

MASS CASUALTY BURN CARE

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Objectives

- Describe the physiological injury and pathology of burn injury.
- Initiate the appropriate supportive and surgical treatment of burn victims.
- Appropriately triage patients with burn injuries.
- Explain the extended burn care models and their use in caring for burn patients in a non-burn intensive care unit (ICU).



Case Study

Due to an electrical defect, a fire occurred in a nearby movie theater. Several people were trapped in the burning building. The first patients start to arrive by foot, complaining of severe burn and pain with blisters on their hands. Some patients arrive without burns but complain of sore throat and shortness of breath. Paramedics are performing cardiopulmonary resuscitation on the scene for a pulseless burn patient. You work in a regional hospital without a burn center but with a 12-bed multidisciplinary ICU.

- How will you appropriately triage these patients?
- How will you initiate the appropriate supportive and surgical treatment of these patients?

I. INTRODUCTION

Burn injuries are very common both in disaster practice and in routine clinical practice. Petroleum derivatives, other industrial chemicals, and compressed gases are often present in our environment, and their mismanagement can result in serious health hazards. On average 60,000 patients require specialized burn unit admissions per year in the United States. Interestingly, some studies suggest that surgery, emergency medicine, and anesthesia residents are better

prepared to respond to an anthrax event, a sarin exposure, or a nuclear explosion than to handle burns. Burn care may require specialized personnel and materials and impose a significant burden on ICUs. Often patients with burns arrive in groups of 5 to 100 before secondary transfer can occur and they are triaged and/or transferred to specially designated facilities. This overwhelms the healthcare resources in nonspecialized medical or surgical ICU settings.

II. BURN INJURIES

Small burn disasters occur frequently, but large-scale burn disasters are less frequent. Between 1900 and 2000, there were 73 significant burn or fire disasters in the United States. Five produced more than 500 fatalities, 15 produced 100 to 500 fatalities, and 14 produced 50 to 99 fatalities. There was a trend toward decreasing frequency and fatality over the century secondary to improved fire-prevention strategies, firefighting, and burn care.

A. Physiopathology of Burns

A burn results from the exposure of the body to heat, electrical current (including lightning), and selected chemical components. An estimated 2 million Americans annually are burned, and 60,000 are admitted to regional specialized burn centers. Each population of 2 to 5 million requires a specialized burn center care. For example, the Montreal Burn Center, which serves 7 to 8 million inhabitants, receives 150 burn patients annually. Burn care has evolved dramatically in the last 30 years. Coordinated care includes plastic surgeons, specialized critical care practitioners, anesthesiologists, nurses, respiratory therapists, psychiatrists/psychologists, and rehabilitation specialists. Care of major burns usually involves 3 phases: 1) the initial resuscitation phase, mainly focused on preservation of vital functions; 2) the reconstructive phase, aimed at reconstructing the burned skin; and 3) the rehabilitation phase, centered on restoring function. Most burn centers around the world are short of staff and run at 90% of their bed capacity. Therefore, even with small-scale disasters, local resources are rapidly overwhelmed.

B. Physiology of Burns

Most burns are secondary to thermal injury to the skin. In a typical burn center, roughly 10% of burns are secondary to electrical or chemical injuries. Even chemical spills result in multiple thermal injuries. Thermal injury to the skin may be due to contact with a heated solid, splashing or immersion in liquids, contact with heated gases, or exposure to radiant warm (infrared). Although different burn mechanisms have different clinical features (**Table 8-1**), the background physiopathology remains the same. The skin can tolerate temperatures up to 111.2°F (44°C) without effects. Skin temperatures in the range of 111.2°F to 125°F (44°C to 51°C) are characterized by progressive and exponential cell death as the temperature increases. In temperatures above 125°F (51°C) there is rapid cell death. The usual temperature of an open flame is 2,200°F (1,200°C), and the temperature during a high-energy explosion is roughly 3,600°F (2,000°C).

Table 8-1. Sources of Burns

Source of Burn	Characteristics of Burn
Hot solid	Very deep burn area that corresponds to the contact area with the hot solid. Nearby skin not in contact with the hot solid is almost normal. No inhalation injury. Infrequent occurrence.
Hot liquid	May be secondary to immersion (burned area corresponds to the immersed area) or splatter (multiple burn areas). Deep burn area when contact is close to normal skin. Circular burn frequent with immersion.
Warm gases and steam	Burns of all depths and topographies on body parts facing both toward and away from source. Clothes offer little protection. Inhalation injury very frequent.
Flame	Mainly deep burns in all exposed areas. Even the "coldest" flame induces a deep burn within seconds. Clothes may provide some protection but may worsen the injury if they melt or ignite. Inhalation injury very frequent.
Thermal radiation	Also called <i>flash burn</i> . Corresponds to exposure to an expanding fireball and the resulting infrared thermal radiation. Burns on exposed parts facing fireball but mostly not on areas protected by clothing or facing away from fireball. Relatively superficial burns with topography that corresponds to clothing. Thermal radiation dissipates with distance from its source at a power of 3, but after a 1-megaton detonation, second-degree burns may be seen within a 15-kilometer (10-mile) radius. May be associated with temporary blindness.

The skin and/or the lungs receive the initial impact of burning. After this insult, all the organs of the body may become involved and lead to a multiorgan failure cascade. This results in massive hemodynamic and fluid resuscitation disturbances, metabolic alterations and protein catabolism, liver and gut alterations, kidney adjustments, and a state of immunocompromise that makes burn patients more susceptible to infection. This cascade has several aspects that closely mirror the inflammatory and sepsis cascade, which complicates the diagnosis and follow-up of super infections in burn patients. Until now, investigations aimed at interfering with this systemic response have not provided definitive interventions that may be widely used. Most of the initial care is thus spent on controlling and supporting the systemic reaction to burn.

