Local National Burn Patients

- Treatment of local national patients with burns is frequently encountered by deployed medical units. The basic tenets of burn care apply to any population. However, decisions regarding futility may arise based on the resources available

both at the field facility and among civilian facilities within the region. The inability to evacuate patients for any further definitive care may preclude initiation of aggressive resuscitative or operative interventions and warrant early transition to comfort care measures if there is no potential for evacuation for definitive care.

- Definitive care of burn patients is resource-intensive and affects personnel, supplies, operating room availability, and the blood bank. Careful planning and staging of operations are essential.
- Graft failure enlarges the overall wound burden. Protection of the healing donor site(s) is also crucial. Likewise, it is very important to utilize all donor sites efficiently, including the scalp.

Summary

- Burn patients must be evaluated as trauma patients, searching for other injuries that may be more immediately life-threatening than the burn itself.
- Patients with burns involving 20% or more of the TBSA generally require formal fluid resuscitation and close monitoring.
- The Rule of Tens provides a simplified means of estimating the initial hourly fluid resuscitation rate in adults.
- Placement of a Foley catheter and close monitoring of urine output are essential parts of the resuscitation process.
- Both under- and overresuscitation are associated with undesired effects that must be avoided.
- In most situations, the key factor affecting whether or not a patient's burns are deemed so severe as to warrant implementing comfort care measures is not the extent of burn alone, but rather the availability and access to definitive care, including long-range evacuation if necessary.
- Early communication and consultation with staff at the burn center are encouraged; early discussion of management and transport options ensures optimal coordination along the continuum of care.
- Consultation may be obtained 24/7/365 by contacting the US Army Institute of Surgical Research (USAISR) Burn Center at Fort Sam Houston, Texas, at (210) 222-BURN (2876) or via email at: burntrauma.consult@us.army.mil.

- Updated Clinical Practice Guidelines (CPGs) related to burn trauma may be found at the Joint Trauma System public website.

**For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs**