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A Review of Thermal Burns for Emergency Clinicians

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Thermal burns represent a substantial proportion of the environmental injuries seen in emergency departments (EDs) across the world. In the United States alone, nearly half a million patients are treated in the ED each year for burn injuries, most of whom are cared for by emergency clinicians and then followed up in the outpatient setting. Emergency medicine clinicians need to be adept at the acute treatment of both minor and major burns and be confident in their ability to decide which patients need referral to a burn center. Along with reviewing the basics of skin anatomy and the complex pathophysiologic processes involved in thermal burns, this article discusses the current classification of burn depth, the sometimes underestimated potential for inhalation injury, and the treatment of acute burn complications, including the need for early airway control, fluid resuscitation, and escharotomy. The authors outline current recommendations for the treatment of minor burns, the initial treatment of more serious thermal injury, and the decision-making algorithm for burn center referral.

Introduction

The most recent data compiled by the American Burn Association highlight the following statistics regarding major burns:

- Approximately 26,000 patients are admitted each year to the nation's 128 burn centers.
- Among the civilian population, a death related to fire occurs every 2.75 hours.
- The ratio of male to female patients admitted to burn centers is two-thirds to one-third.
- Seventy-three percent of such injuries occur in the home setting.
- The single greatest cause of burns requiring care in a burn center are those caused by flame (43%), followed by scalding (34%), direct contact (9%), electrical (4%), chemical (3%), and other (7%).[1]

The most common type of burn in pediatric patients younger than 5 years of age is scalding.[2] The overall survival rate among burn center patients is close to 97%.[1]

Thermal burns seen in the emergency setting can be thought of as falling into three overlapping categories of descending prevalence: 1) relatively minor superficial burns of limited extent that may be quite painful but that have minimal potential for complications; 2) deeper burns of greater or lesser extent that carry some potential for complications; and 3) extensive partial- or full-thickness burns that have serious sequelae and may require immediate life-saving interventions. Since thermal burns are an especially dynamic injury because of

EXECUTIVE SUMMARY

- Cool, running tap water is an effective method for reducing injury from superficial and superficial partial-thickness burns.
- Inhalation injuries are more common in enclosed-space fires and in conditions causing impaired consciousness.
- Consider carbon monoxide poisoning or cyanide toxicity as potential causes of impaired consciousness in thermal burn victims.
- Full body exposure is necessary to accurately estimate the extent of burn involvement.
- Areas that are superficially burned are not included when calculating the percentage of body area injured by a thermal burn.
- Initiate fluid resuscitation using lactated Ringer's solution based on the extent of the burn injury.
- Do not apply opaque ointments to burns prior to transfer to a burn center.

the progressive inflammatory damage in the hours to days following the initial insult, acute estimates of injury severity can be difficult to make. Along with understanding the range of acute treatment strategies, emergency clinicians need to be well versed in techniques for estimating burn surface area and in determining burn depth. Although most thermal burns seen in the emergent setting are relatively minor and easily treated, crucial disposition decisions depend on clinical burn assessment skills, which this article will review in detail.[3]

Review of Skin Anatomy

The skin is the largest organ of the body, comprising an average surface area of 1.8 m^2, and is composed of three layers of tissue: epidermis, dermis, and hypodermis.[4] Serving multiple functions, the skin provides the body with a durable chemical and physical barrier, regulates body temperature, prevents fluid loss, provides sensory information, and aids with vitamin D production. The epidermis consists of constantly regenerating epithelium cells, while the dermis contains nerves, blood vessels, and assorted other structures, including sweat glands and hair follicles.[5] The hypodermis is subcutaneous adipose tissue beneath the dermis that provides insulation, functions as a cushion in the event of trauma, and acts as a local energy reserve.[5]

Pathophysiology of Thermal Burns

Exposure to thermal energy can lead to cellular damage, resulting in a burn injury. Temperatures below 44°C typically do not injure human tissue.[6] However, as temperatures rise, increasing damage to cells occurs, eventually leading to cellular death. Increasing temperature leads to protein denaturation, with most proteins becoming denatured at temperatures exceeding 60°C.[2] When temperatures range between 45°C and 51°C, injury occurs within minutes, and when temperatures rise to between 51°C and 70°C, injury happens within seconds. Exposure to temperatures above 70°C leads to instantaneous injury.[4] The ultimate extent of injury depends on the temperature and duration of exposure to the heat source. Damage caused by thermal burns compromises the skin's ability to maintain its barrier and homeostatic functions, leading to systemic complications.

Once a thermal injury occurs, three zones are present at the wound: the zone of coagulation, the zone of stasis, and the zone of hyperemia.[7] The zone of coagulation contains cells damaged at the time of injury that linger in a state of coagulated necrosis. The zone of stasis surrounds the coagulated area and undergoes inflammation and decreased perfusion.[7] Depending on the nature of the wound, tissue in this zone may survive the insult or progress to coagulative necrosis, often within 48 hours of the initial injury.[4,7] The final area is the zone of hyperemia, marked by vasodilation due to the inflammation surrounding the burn injury. Tissue in this region still is viable and usually is not subject to advancing necrosis.[4]

Burns can cause a protean cascade of secondary injury. Microvascular dysfunction in the afflicted tissue results in vascular damage from thrombosis of vessels, increased production of inflammatory cytokines, and increased proapoptotic factors like histamine, kinins, tumor necrosis factor, interleukins, and free radicals.[7] Extensive burn injuries, particularly those covering greater than 30% of the total body surface area (TBSA) often lead to hypovolemia and "burn shock" from inflammation-mediated cell membrane dysfunction.[8] This inflammatory response generates cardiovascular dysfunction secondary to insufficient oxygen and diminished nutrient delivery to tissues in conjunction with poor cellular waste removal. Increased pulmonary and systemic vascular resistance may arise despite appropriate fluid resuscitation. This leads to myocardial depression and decreased cardiac output, further promoting tissue hypoperfusion, worsening inflammatory response, and ultimately leading to organ failure.[8] The resultant hypermetabolic state and hypovolemia lead to additional systemic effects, including increased protein degradation, renal failure from reduced renal blood flow, and mucosal atrophy in the gastrointestinal tract.[8]

Burn Evaluation

It is essential for clinicians to evaluate the TBSA affected by a burn accurately to guide treatment. Multiple methods for estimating burn size have been created. One method assigns the area of the back of a patient's hand as 1% of TBSA. The total area burned is equal to the number of hands used to cover the areas burned.

Another is the Rule of Nines. This system divides the body into sections of approximately 9%, with larger areas being multiples of 9%, adding up to 99%, and the genitalia and perineum

Table 1. Estimating the Extent of Burns

Method	Technique
Rule of Nines for adults	Head/neck: 9% TBSA Each arm: 9% TBSA Anterior thorax: 18% TBSA Posterior thorax: 18% TBSA Each leg: 18% TBSA Perineum: 1% TBSA
Rule of Nines for children	Head/neck: 21% TBSA Each arm: 10% TBSA Anterior thorax: 13% TBSA Posterior thorax: 13% TBSA Buttocks and genital area: 6% TBSA Each leg: 13.5% TBSA
Palm method	Patient's palm or back of hand (not including fingers and wrist): 1% TBSA
Lund-Browder diagram	This diagram is adjusted for age, providing allowances for the anatomic variations present as ages change. It is very useful in pediatric burns.

TBSA = total body surface area

contributing 1%. Since children and infants have different proportions because of their larger heads and smaller legs, the Rule of Nines must be modified for use in this population.[9] (*See Table 1.*) A third and more precise system is the Lund-Browder burn diagram. This diagram is adjusted for age, providing allowances for the anatomic variations present in children.

Overestimation and underestimation of burn extent can occur because of the subjective nature of the process, even with more accurate approaches like Lund-Browder.[10] The more experienced providers are with burn care, the more accurate their estimations of TBSA will be when assessing burns.[10]

Because burn depth is directly related to the degree of tissue injury and correlates to the level of treatment necessary, accurate burn depth estimation also is important. Although several techniques have been proposed to evaluate burn depth, the most common approach outside of burn centers is clinical examination.[11] Telemedicine is becoming a more popular and useful strategy for assessing both burn depth and burn extent in facilities less familiar with burns.[12]

Traditionally, burn depth was classified as first, second, or third degree, but burn nomenclature is transitioning to a more nuanced classification system that considers the need for surgical intervention.[3] This paradigm classifies burns as superficial, superficial partial-thickness, deep partial-thickness, or full-thickness. (*See Table 2.*)

Superficial burns involve the surface layers of the epidermis only and do not generate blisters.[13] These burns often are painful and tender, with the affected skin turning pink or red. Sunburn is a commonly referenced descriptive example.[13] Superficial burns are not emergent and should not be included in TBSA calculations.[13] They typically heal within seven days and do not form scars.[3]

Superficial partial-thickness burns result from damage to the epidermis and superficial dermis, sparing the deeper layers of the dermis.[3] These burns are characterized by blisters and edema, and are quite painful.[11] Depigmentation can occur if melanocytes are injured from the burn.[11] They usually heal within 14 to 21 days, and often do not scar because the basal cells of the epidermis remain intact, allowing for regeneration.[3,11]

Deep partial-thickness burns extend through the epidermis into the deeper structures of the dermis, damaging sebaceous glands and hair follicles.[11] Skin will be red or white for these burns without blister formation.[2] Burns to this depth cause damage to capillaries, resulting in a diminished or missing capillary refill, and pain may be absent in the central region of the burn.[3]

Full-thickness burns destroy the epidermis and dermis, and extend into the subcutaneous fat and muscle. The skin will have a leathery, white-brown appearance without blanching or pain. These burns will require surgical excision and skin grafting to heal appropriately.[11] Scarring from a full-thickness burn will be severe, even after treatment.[3]

Note that the presence of pain does not rule out deep partial-thickness burns, since the edges of the wounded tissue and surrounding area still may have intact innervation and can convey intense pain from the injury. Because of the depth of these burns, individuals may require surgical excision, at which time skin grafting becomes necessary for healing.[11]

Burn Center Transfer

The American Burn Association has created guidelines on when it is appropriate to refer a patient with a burn injury to a burn center.[14] Any electrical or chemical burns should be referred, as well as burns in children. If a pediatric burn center is not available, an adult burn center is an acceptable alternative. Burns present on the face, hands, feet, genitalia, perineum, or major joints, as well as full-thickness burns, should be considered for transfer.

Providers should have a lower threshold for transferring burn-injured patients with comorbidities because of the potential for more complicated management strategies with delayed healing and higher rates of mortality. This includes patients who will need special social, emotional, or rehabilitation interventions alongside treatment for their burn injuries.

Patients with simultaneous trauma (e.g., fractures, internal organ injuries) will have a more complicated course. If such trauma is the greater concern, it should be addressed first. Patients must be stabilized to the greatest degree feasible prior to transfer to a burn center. In borderline cases, consult with the burn center to discuss the situation. This

Table 2. Burn Depth Classification

Type	Structures Involved	Appearance and Symptoms	Potential for Scarring
Superficial	• Involves only superficial layer of epidermis	• Red or pink skin appearance • No blisters • Can be very painful	• None • Do not include in % TBSA calculations
Superficial partial-thickness	• Involves damage to epidermis and superficial dermis	• Characterized by blisters, possible edema • Very painful	• Usually heal by primary intention from epithelial tissue in intact follicles, often within two to three weeks or less, and may not cause scarring
Deep partial-thickness	• Involves epidermis and deeper layers of the dermis, with damage to sebaceous glands and hair follicles	• Blisters may be absent, with the burn appearing red or pale skin, with possible loss of capillary refill • Pain may be absent in deeper burns, but pain will be present in surrounding margins of lesser depth burn	• Healing is by secondary intention and often involves scarring and contraction
Full-thickness	• Burn extends entirely through the epidermis and dermis into subcutaneous fat and muscle, and possibly to bone in severe examples	• Classic appearance is that of leathery, white-brown tissue without blanching or pain	• In more extensive full-thickness burns, surgical debridement and skin grafting will be needed to preserve as much function as possible

TBSA = total body surface area

individual approach can assist with preventing unnecessary transfer and overtriage in patients who may not require a transfer to receive appropriate care.[15]

Criteria for burn center transfer are noted in Table 3.