C. Burn Depth and Surface Area

1. Burn Depth

Initial assessment of burn surface area and depth is the cornerstone of burn care because the accurate identification of those factors helps stratify the prognosis and focus the initial resuscitation. Burn depth has traditionally been classified as first degree, second degree, or third degree. Most essential, however, is to differentiate superficial second-degree burns from deep second-degree burns (**Table 8-2**). In superficial second-degree burns, there are remaining epidermal cells and the epidermis can regenerate alone, whereas in deep second-degree burns, there are no viable epidermal cells remaining and surgery is required. Deep second-degree burns and third-degree burns are referred to as *full-thickness burns*. The depth of a burn is a strong determinant of prognosis and resource utilization. First-degree burns compare with sunburns and usually resolve within 48 hours (**Figure 8-1**). Superficial second-degree burns usually present with impressive fluid-filled blisters (**Figure 8-2**). The roof of the blister is necrotic epidermis that must

be removed; after removal, the skin will be red and have a very rapid capillary refill. Deep second-degree burns have a very different appearance (Figure 8-3). The skin will not appear redder, but will be withered and have a leathery appearance. At first glance third-degree burns may seem less serious than superficial second-degree burns, but in fact, there is total skin necrosis in the affected areas, with necrosis extending into the subcutaneous fat tissue and muscle (Figure 8-4). Some technologies are being developed to objectively assess burn depth (laser Doppler, infrared spectroscopy), but clinical judgment remains the most accurate assessment tool widely available.

Definitive assessment of burn depth is difficult, and even trained surgeons may not correctly assess intermediate-depth burns for the first 24 to 48 hours. With intermediate superficial burns the involved area may be sufficiently perfused to survive and heal spontaneously. In cases of prolonged shock or infection, however, perfusion will not be sufficient and necrosis will develop. This phenomenon will give the impression that the burn deepened after 24 to 48 hours.

Table 8-2. Burn Depth Assessment

	First Degree	Second Degree Superficial	Second Degree Deep	Third Degree
Aspect	Red (sunburn)	Fluid-filled blisters	White/leathery	White or brown
Capillary refill	Perfused	Perfused, area becomes white with pressure and recolors rapidly	Not perfused, leathery aspect	Thrombosed capillary and vessels in the burn scar
Pain	Moderate	Severe	Almost none	None
Sensibility	Moderate pain	Very painful	Dull	No sensation
Bleeding on pinprick	Bleeding	Brisk bleeding	Slow bleeding	No bleeding
Hair	Attached	Attached	Easy to remove	Burned
Healing	Heals within 48 h	Self-heals within 1-2 wks	Requires surgery and skin grafting	Requires surgery and skin grafting

2. Burn Surface Area

Burn surface area is usually measured in adults using the rule of nines. Distribution is as follows: arms, 9% each; head/neck, 9%; anterior and posterior chest and abdomen, 9% each; thighs, 9% each; and lower legs, 9% each. The remaining 1% represents the genital area. A more detailed distribution is available, but all derive from the same basic rule of nines (Figure 8-5). In adults the palmar surface of 1 hand represents 1% of body surface, so it can also be used to estimate the burned surface area. In massively burned patients, it is easier to measure the non-burn area compared to the burn area. The objective of the primary

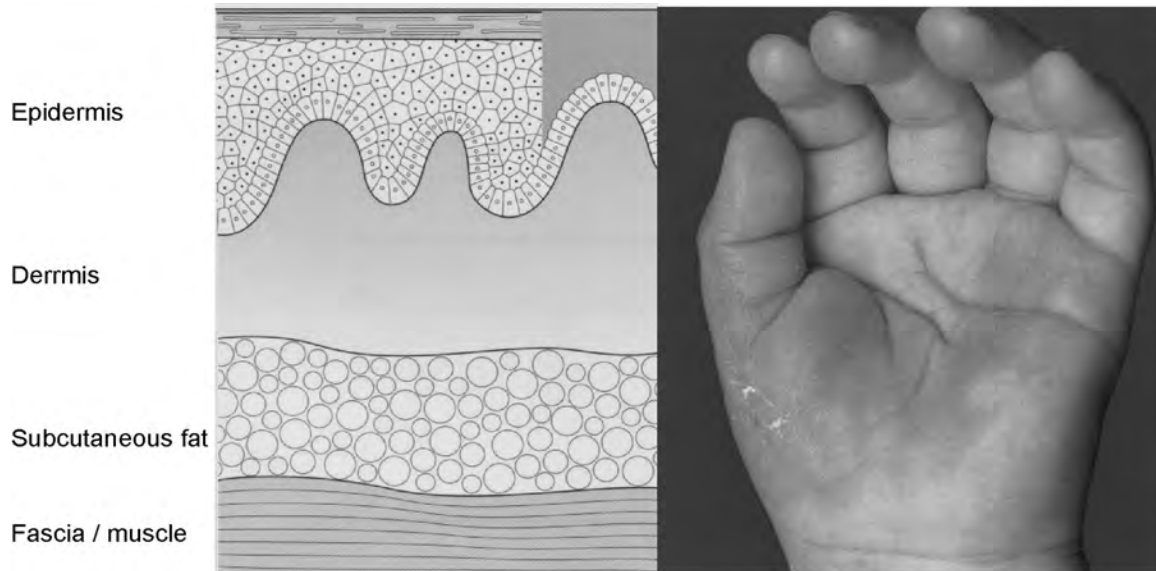
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To rapidly assess burn depth, look for the skin to appear as follows: first degree appears sunburned, second degree superficial appears blistered, second degree deep appears leathery, third degree appears charred.

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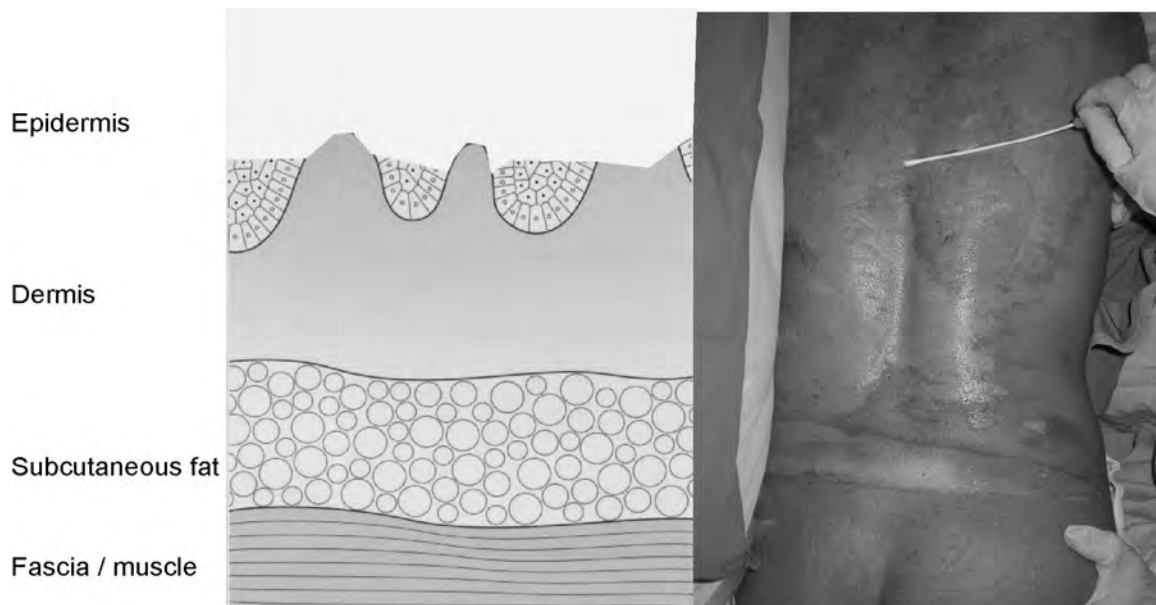
assessment is to estimate the total and surgical burn surface area with a 5% margin so as to have a starting point for initial fluid resuscitation. The rule of nines has to be adapted for children because children have a greater head-to-body surface ratio and the percentages of the body parts differ from those of an adult. The Lund-Browder classification is used for pediatric burn assessment.