Inhalation Injury

Inhalation injury poses a significant threat to those with thermal burns, especially burns acquired from fire exposure. Burn patients with an inhalation injury have an overall mortality rate of about 20%, as opposed to patients without smoke inhalation, who experience an approximate 2% mortality.[16] Of those patients with burns from flame injury, 15% had simultaneous inhalation injury present.[16]

Respiratory tract injury severity is influenced by temperature, duration of exposure, and composition of the smoke. The injury itself is a combination of insults to the airway — supraglottic thermal injury, subglottic airway and alveolar poisoning, and systemic poisoning from small-molecule toxins absorbed from the smoke.[17] Fires that occur in enclosed spaces, as well as conditions resulting in impaired consciousness (alcohol and drug intoxication, overdose, head injury, etc.), are associated with an increased risk of inhalation injury.[3]

Signs of inhalation injury include facial burns, soot surrounding the mouth or nose, carbonaceous sputum, wheezing, stridor, change in voice, cough, dyspnea, and corneal burns.[18] These signs can be variably present and do not always correspond with lower airway injury. Bronchoscopy remains the gold standard for diagnosing inhalation injury below the glottis, allowing for direct visual evaluation and confirmation of injury and allowing for the prediction of outcomes based on the extent of injury.[18,19] Alternatively, the supraglottic region can be inspected for injury with direct or video laryngoscopy.[18] Chest radiographs often are normal on the initial presentation of patients with substantial inhalation injuries.[18]

The supraglottic region usually bears the brunt of thermal injury because of the efficient heat dissipation in the upper airway and the low heat capacity of air. When the glottis is exposed to the irritation of smoke, it tends to close reflexively, protecting the infraglottic structures.[17] Supraglottic edema can develop and progress quickly to the point of compromising ventilation. Furthermore, once established, such swelling can complicate intubation efforts.

Subglottic injury is seen less commonly in direct heat injuries, with the exception of steam, which is less irritating and less likely to cause reflexive glottic closure than breathing noxious chemicals and irritants.[20] These noxious agents also can inflict direct damage on airway tissue and can provoke inflammation in lung parenchyma. This disrupts respiration and leads to airway mucosal hyperemia, bronchospasm, and cast formation from mucosal sloughing, fibrinous exudate, loss of surfactant, and impaired mucociliary escalator function.[17] Mucosal hyperemia results in physical narrowing of the airways, edema, and increased exudates. Concomitant bronchospasm further narrows the airway and, combined with

Table 3. Criteria for Burn Center Referral

1. Partial-thickness burns of 20% or greater total body surface area (TBSA) for patients between 10 and 50 years of age
2. Full-thickness burns of 5% or greater TBSA in all age groups
3. Partial- or full-thickness burns involving the major joints, perineum, distal extremities, or face or facial structures
4. Partial-thickness burns of 10% or greater TBSA in children younger than 10 years of age or adults older than 50 years of age
5. Burns with inhalation injury
6. Patients with significant comorbidities, major trauma, needs for special emotional or social support, and cases involving suspected child abuse
7. Significant electrical burns

the decrease in surfactant, increases the risk of alveolar collapse and atelectasis.[17]

Injury to the lung parenchyma leads to compromised ventilation and decreased capacity for oxygenation in the injured lung. Uninjured tissue may experience injury secondary to tidal volume redistribution to unobstructed areas. Injury to intact tissue occurs from barotrauma, acute respiratory distress syndrome, and pneumothorax.[17] Acute respiratory distress syndrome after thermal injury may have an onset two to five days after the initial burn trauma, and is seen more frequently in patients with an inhalation injury.[20] Inhalation injury is complicated further systemically by hypoxemia, hypercapnia, acidosis, and the release of inflammatory mediators.

Carbon Monoxide Poisoning

Inhalation injury carries a significant risk of carbon monoxide poisoning due to the incomplete combustion of carbonaceous materials in the inciting fire. A colorless, odorless gas, carbon monoxide is difficult to notice without a detector.[21] When inhaled, carbon monoxide binds tightly to hemoglobin, preventing oxygen from binding to receptor sites on the hemoglobin molecule and displacing oxygen that has already been bound.

Clinicians should maintain an especially high index of suspicion for carbon monoxide poisoning in burn victims and firefighters who present with nausea, vomiting, headache, fatigue, dizziness, altered mental status, loss of consciousness, shortness of breath, and chest pain. Routinely check carboxyhemoglobin levels and do not be misled by relatively benign-appearing oxygen saturation levels.[21] Pulse oximetry does not distinguish well between oxyhemoglobin and carboxyhemoglobin, and saturation levels may appear reasonably normal in the setting of severe carbon monoxide poisoning.[22]

Carboxyhemoglobin levels of greater than 5% in nonsmokers or greater than 10% in smokers should raise suspicion for potential carbon monoxide poisoning.[23] Levels exceeding 30% at the time of exposure to carbon monoxide often are present in the setting of severe poisoning.[23] Treatment for carbon monoxide poisoning is 100% oxygen administration along with continuous observation in case of cardiovascular instability or alterations in mental status, particularly in moderate and severe carbon monoxide poisoning.[24] Patients experiencing syncope, seizures, ischemic electrocardiogram changes, coma, or pregnancy with continuing fetal or maternal distress, and whose burns are otherwise stable, may benefit from treatment with hyperbaric oxygen.[24]