Figure 8-1. First-degree Burn



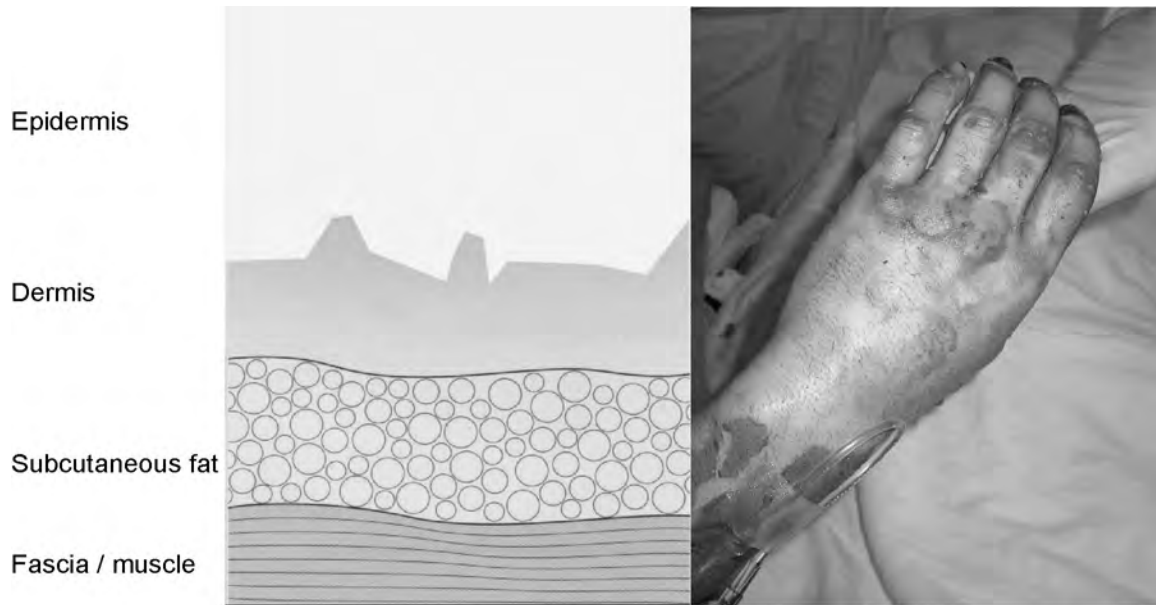
The skin is red with a sunburned appearance.

Figure 8-2. Superficial Second-degree Burn



Fluid-filled blisters are visible. The area is painful and red after blister removal.

Figure 8-3. Deep Second-degree Burn

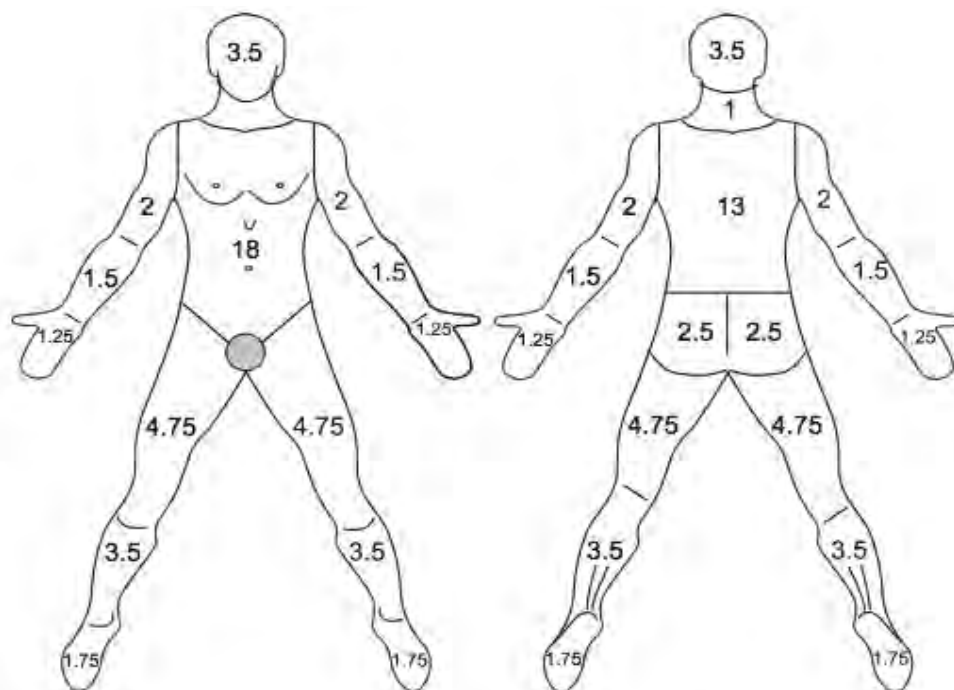


The burned area has a leathery appearance, is less painful, has dull sensation, and almost totally lacks capillary refill.

Figure 8-4. Third-degree Burn



The epidermis and dermis are completely burned. The area is insensible and has no capillary refill.

Figure 8-5. Assessment of Burn Surface

Burn surface is assessed using the rule of nines or similar charts.

D. Burns and the Lungs

After the skin, the airways and lungs are the most vulnerable to thermal injury. Not only may the lungs be thermally or chemically injured, but they are also the point of entry for carbon monoxide and cyanide, which lead to systemic toxicity. Thermal inhalation injury, cyanide intoxication, and carbon monoxide intoxication are not interrelated. For example, a patient may have carbon monoxide intoxication without having inhalation burn or cyanide intoxication (**Table 8-3**). Fumes toxic to the epithelial and capillary endothelial cells are generated from a number of burning products. Sulfur dioxide, nitrogen dioxides, ammonia, and chloride are formed from burning plastic and rubber products. When those combine with airway and alveolar water, the result is alkali and acids. Toxic aldehydes are formed from burning cotton and wool. Wood and paper release significant amounts of carbon monoxide. Cyanide is released from glues in laminated wall paneling and furniture.