Cyanide Toxicity

Because hydrogen cyanide can be released during the combustion of materials containing nitrogen, such as the plastics and nylon commonly found in modern households, individuals burned in house fires are at a higher risk of cyanide poisoning.[25] Cyanide disrupts oxidative phosphorylation within the mitochondria by strongly binding to the ferric ions of cytochrome oxidase a3, thus disrupting the electron transport chain and inhibiting oxygen use in tissues. This leads to anaerobic metabolism, which generates metabolic acidosis from increased lactate production.[26]

Patients with mild acute cyanide toxicity experience headache, nausea, drowsiness, a metallic taste in their mouths, dizziness, anxiety, and tachypnea.[26] Later symptoms such as dyspnea, arrhythmias, bradycardia, hypotension, and episodes of cyanosis or unconsciousness develop. More severe cases can lead to coma, convulsions, and cardiovascular collapse with lethal outcomes.[26] Cherry-red skin can be found in those experiencing cyanide poisoning because of the increase in venous oxygen content when tissues are unable to use the oxygen in arterial blood, but it does not reliably appear on initial presentation.[27] This also can result in an absence of cyanosis despite poor tissue oxygenation. An odor also may be present on the patient's breath, ranging from the classic bitter almond odor to a musty, putrid, or ammonia smell.[27]

The preferred treatment for cyanide poisoning is hydroxocobalamin,[28] which binds to cyanide, forming the nontoxic cyanocobalamin, which subsequently is excreted from the body in the urine. An initial dose of 5 g is administered intravenously over 15 minutes. In patients with severe toxicity or who do not respond well to the initial dose, a second dose of 5 g may be given. An alternative therapy is 300 mg of sodium nitrite and 12.5 g of sodium thiosulfate; the sodium nitrite serves to induce methemoglobinemia, while the sodium thiosulfate acts as a sulfur donor.[27] Hydroxocobalamin has been found to be the safer therapy, since treatment with nitrites can result in hypotension alongside the methemoglobinemia, potentially endangering tissue oxygen delivery further.[28]

Prehospital Care

The field assessment of a patient with a burn injury follows a similar approach to other trauma with a primary and secondary survey, although some key differences exist. When initially addressing any burn injury, the first step is to stop the mechanism instigating the burn to prevent further damage. If possible, the burned area and any adjacent regions should be fully exposed, and clothes or other coverings (e.g., diapers on infants) should be removed and the patient should be covered with clean sheets.[13] Inspect the patient's burned areas for items that conduct heat or restrict circulation and remove them to prevent further burning or complications from swelling post-injury.

If there is access to water at the scene of injury, pouring it directly on the burned area can aid in reducing the depth of the burn and decreasing the pain.[29] However, exercise caution because excessive cooling can induce hypothermia, a special concern because significant burn injuries can compromise the body's thermoregulation ability. Ice and ice packs should be avoided for this reason, as well.

Direct attention rapidly to the airway, assessing for signs of inhalation injury — especially if the patient may have been exposed to smoke and other heated gasses.

Expose the patient's chest to allow adequate assessment of ventilation. Circulation can be assessed through pulse rate and the color of unburned skin.[30] Blood pressure may be used, but can become unreliable because of the physiologic changes that accompany a burn injury as well as edema in the extremities.[31]

When establishing intravenous access, large-bore, indwelling venous catheters are preferable. For burns exceeding 20% of the TBSA, two large-bore intravenous catheters should be inserted.[30] If intravenous access is obtained in the field, initiate fluid resuscitation; however, this should not delay transportation of the burn patient to the hospital.

In the prehospital setting, for patients with significant visible burns, initial fluid rates are based on the patient's age before TBSA is calculated, as follows:

- Patients 5 years of age or younger receive 125 mL lactated Ringer's per hour.
- Patients 6-13 years of age receive 250 mL lactated Ringer's per hour.
- Patients 14 years of age and older receive 500 mL lactated Ringer's per hour.

A head-to-toe secondary assessment should be conducted to check for additional injuries. If possible, obtain information about the patient's past medical history, current medications, and allergies.[31] Lastly, prehospital wound care should not be elaborate and should focus on applying a clean dressing or other covering to protect the burned areas from the environment. Pain control may be used if approved for local emergency medical services (EMS), but it should be limited to intravenous administration sufficient to control pain.[31]

Emergency Department Assessment

Providers should assess burn patients arriving in the ED as they assess any trauma patients, by following advanced trauma life support (ATLS) protocols. Avoid the pitfall of allowing the appearance of severe burns to detract from rapid assessment of the patient's respiratory and cardiovascular status.[30] A focused history should be obtained from EMS personnel and the patient, when possible.[3] Details of the mechanism of injury include whether it occurred in an open or closed area, whether loss of consciousness occurred, whether significant chemical exposures were involved, the approximate duration of exposure to heat, and whether explosions, falls, and so forth occurred. Obtain information on past medical and surgical history, medications, allergies, and tetanus immunization status.[2]

During the primary survey, remove all clothing, jewelry, piercings, or other objects that can transfer heat or otherwise restrict tissue. If there are signs of potential respiratory compromise (i.e., neck swelling, burns inside the mouth, stridor), endotracheal intubation should be performed. If any inhalation injury is suspected, provide the patient supplemental oxygen as early as possible.[31] Circulatory status should be assessed through blood pressure readings, capillary refill time, urinary output, and mental status.[3] If intravenous access has not yet been obtained, venous catheters should be inserted, if possible, in unburned areas; if no unburned area is available, use a burned area so that fluid resuscitation can begin.[30]

Once the primary survey has been completed and initial stabilization accomplished, conduct an assessment for secondary trauma and to estimate the size and depth of the burn injury.[32] Obtain routine lab tests (complete blood count [CBC], electrolyte measurements, glucose, blood urea nitrogen [BUN], and creatinine), along with an arterial blood gas, carboxyhemoglobin levels, lactate, and serum creatine kinase.[3,7,28]

In burns are sustained in enclosed spaces with patients exhibiting signs of inhalation injury with altered consciousness in the face of a benign-appearing SaO_2 on pulse oximetry, a clinical suspicion of cyanide poisoning is sufficient to initiate treatment with hydroxocobalamin. Keep in mind that the classic signs of cyanide poisoning, such as cherry red skin and a bitter almond odor, may not be obvious.[26] Results of laboratory tests for cyanide generally are not available in time to be of clinical utility.

Burns in children warrant special care in obtaining a clear history and to compare the described mechanism with the burn injury to ensure that the story matches the clinical picture.[33] Although most burns in young children are unintentional and a result of not possessing the awareness or motor ability to avoid hot objects, if the nature of the injury does not match the developmental status of the child, it should raise suspicions for abuse.[33]

Other signs of inflicted burns include uniform burn depth, sharply delineated burn margins, sparing of creases and opposing skin surfaces, or imprinting of an object.[32] Cigarette burns are among the most common form of abusive object burns in children. Cigarette burns usually are more circular than impetigo patches and tend to be about 1 cm in diameter. Although scalds are found commonly as a mechanism of inflicted burns, the incidence of scalds compared to accidental burns is identical, rendering it an unreliable indicator of abuse.[34]

Fluid Resuscitation

A critical aspect of treating serious burn injury patients is appropriately managing their fluid resuscitation. The physiologic changes that accompany severe burns lead to intravascular fluid deficits and an increase in capillary permeability, resulting in decreased tissue perfusion.[30] Proper fluid resuscitation improves patient outcomes in severe burns, whereas over-resuscitation or under-resuscitation has been associated with increases in morbidity.[35]

Table 4. Fluid Resuscitation for Patients with Burns (Other than Superficial) of 20% TBSA or Greater

Total body surface area (TBSA) burn % includes only areas of partial- and full-thickness burns

Parkland Formula (24-hour total)
- 4 mL crystalloid × % TBSA × weight in kg
- Half given over first eight hours; half given over following 16 hours

Modified Brooke Formula (24-hour total)
- 2 mL crystalloid × % TBSA × weight in kg
- Half given over the first eight hours; half given over following 16 hours

As mentioned earlier, use large-bore peripheral intravenous catheters for fluid resuscitation, preferably through unburned skin when circumstances permit.

Although many different formulas are used to calculate the fluid needs for a severe burn patient, the Parkland formula and the modified Brooke formula are used most frequently.[30] (*See Table 4.*) The Parkland formula calculates the total crystalloid fluid administered as 4 mL/kg multiplied by the percent burned TBSA during the initial 24 hours. The modified Brooke formula calculates the fluid load as 2 mL/kg multiplied by the percent burned TBSA during the initial 24 hours. Regardless of which formula is used to calculate the fluid quantity, the first half of the fluid is given to the patient in the first eight hours, and the other half of the fluid is given over the following 16 hours.[30] It is important to note that when calculating the TBSA burned, only partial-thickness and full-thickness burns are used. Superficial burns do not require fluid resuscitation, and including them in the calculation can lead to over-resuscitation.[30]

Ultimately, the fluid administration guidelines serve to sustain sufficient cardiac output throughout the course of care for the burn patient. To that end, different methods are used to estimate tissue perfusion and cardiac output to adjust how much fluid is given. A common method is to titrate fluids to a urinary output between 0.5 mL/kg to 1 mL/kg per hour in adults, with adjustments made to the bring the urinary output in line with this goal if it is higher or lower.[36] In children, a goal of 1 mL/kg per hour is ideal in those weighing less than 30 kg; those weighing greater than 30 kg should aim for a goal of 0.5 mL/kg per hour.[30] More invasive hemodynamic monitoring devices, such as central venous or pulmonary artery catheters, have been employed to guide fluid administration, but studies have not shown definitively that they improve outcomes.[37]

Of the available crystalloid solutions, lactated Ringer's solution is the most commonly used for resuscitation efforts.[36] Hypertonic saline has been shown to carry an increased risk of renal failure, hypernatremia, and mortality when used for resuscitation. Colloids and fresh frozen plasma are controversial options for resuscitation, with some studies showing benefit while others show no improvement in mortality over crystalloids alone.[36,38]

Airway Issues

During the course of treatment, clinicians must ensure that airway patency is maintained, and sufficient oxygenation is continued until the patient recovers. This is particularly important during initial care because of the risk of injury-related airway compromise. For any suspicion of inhalation injury, initiate supplemental oxygen.[17] In patients with signs of respiratory distress or central facial burns concerning for a supraglottic inhalation injury, early intubation is warranted to protect the airway before laryngeal edema complicates the ability to pass an endotracheal tube.[39] Other indications for early intubation include burns exceeding 40% to 50% of TBSA, difficulty swallowing, impaired levels of consciousness, or lack of a qualified provider to intubate during transfer to a larger burn center.[40] Patients who receive their burns in an enclosed space are at higher risk for an inhalation injury than those in an open space and are more likely to require intubation.[41]

The provider should select an endotracheal tube that is large enough to allow for diagnostic and therapeutic bronchoscopy as well as sufficient pulmonary hygiene on transfer.[30] Once successful placement of the tube in the airway has been confirmed, securing the tube is important. Adhesive tape does not adhere well to burned skin on the face and will not be a reliable mechanism to maintain the tube's position. The tube can be maintained in place using ties passed around the head, with care taken to avoid looping around the ears to protect the patient from further tissue damage or injury to the cartilage.[30]

Escharotomy

Circumferential burns lead to a loss of elasticity in the damaged skin and the formation of a noncompliant eschar.[42] As fluid resuscitation occurs and concurrent soft tissue edema from the burn worsens, compartment syndrome can set in, compromising perfusion alongside the neurologic function in the affected area. Further, if the chest or abdomen is affected by full-thickness burns, the patient may experience respiratory dysfunction, decreased cardiac output, splanchnic ischemia, or acute kidney injury.[43] Failure to identify and relieve the pressure ultimately can lead to permanent nerve damage and necrosis, and could necessitate amputation. Relieving this pressure through escharotomy restores perfusion to the underlying tissue, preventing further damage. However, it is important to rule out other causes of these symptoms before electing to perform this procedure.