Table 8-3. Burns and the Lungs

	Inhalation Injury	Carbon Monoxide Intoxication	Cyanide Intoxication
Risk factors	Closed space Entrapment Prolonged exposure	Closed space Entrapment Prolonged exposure	Closed space Entrapment Prolonged exposure
Signs	Black deposits in the oropharynx Pharyngeal erythema Soot-tainted expectorations Voice changes Hoarseness	Normal peripheral saturation by pulse oximetry Depressed vigilance	Bright red venous blood Bright red skin Increase in lactic acid compared to shock state
Definitive diagnosis	By bronchoscopy	By arterial blood gases and co-oximetry	By blood gas or expired air analysis

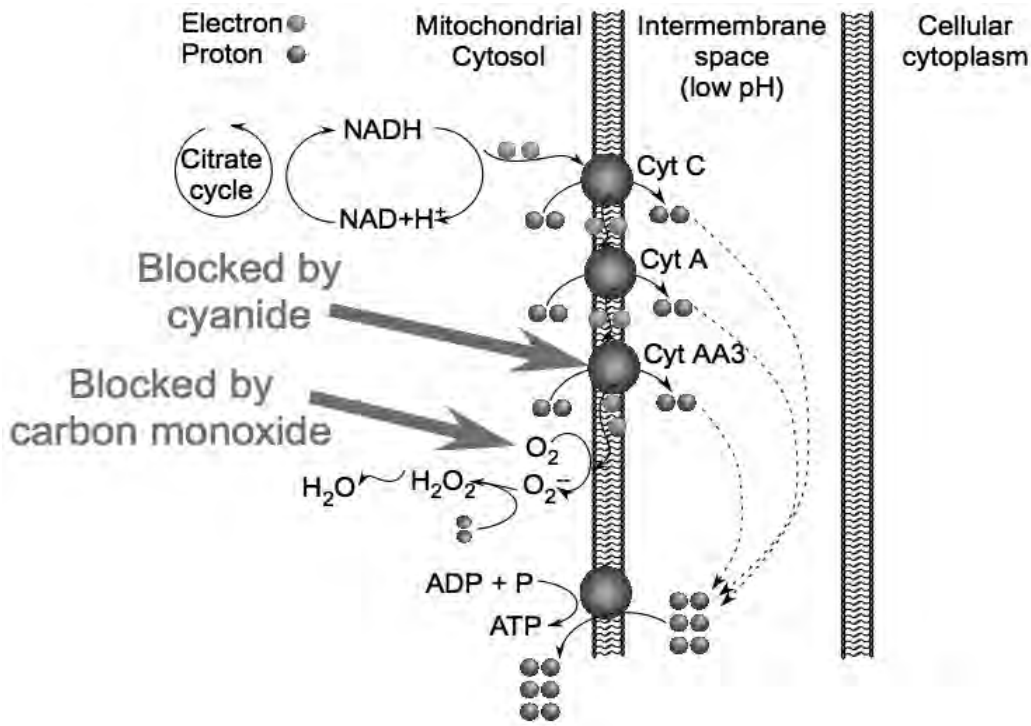
1. Thermal Inhalation Injury

Stridor is an ominous and late sign of impending upper airway loss. Both cyanide and carbon monoxide impair oxygen utilization and synthesis of adenosine triphosphate but in different manners (**Figure 8-6**). The definitive diagnosis of inhalation injury is by bronchoscopy, and a scoring system has been proposed (**Table 8-4**).

The site of severe inhalation injury depends on the size of the particulate matter in the burn smoke. Larger particles tend to deposit in the upper airways, leading to upper-airway edema and compromise, and smaller particles tend to deposit lower in the airways. Steam is a particular problem because it converts to water in the alveoli and releases huge amounts of heat (ie, 571 kcal/g water); acute respiratory distress syndrome (ARDS) then ensues.

Mucosal erythema and easy bruising characterize moderate lung injury. In severe lung injuries, there is mucosal necrosis and liquefaction. After 24 to 48 hours, the necrotic mucosa progressively peels from the underlying cartilage and creates deposits of airway debris. This debris can result in obstruction and sudden respiratory compromise. Patients with severe lung injuries benefit from daily bronchoscopy aimed at clearing the necrotic airway debris. Ventilator-associated pneumonia (VAP), which is common in patients with inhalation burns, is associated with increased mortality. The risk factors for VAP include ciliary dysfunction, impaired clearance of secretions, and relative immunosuppression. The diagnosis is complicated by local pulmonary inflammation, noninfectious ARDS, and pulmonary fluid accumulation. The potential benefits of early (upon admission) prophylactic antibiotics are debated, but patients with severe lung injuries definitely require careful microbiological evaluation.

Figure 8-6. Effect of Cyanide and Carbon Monoxide on Mitochondrial Respiration



Carbon monoxide blocks oxygen transport and delivery, whereas cyanide blocks mitochondrial respiration, not allowing oxygen to be consumed.

Table 8-4. Scoring System for Inhalation Injuries ^a

Grade	Description
0 (no injury)	Absence of carbonaceous deposits, erythema, bronchorrhea, obstruction
1 (mild injury)	Minor or patchy areas with erythema, carbonaceous deposits in proximal or distal bronchi (any or combination)
2 (moderate injury)	Moderate degree of erythema, carbonaceous deposits, bronchorrhea with or without compromise of the bronchi (any or combination)
3 (severe injury)	Severe inflammation with friability, copious carbonaceous deposits, bronchorrhea, bronchial obstruction (any or combination)
4 (massive injury)	Evidence of mucosal sloughing, necrosis, end luminal obliteration (any or combination)

^a Reprinted with permission from Endorf FW, Gamelli RL. Inhalation injury, pulmonary perturbations, and fluid resuscitation. *J Burn Care Res.* 2007;28(1):80-83.