Escharotomy is indicated when there is an increase in compartment pressure, the presence of neurologic symptoms, the absence of Doppler signals in the limb, or a decrease in oximetry signals.[44] When interpreting Doppler signals, note that triphasic flow is physiologically normal; monophasic or biphasic flow is an abnormal finding.[45] When measuring intramuscular pressure, two consecutive measurements exceeding 30 mmHg indicate escharotomy for the affected limb.[42]

Escharotomy is performed by creating incisions along the lateral and medial aspect of the affected limb, with attention to avoiding underlying nerve and vascular structures.[31] The incision only needs to travel through the dermis and dermal bands, avoiding the subcutaneous tissue as much as possible. Incisions that are made down to the fascia add a greater risk of morbidity for the patient.[45] When performing escharotomy on the chest, the incisions are made from the level of the second rib to the 12th rib in the anterior axillary line.[3] When escharotomy is necessary, it should be performed via electrocautery in a clean environment, ideally by a physician who is familiar with the underlying anatomy and technique.[31] Consultation with a burn surgeon may be helpful when considering this course of action.[30]

Cooling

After the initial thermal injury, the wound can be placed under cool running tap water to help stop further damage to the underlying tissue.[46] Cooling with ice or iced water is inadvisable, since this carries the potential risk for further tissue damage and hypothermia.[29] Maintaining the application of cool water for at least 20 minutes has been shown to help reduce burn depth in superficial and mid-dermal injures.[47] However, there is not a consensus on what temperature is most effective for cooling burn injuries.[48] And, it should be noted that a reduction in wound depth and healing time was not found for deep partial-thickness burns or worse.[47] Cooling the burned area should not delay transportation to the hospital for care, but the value of this effective and appropriate first aid leads to a reduction in wound depth, swifter healing, and a reduction in skin grafting requirements.[47]

Blister Care

Blisters are a frequent companion to burn injuries. They are seen mostly with partial-thickness burns. Deeper burns do not commonly result in blister formation.[4] Superficial partial-thickness burns result in thin-walled blisters with intact sensation that weep fluid. Deep partial-thickness burns will have thick-walled, white-skinned blisters that may have intact or impaired sensation.[49]

The management of burn blisters is controversial.[50] They can be managed by deroofing the blister, aspirating the fluid, or leaving the blister intact. The advantages of an intact blister are that the blister forms a mechanical barrier to prevent exposure to microorganisms while keeping the internal aspect of the wound moist, which assists with re-epithelialization during wound healing.[50] However, the fluid also contains substances, such as vasoactive prostanoids, unfavorable to wound healing. Additionally, the fluid itself has been found to impede fibrinolysis and inhibit the innate immune response against *Pseudomonas aeruginosa*, risking further dermal injury with infection.[49]

The literature does not show a definitive benefit in outcome to deroofing blisters vs. leaving them intact.[48] More research is needed.

However, a blister that has ruptured already or is likely to rupture should be debrided. Blisters that decrease the mobility of the patient or otherwise impede their functionality also should be debrided. Debriding blisters also reduces the time and resources required for subsequent wound care.[50] An additional benefit of debriding blisters is the ability to fully assess the extent of burns at the initial patient contact and again later after any progression to the burn depth has occurred.[48,50] This approach allows wound dressings to have direct contact with underlying viable tissue at the site of injury, rather than with the dead tissue of the blister. To remove the blister, clip the top with scissors to deroof it, then debride the tissue with forceps.[51]

Dressing Types/Ointments

Once burn wounds have been assessed and cleaned appropriately, it is essential to dress the wounds appropriately to maintain a moist environment for healing. Preventing infection is essential for timely wound healing, since infection can lead to failure of skin grafts and delayed healing.[52] It is important to note that superficial burns do not require a dressing or further follow-up, but treating the burn with aloe vera gel regularly can result in reduced pain and faster healing time.[53] Wound care should be conducted one area at a time to minimize exposure.[30] The dressing choice for any burn wound should be a nonstick medium to minimize pain and discomfort during wound inspections and dressing changes.[51]

Silver sulfadiazine still is a commonly used topical antibacterial cream, especially for deep burns and those that will heal spontaneously, but it should be avoided in partial-thickness burns because it prevents re-epithelialization.[54] Silver sulfadiazine also carries the potential for long-term skin staining. Dressing a burn with silver sulfadiazine before transferring a patient to a burn center will make burn assessment more difficult for the receiving clinicians. Check with the accepting burn surgeon regarding the preferred dressing.

Topical antimicrobial ointments appropriate for burn wounds include bacitracin or double antibiotic ointment, and they should be applied to the dressing then placed over the wound.[30,54] Dressings should be changed at minimum daily; however, silver-impregnated dressings can be left in place for five to seven days.[48] The frequency of dressing changes should be tailored to the patient based on soiling of bandages, availability of a replacement dressing, and how often topical ointment needs to be reapplied.

Analgesia

Pain control is a vital component in the care of burns, which frequently are extremely painful. Effective pain control has been associated with better wound healing, prevention of psychological trauma, and improved quality of life over the course of recovery.[55] Pain during burn injury passes through several high points — at the onset of injury, during debridement and dressing changes, and with surgery.