2. Carbon Monoxide Poisoning

Patients with carbon monoxide poisoning present with headache, dizziness, coma, and convulsions. Cardiovascular signs include myocardial ischemia and atrial fibrillation. The patient's skin looks flushed and remains pink. Diagnosis is based on arterial blood gas studies and co-oximetry. Regular satometers cannot identify carboxyhemoglobin. Treatment is oxygenotherapy, including hyperbaric oxygen therapy. The elimination half-life of carbon monoxide is 60 (30-90) minutes in 100% oxygen and decreases to 20 (15-23) minutes in a 3-atmosphere hyperbaric chamber. Hyperbaric oxygen therapy is controversial outside the field of disaster management. In a mass casualty incident, the logistic issues, including time to compression (versus carboxyhemoglobin half-life) and resources used for a single hyperbaric treatment, should be weighed against the benefit of the therapy. Moreover, the care of a hemodynamically unstable, severely burned patient in a hyperbaric chamber is challenging.

3. Cyanide Poisoning

Patients with cyanide poisoning usually present with neurological signs, such as loss of consciousness and coma, and cardiovascular signs that include hypertension and tachycardia followed by hypotension and asystole. Other signs include expired gases that have the odor of bitter almond, cherry red mucous membranes and skin, and bright red venous blood (due to unutilized oxygen). Cyanide dose may be determined in the laboratory, but because that process usually takes too long, treatment has to be based on clinical presumption. The aim of a cyanide antidote is to remove cyanide from the tissue and blood through the formation of nontoxic metabolites (Table 8-5). This detoxification must be instituted very rapidly in order to reverse the effects of cyanide.

III. Management of Major Burns in a Mass Casualty Incident

Patients with burn injuries may have also experienced trauma. Deaths that occur in the initial minutes of a fire-related mass casualty incident are more likely to be caused by an uncontrolled airway or a missed bleeding injury than by burns. Therefore all patients with burns must receive a complete, standard trauma workup. During this workup special care must be taken to avoid hypothermia and wound contamination. The usual ABC (airway, breathing, circulation) sequence is followed, and life-threatening injuries are attended to first. Intubation



In initial burn management, most patients have concomitant trauma and require standard trauma workup. Manage airways using rapid sequence with the largest tube possible. Manage breathing using protective ventilation, using 1.0 FIO₂ until carbon monoxide and cyanide are ruled out. Manage circulation using Parkland as a starter guide, adapt to response, and minimize fluids. Use enteral fluid support in disaster conditions or when feasible.



criteria specific to burn injuries are summarized in **Table 8-6**. The endotracheal tube diameter is important and should be large enough to accommodate repeated bronchoscopies and sustained mechanical ventilation. It is virtually impossible to perform an endotracheal tube exchange after fluid resuscitation.

Table 8-5. Therapies for Cyanide Poisoning

Principle	Treatment	Dose
Methemoglobinemia induction	<p>The principle is to induce a moderate methemoglobinemia. Methemoglobin will avidly bind cyanide from tissues to yield cyanmethemoglobin. Cyanmethemoglobin has a relatively low toxicity.</p> <p>Common side effects include hypotension, rash, syncope, and dizziness. Carbon monoxide intoxication is a contraindication to amyl nitrate use; thus it is not used in patients with inhalational injuries from fires. Inducing methemoglobinemia in patients with carbon monoxide poisoning is risky because the methemoglobin produced by sodium nitrite may exacerbate the already decreased oxygen-carrying capacity of hemoglobin.</p> <p>Of note, neither methemoglobinemia nor carboxyhemoglobinemia may be detected by regular peripheral saturation devices; a co-oximeter is required for detection.</p>	<p>Before intravenous access is established, amyl nitrite can be given by inhalation (crush 1 0.3 mL ampule and have patient inhale for 15-30 seconds every 2-3 minutes). Sodium nitrite is the primary methemoglobin agent: 300 mg (10 mL of a 0.3% solution over 2-4 minutes). For children the dose is 7 mL/m² or 0.2 mL/kg up to a total of 10 mL of a 0.3% solution. Amyl nitrite pearls achieve a methemoglobin level around 3%, and sodium nitrite achieves a methemoglobin level between 5% and 10%.</p>
Neutralization with direct binding	<p>Hydroxycobalamin directly binds cyanide ions and may be used individually or in combination. The efficiency of hydroxycobalamin is probably equal to that of sodium nitrite plus thiosulfate.</p> <p>Side effects include hypertension and red discoloration of the skin. High hydroxycobalamin concentration interferes with co-oximetry and produces carboxyhemoglobin levels as much as 10%-15% above actual levels.</p>	5 g initial bolus, up to 15 g.
Sulfur donors	<p>Sulfur donors such as sodium thiosulfate are used to detoxify cyanide by transforming it to thiocyanate. This reaction is catalyzed by the hepatic enzyme rhodanese. Thiocyanate, which is not toxic, is then renally excreted.</p> <p>Sodium thiosulfate acts too slowly to be used as a single agent.</p>	<p>The adult dose is 12.5 g IV bolus. For children use 7 g/m² up to 12.5 g.</p>

The combination of sodium nitrite plus thiosulfate or hydroxycobalamin is the best available treatment against cyanide salts and hydrocyanic acid poisoning. The North American cyanide antidote package contains 12 0.3-mL amyl nitrite ampules for inhalation, 2 300-mg sodium nitrite vials for intravenous injection, and 2 12.5-g vials of thiosulfate, whereas Europeans tend to prefer high-dose hydroxycobalamin as a first line of treatment. The methemoglobin formation agent 4-dimethylaminophenol and the direct scavenger dicobalt edetate have been proposed for cyanide intoxication, but their side effects make them less suitable than the agents presented in the table.

Table 8-6. Criteria and Sequence for Burn Intubation

Immediate Intubation Criteria for Patients With Burn Injury

- Inhalation injury (or suspicion of inhalation injury)
- Deep face burn (deep second degree or third degree)
- Circular burns to the neck (>75% of circumference)
- Burns with over 40% of the body surface as severe burn
- Explosion with blast injuries
- Carboxyhemoglobin >10%
- Cyanide poisoning

Intubation Technique for Patients With Major Burns

- Do not wait. Delaying intubation may render it difficult.
- Anticipate a difficult intubation: skilled personnel and proper materials are required.
- Use a very large tube (7.5-9.5 mm) because tube exchange is not possible during the first few days.
- Do not use a nasotracheal tube due to its limited diameter and the possibility of nose necrosis.
- Succinylcholine is safe during the first 24-48 h.
- Tube fixation must be careful because tape adherence to burned skin is very limited. Strap suggested.
- Measure distance from teeth (not lips). With swelling the teeth-lip distance increases, and the tube may need readjustment.

Standard mechanical ventilator support, including protective lung strategies for ARDS (ie, low tidal volumes and positive end-expiratory pressure at the lower inflexion point), may be supplied. If cyanide or carbon monoxide intoxication is suspected, F_{IO_2} is maintained at 100% until such intoxication is ruled out. In cyanide intoxication this will maximize oxygen delivery to the few remaining unblocked mitochondria, and in carbon monoxide poisoning it will increase dissolved oxygen and enhance carbon monoxide release from the hemoglobin. Although hyperbaric oxygen therapy is usually advocated in carbon monoxide poisoning, such treatment is impractical in a disaster.

The diagnosis of pneumonia is difficult, and the emergence of multidrug-resistant microorganisms requires that accurate and quantitative microbiologic evaluation be done. This is sometimes difficult in disaster situations, but inappropriate diagnosis will require additional resources, inappropriate antibiotics and additional ventilator days or morbidity.

Small airways may become obstructed by an accumulation of necrotic mucosal debris, soot, and secretions. Meticulous and repeated pulmonary hygiene is mandatory, and patients with severe inhalation injury require daily or twice-daily bronchoscopic cleaning. Bronchial lavage is routinely performed with repeated aliquots of 3 to 5 milliliters of warmed normal saline. Additives or aerosols such as mucolytics, recombinant antithrombin, heparin, alpha-tocopherol, or diluted sodium bicarbonate have been proposed.

A. Fluid Resuscitation

Initial circulatory support consists mainly of fluid resuscitation. Loss of fluid from burned skin is 5 to 10 times greater than that from unburned skin. In addition, there is a major fluid transfer from the vascular compartment to the interstitium in burned and unburned areas. Fluid shifts are maximal during the first 24 hours. The most appropriate repletion regimen remains unknown (eg, albumin, colloids, endpoints of fluid resuscitation). Adults with burns covering less than 15% of body surface area do not require specific fluid resuscitation and should be supported with oral fluids only. Adults with burns covering 15% to 20% of body surface area require fluid resuscitation to maintain intravascular volume despite massive fluid extravasations. The initial formula by Baxter (also called the Parkland formula) has been challenged for the last 40 years but remains the basis of fluid resuscitation (**Table 8-7**). Resuscitation endpoints in burn patients are debated: most burn centers use urine output despite the fact that it is not a good predictor. Urine output should be combined with arterial waveform analysis and other indicators of circulating volume.

Table 8-7. Fluid Resuscitation for Patients With Burn Injuries

First 24 Hours

Adults: fluids for the first 24 h after burn

- 4 mL/kg body weight/% burn surface area (include second- and third-degree burns only)
- 50% during the first 8 h
- 50% during the next 16 h
- Endpoint: urine output of 0.5-1 mL/kg/h

Children: fluids for the first 24 h after burn (Galveston formula)

- 2,000 mL/m² total body surface area (maintenance)
- Plus 5,000 mL/m² burned surface area (include second- and third-degree burns only)
- 50% during the first 8 h
- 50% during the next 16 h
- Endpoint: urine output of 1-2 mL/kg/h

Key Points

- Use warmed lactated Ringer solution
- Avoid normal saline due to hyperchloremic metabolic acidosis
- Consider glucose-containing solution for children
- Serially test blood levels and aggressively replace potassium, magnesium, and phosphorus
- Monitor albumin closely; maintain >15 g/L
- Use artificial colloids for hemodynamic instability or endpoints not reached
- Monitor hemoglobin level: increasing level indicates fluid deficit

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Table 8-7. Fluid Resuscitation for Patients With Burn Injuries (continued)**Second 24 Hours**

- Use the digestive track to give fluid and food as soon as possible (ideally within 6 h from the burn)
- Start at 50% of the fluid requirements during the first 24 h for the next 24 h
- Rapidly introduce free water, preferably by continuous enteral route (20-120 mL/h as tolerated)
- Replace part of the lactated Ringer solution with free water, such as 5% dextrose in water or half-saline

If Resuscitation Endpoints Are Not Met

- Ascertain if the patient needs more fluid.
- Try fluid boluses, artificial colloids if available, and assess responsiveness.
- Maintain plasma albumin level above 15 g/L.
- Rule out potential burn-related myocardial depression (cardiac echo, continuous cardiac output).

If Resuscitation Endpoints Are Exceeded

- If the patient becomes polyuric, decrease fluid administration.

Oral Fluid Resuscitation Solutions for Burns^a

- World Health Organization's oral rehydration therapy solution
- Clean water: 1 liter with 8 teaspoons of sugar or glucose, ½ teaspoon of salt, and ½ teaspoon of baking soda^b
- Lactated Ringer's solution: 1 liter with 8 teaspoons of sugar or glucose
- Gatorade: 1 quart (946 mL) with ¼ teaspoon of salt and ¼ teaspoon of baking soda^b

^aData from Kramer GC, Michell MW, Oliveira H, et al. Oral and enteral resuscitation of burn shock: The historical record and implications for mass casualty care. *J Burns Wound Care*. 2003;2(1):19. http://www.journalofburnsandwounds.com/volume02/volume02_article19.pdf.

^bIn the absence of baking soda, double the amount of salt.

Hematocrit should be checked every 6 to 8 hours for the first 48 hours in patients with major burn injuries: rising hematocrit is a crucial warning sign that the patient needs more fluids. Conversely, overly generous fluid resuscitation may promote fluid extravasations and interstitial edema. Often patients are given more fluid than required. If urine output exceeds 2 to 3 mL/kg/h for several hours it is wise to reduce the volume of fluid administered. Fluid resuscitation in patients with burns is often focused on preventing under-resuscitation, which can result in progressive end-organ dysfunction. However, over-resuscitation is also associated with specific morbidities, such as abdominal compartment syndrome and pulmonary edema. The optimal range of fluid is narrow and requires repeated assessment during the first 24 to 48 hours.

B. Enteral Support

Prior to the now widely available intravenous fluids, enteral fluid support was the only fluid resuscitation method for burns. The method has been largely forgotten since then, but in disaster conditions it should be considered if a patient's face is not burned, the airway is intact, and the

gut is functioning. Patients with burns up to 35% have been successfully managed using enteral fluids exclusively. Several solutions have been proposed (**Table 8-7**), but data are lacking to support definitive recommendations.