Begin by assessing the patient's level of pain. Visual and analog scales both are effective in accurately measuring pain.[55] When selecting medication, additional consideration should be given to the underlying source of the pain, whether it is background pain from the injury, temporary but expected pain from interventions, breakthrough pain, or chronic pain.[52]

In the ED, morphine, fentanyl, and hydromorphone are effective in controlling extreme pain.[50] Because of the loss of albumin from thermal injury and subsequent fluid resuscitation, an increase in the volume of distribution can lead to greater requirements for pain medication compared to in an unburned patient.[55] Ketamine can be useful because of its dissociative properties in managing procedural burn pain.[52] Nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen also are useful adjuncts in pain management, particularly once initial severe pain has been controlled.[55] Pregabalin has been shown to be effective in treating neuropathic pain and reducing opioid consumption for pain in the acute setting.[56] Other nonopioid medications, such as antidepressants, benzodiazepines, and gabapentin, also have been successful for pain reduction.[57] Intranasal fentanyl and ketamine are effective in pediatric patients with similar analgesic effects.[58] However, intranasal fentanyl may have a better side effect profile regarding sedation and dizziness than ketamine.[59]

Summary

Burns are complex injuries that can lead to multisystem complications, shock, and cardiovascular collapse due to systemic inflammatory mediator release. Accurate estimations of the extent of burn injury are vital for patient disposition and fluid resuscitation. The Lund-Browder diagram is the most accurate tool, but it requires experience. The hand rule of estimation is a reasonably reliable method. In evaluating TBSA percent burned, only superficial partial-thickness through full-thickness burns are counted.

Transfer to a burn center is indicated when superficial partial-thickness burns exceed 10% of TBSA, deep partial-thickness and full-thickness burns exceed 20%, or full-thickness alone exceeds 5%. Additionally, patients with signs of inhalation injury and those with burns on sensitive areas necessitating special treatment (hands, feet, face, perineum, and genitalia) should be transferred. Consult with a burn center in ambiguous situations rather than following a black-and-white decision matrix to initiate transfer.

Inhalation injury poses a serious threat to burn patients. Signs concerning for inhalation injury include wheezing, stridor, hoarseness, carbonaceous sputum, cough, and facial burns. However, the presence of these signs does not correlate directly with the presence of inhalation injury. Direct visualization with laryngoscopy or bronchoscopy allows for confirmation of injury. Early endotracheal intubation can preserve the airway before edema renders intubation difficult. Burn injuries carry the risk of carbon monoxide and cyanide poisoning. Clinical suspicion of either is sufficient to initiate treatment. Cyanide poisoning should be suspected in patients with recent fire exposure experiencing altered mental status and cardiovascular collapse. Treatment for carbon monoxide poisoning is 100% supplemental oxygen. Cyanide poisoning is treated with hydroxocobalamin.

Prehospital burn treatment includes stopping the mechanism of burn injury and removing any objects that can conduct heat or restrict tissue in the event of swelling. Cool, running water can be applied, but ice or ice packs should be avoided. Assess the airway and administer supplemental oxygen if signs of respiratory distress are present. A secondary assessment for signs of non-burn-related trauma, as well as medical history and pertinent details, should be conducted once the primary survey is completed and pain control initiated.

In the ED, burn patients are evaluated following ATLS guidelines, including rapid airway control when indicated. When evaluating children, compare the caregiver's story with the physical injuries to make sure there are no inconsistencies. Evaluate fluid resuscitation needs with either the Parkland formula or the modified Brooke formula. Over-resuscitation and under-resuscitation both carry risk, so take care to closely monitor the patient. Urine output is used to gauge resuscitation status, with a goal of 30 mL to 50 mL per hour in adults. Children should be titrated to a goal of 1 mL/kg per hour if they weigh less than 30 kg, and 0.5 mL/kg if they weigh more than 30 kg.

Escharotomy may be needed when patients experience ventilatory or neurovascular compromise. Consider debridement of blisters that have ruptured already, that are in areas predisposed to rupture, or that compromise the patient's mobility and function. Dressings for burns should be nonstick, and the topical antimicrobial ointment of choice should be applied to the dressing before applying it to the wound. Initial pain control with opioid analgesics is effective in managing extreme pain. Consider using nonopioid medications, such as ketamine, as well as NSAIDs and acetaminophen whenever possible.

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CME/CE Questions

1. The most common type of burn injury in pediatric patients younger than 5 years of age is related to:
   a. electrical burns.
   b. contact burns.
   c. scalding.
   d. smoke inhalation.

2. The most accurate method of assessing percent total body surface area in children involves:
   a. the palm method.
   b. the modified Rule of Nines.
   c. the Lund-Browder chart for burns.
   d. the modified Brooke pediatric burn assessment formula.

3. How much crystalloid should be administered over the first eight hours to a 70-kg man who has a 35% partial-thickness burn, using the Parkland burn resuscitation formula?
   a. 4,900 mL
   b. 2,450 mL
   c. 3,780 mL
   d. 1,500 mL

4. A 65-year-old male is brought to the emergency department by emergency medical services (EMS) after being recovered from a burning house trailer. He had made his own way outside, but collapsed and was unresponsive when EMS arrived on the scene. He is now confused, hypotensive, and has mild-appearing, partial-thickness burns on his anterior chest and both arms. His hair is slightly singed. There is no soot in his mouth or nose. EMS reports that there was intense smoke pouring out of the trailer door. His oxygen saturation is 95%, blood pressure 90/65 mmHg, pulse rate is 120 beats/min, and respiratory rate is 25. He is confused but following commands. His voice sounds normal. Secondary assessment reveals no other obvious signs of trauma or head injury. Which of the following steps would be *least* helpful?
   a. Administer 100% oxygen.
   b. Draw a stat cyanide level.
   c. Administer hydroxocobalamin.
   d. Check a carboxyhemoglobin level.