Early enteral nutrition is advised in all severely burned patients in order to decrease the risk of gut bacterial translocation. Postpyloric access is preferred but not always easy to rapidly attain. Gastric nutrition should be attempted with attention to absorption and gut motility (residuals, vomiting, etc). Even with severe shock, an obviously hypocaloric feeding is preferable to no nutrition at all: It will decrease gut bacterial translocation, maintain gut trophicity, decrease muscle catabolism, and maintain higher hepatic glycogen stores with hepatic synthetic capacity. The aim should be to achieve full nutritional support within 24 to 48 hours.

C. Initial Management of Burns

Initial management of burn injuries is aimed at decontaminating the wound and protecting against heat and water losses as well as bacterial colonization. A cleaning and disinfection phase is essential; all debris, dead skin, and foreign bodies should be cleared. Surgical chlorhexidine sponges are an efficient and ready wound cleanser. The ideal burn dressing is matter of debate, and most burn centers use their own specific methods. The suggested strategy is aimed at simplicity, providing a waiting dressing that does not require specialized resources (**Table 8-8**). A waiting dressing is one that can be changed every 24 hours and that offers adequate protection against bacterial colonization for the first 2 to 3 days. In disaster conditions, a waiting dressing should be easily applied by non-burn specialists and should control colonization, even in the presence of necrotic debris, until definitive surgical care can take place.

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The aim of wound management is to decontaminate the burn and remove necrotic debris. Protect the wound from heat/water losses and bacterial contamination, and close the wound in disaster conditions.

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1. Escharotomy

During the first hours of a burn, the deep burn scar may shrink slightly and subcutaneous edema will appear. This may lead to limb and thoracic-abdominal compartment syndrome associated with circular wounds. In circular wounds (burns covering over 75% of the circumference of a limb or the trunk), decompression by escharotomy is advised. The indication for thoracic or abdominal escharotomy is based on ventilator compliance and intra-abdominal pressure. Escharotomies are not fasciotomies: the aim of an escharotomy is to open the skin and dermis but not the fascia. An escharotomy must be done from 1 area that is not deeply burned to another area that is not deeply burned. If the dermis is not opened completely, bridges of burned skin may remain and compress the limb or trunk (**Figures 8-7 and 8-8**).

Escharotomies are best done during the initial workup but may be performed at the bedside by a surgeon. Escharotomies often require the preparation and draping of large surfaces. This may lead to the spill of alcohol-based disinfection solution, which should be flushed with saline before

cautery begins. Electrical cautery at moderate power can be used to incise the skin and ensure hemostasis. Careful hemostasis is mandatory because most of these patients will develop shock-related and dilutional coagulopathy secondary to fluid resuscitation. On the trunk, an anterior axillary line escharotomy is often sufficient. If necessary, adding a median, posterior axillary line, and/or transverse escharotomy may help ventilator mechanics. Horizontal or subcostal escharotomies have been advocated to allow independent movement of the chest and abdomen.

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Escharotomies require full dermis opening from 1 unburned area to another. Do not leave strictures, avoid neurovascular packages, and keep fascia closed whenever possible.

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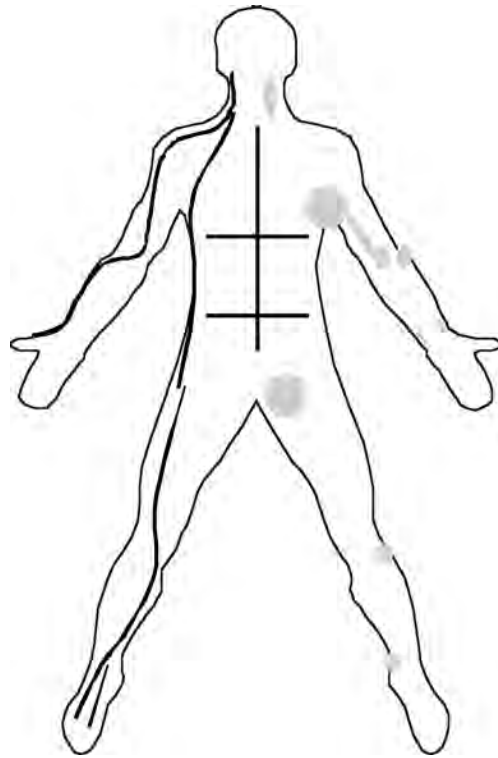
2. Debridement and Coverage

The next step in burn care is early wound debridement and coverage. This lowers the potential for complications, including the risk of secondary infection and sepsis, and decreases the secondary catabolic phase. This step improves resource utilization and helps to reduce length of stay. If the burn surface is limited, a patient’s healthy skin can be used in the split thickness grafting technique, but if the burn area is extensive, temporary coverage will be needed. Most centers have a cadaveric donor skin bank from which to draw for temporary coverage. In a disaster with many burn injuries, however, this resource will be quickly depleted.

Table 8-8.	Initial Burn Dressing
<p>Objectives</p> <ul style="list-style-type: none"> • Decontaminate the wound • Avoid thermal losses • Avoid free water losses • Avoid bacterial colonization <p>Dressing the Burn</p> <ul style="list-style-type: none"> • Use very large surgical sponges (abdominal sponges) • Dip in normal saline and wring • Silver sulfadiazine^a on sponge • Apply to wound with silver sulfadiazine a side on burn • Dry sponge • Gauze bandage (limbs) • Operating room drapes (trunk) • Paraffin gauze dressing in escharotomy lines (optional) 	

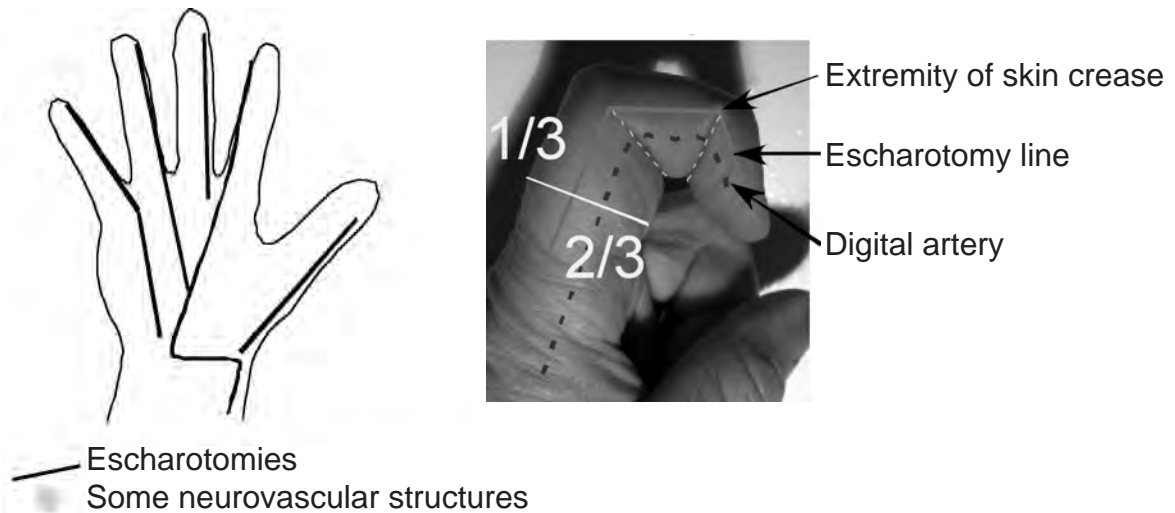
^aSilver sulfadiazine should not be used in children with glucose 6-phosphate dehydrogenase deficiency as it can lead to severe hemolysis.