5. Which type of burn extends into the deeper levels of the dermis, damaging sebaceous glands and hair follicles, and may result in minimal pain and no blistering?
   a. Superficial burn
   b. Superficial partial-thickness burn
   c. Deep partial-thickness burn
   d. Full-thickness burn

6. A 5-year-old male is brought to the emergency department for fever and vomiting and is noticed to have a number of well-demarcated, circular, 1 cm healing lesions on the face, torso, and upper extremities that appear to be in different stages of healing. The child's caretaker reports them to be insect bites. Which of the following statements is true?
   a. Cigarette burns are a rare form of abusive object burns.
   b. Cigarette burns are seldom seen in children younger than 10 years of age.
   c. Cigarette burns are characterized by persistent blistering.
   d. Cigarette burns usually are more circular than impetigo patches and tend to be about 1 cm in diameter.

7. Which of the following is the preferred crystalloid in burn resuscitation?
   a. D5 ½ normal saline
   b. Normal saline
   c. Lactated Ringer's
   d. Hypertonic saline

8. Escharotomy on compromised extremities is performed by making incisions through the dermis:
   a. on the dorsal and volar aspects of the limb down through the subcutaneous tissue and fascia.
   b. on the lateral and medial aspects of the limb, avoiding the subcutaneous tissue and fascia.
   c. on the dorsal and volar aspects of the limb, avoiding the subcutaneous tissue and fascia.
   d. on the lateral and medial aspects of the limb down through the subcutaneous tissue and fascia.

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RELIAS MEDIA

EMERGENCY MEDICINE REPORTS

A Review of Thermal Burns for Emergency Clinicians

Burn Depth Classification

Type	Structures Involved	Appearance and Symptoms	Potential for Scarring
Superficial	• Involves only superficial layer of epidermis	• Red or pink skin appearance • No blisters • Can be very painful	• None • Do not include in % TBSA calculations
Superficial partial-thickness	• Involves damage to epidermis and superficial dermis	• Characterized by blisters, possible edema • Very painful	• Usually heal by primary intention from epithelial tissue in intact follicles, often within two to three weeks or less, and may not cause scarring
Deep partial-thickness	• Involves epidermis and deeper layers of the dermis, with damage to sebaceous glands and hair follicles	• Blisters may be absent, with the burn appearing red or pale skin, with possible loss of capillary refill • Pain may be absent in deeper burns, but pain will be present in surrounding margins of lesser depth burn	• Healing is by secondary intention and often involves scarring and contraction
Full-thickness	• Burn extends entirely through the epidermis and dermis into subcutaneous fat and muscle, and possibly to bone in severe examples	• Classic appearance is that of leathery, white-brown tissue without blanching or pain	• In more extensive full-thickness burns, surgical debridement and skin grafting will be needed to preserve as much function as possible

TBSA = total body surface area

Estimating the Extent of Burns

Method	Technique
Rule of Nines for adults	Head/neck: 9% TBSA Each arm: 9% TBSA Anterior thorax: 18% TBSA Posterior thorax: 18% TBSA Each leg: 18% TBSA Perineum: 1% TBSA
Rule of Nines for children	Head/neck: 21% TBSA Each arm: 10% TBSA Anterior thorax: 13% TBSA Posterior thorax: 13% TBSA Buttocks and genital area: 6% TBSA Each leg: 13.5% TBSA
Palm method	Patient's palm or back of hand (not including fingers and wrist): 1% TBSA
Lund-Browder diagram	This diagram is adjusted for age, providing allowances for the anatomic variations present as ages change. It is very useful in pediatric burns.

TBSA = total body surface area

Criteria for Burn Center Referral

1. Partial-thickness burns of 20% or greater total body surface area (TBSA) for patients between 10 and 50 years of age
2. Full-thickness burns of 5% or greater TBSA in all age groups
3. Partial- or full-thickness burns involving the major joints, perineum, distal extremities, or face or facial structures
4. Partial-thickness burns of 10% or greater TBSA in children younger than 10 years of age or adults older than 50 years of age
5. Burns with inhalation injury
6. Patients with significant comorbidities, major trauma, needs for special emotional or social support, and cases involving suspected child abuse
7. Significant electrical burns

Fluid Resuscitation for Patients with Burns (Other than Superficial) of 20% TBSA or Greater

Total body surface area (TBSA) burn % includes only areas of partial- and full-thickness burns

Parkland Formula (24-hour total)

- 4 mL crystalloid × % TBSA × weight in kg
- Half given over first eight hours; half given over following 16 hours

Modified Brooke Formula (24-hour total)

- 2 mL crystalloid × % TBSA × weight in kg
- Half given over the first eight hours; half given over following 16 hours

Supplement to *Emergency Medicine Reports*, June 15, 2020: "A Review of Thermal Burns for Emergency Clinicians." Authors: Cody F. Newell, DO, MHSA, CAPT, USAF, Resident in Emergency Medicine, Brooke Army Medical Center, San Antonio, TX; Frank J. Edwards, MD, FACEP, Designated Institutional Official, Arnot Health Graduate Medical Education, Elmira, NY. *Emergency Medicine Reports'* "Rapid Access Guidelines." © 2020 Relias LLC. Editors: Sandra M. Schneider, MD, FACEP, and J. Stephan Stapczynski, MD. Nurse Planner: Andrea Light, MS, BSN, RN, EMT, TCRN, CEN. Executive Editor: Shelly Morrow Mark. Editorial Group Manager: Leslie Coplin. Accreditations Director: Amy M. Johnson, MSN, RN, CPN. For customer service, call: 1-800-688-2421. This is an educational publication designed to present scientific information and opinion to health care professionals. It does not provide advice regarding medical diagnosis or treatment for any individual case. Not intended for use by the layman.