Figure 8-7. Body Escharotomies



An escharotomy is a decompressive procedure that allows limb perfusion, facilitates mechanical ventilation, or relieves intra-abdominal pressure. Classic neurovascular structures (shown in gray) must be carefully avoided.

Figure 8-8. Hand Escharotomies



Digital escharotomies must be performed on the dorsal side to avoid the digital arteries. Care must be taken to avoid a non-decompressed area at the metacarpal-phalangeal joint area.

D. Burn Triage and Logistics

Triage of burn patients is difficult and depends on 3 main factors: the amount of body surface area burned, the presence of inhalation injury, and the age/physiological reserve of the patient. Several prognostic scales and scores have been proposed for burns, but they reflect historical populations or are too complicated for nonspecialists to apply. The stratification proposed by Ryan in 1998 is simple and provides a rough estimate of a patient’s likelihood of survival (**Table 8-9**).

In a blast bombing, 15% to 25% of patients will present with significant burn injuries. Patients with severe burns (>20% of body surface area) usually require 0.7 to 1.8 days in the ICU for each percent of deep burn and a total of 1.2 to 2 days for each percent of burned body surface area. This must be taken into account when planning ICU capabilities during a disaster. Patients with burns require numerous operating room hours for trauma and surgery. Thus, in developing guidelines for burn care during a disaster, planners must consider the relationship between resource utilization and clinical benefit, and should balance patients’ probability of survival and quality of life against the resources necessary to provide care. The American Burn Association provides some useful estimates, shown in **Table 8-10**. Although the table does not help in determining the timing of required care or in setting priorities for the emergency department and the use of operating rooms, it does provide a rough benefit/resource value and weighs the total acute care resources necessary for a given patient against the patient’s expected length and quality of survival.

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In classical triage, higher priority is given to patients requiring faster workup and treatment. In burn triage, there is balance between resources required for survival and the quality of survival after the burn.

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Table 8-9. Ryan Burn Prediction Score^a

Risk Factors

- Burn surface area >40%
- Age >60 years
- Inhalation injury present

Mortality Based on Number of Risk Factors

- None of above risk factors: 0.3%
- 1 risk factor: 3%
- 2 risk factors: 33%
- 3 risk factors: 87%

^aData from Ryan CM, Schoenfeld DA, Thorpe WP, et al. Objective estimates of the probability of death from burn injuries. *N Engl J Med.* 1998;338(6):362-366.

Table 8-10. Benefit-to-Resource Ratio in Relation to Age and Burn Surface Area^a

Age (yr)	Full-Thickness Burn Surface Area (%)									
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90+
0-2	High	High	Medium	Medium	Medium	Medium	Low	Low	Low	Minimal
2-5	Out-pt	High	High	Medium	Medium	Medium	Medium	Low	Low	Low
5-20	Out-pt	High	High	High	Medium	Medium	Medium	Medium	Medium	Low
20-30	Out-pt	High	High	High	Medium	Medium	Medium	Medium	Low	Low
30-40	Out-pt	High	High	Medium	Medium	Medium	Medium	Medium	Low	Low
40-50	Out-pt	High	High	Medium	Medium	Medium	Medium	Low	Low	Low
50-60	Out-pt	High	High	Medium	Medium	Medium	Low	Low	Minimal	Minimal
60-70	High	High	Medium	Medium	Medium	Low	Low	Low	Minimal	Minimal
70+	High	Medium	Medium	Low	Low	Minimal	Minimal	Minimal	Minimal	Minimal

Abbreviation: out-pt, outpatient.

This triage table provides a rough benefits value in terms of survival and quality of life versus resources necessary to treat these patients. The benefits-to-resource ratio was stratified as high, medium, low, and minimal. This ratio expresses the acute care resources necessary for a given patient against the patient's expected length and quality of survival, based on age and burn surface area.

^aReprinted with permission from ABA Board of Trustees, Committee on Organization and Delivery of Burn Care. Disaster management and the ABA plan. *J Burn Care Rehabil.* 2005;26(2):102-106.

Minimal skin-incision techniques should be used to repair fractures as early as possible, before secondary infection occurs. Centromedullary nailing is a good option to fix long-bone fractures in patients with burns. Surgical debridement of the wound is planned for days 2 to 5. This procedure induces copious bleeding, and temporary coverage will be required. The most often used temporary covering for deep burns in the United States is donor skin.

Even to the experienced clinician, all burn wounds look very similar. This tendency may be compounded in a disaster with many burn casualties. Digital photography offers a unique

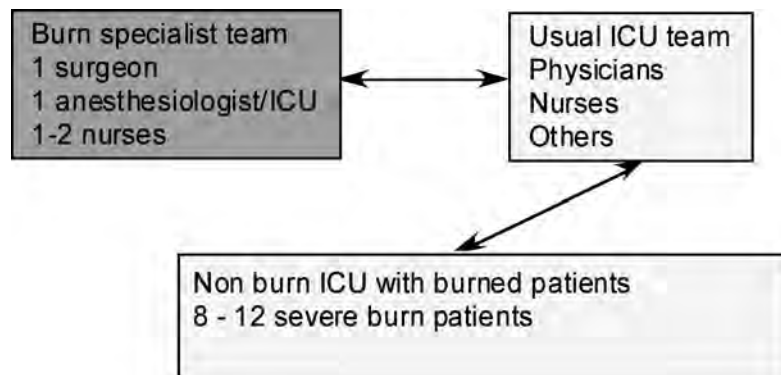
opportunity to assess and visualize a patient’s wound without opening the dressing. It also allows the sending of photos to remote burn centers or specialists when seeking advice. Very high definition is unnecessary; a 2-megapixel digital camera in a cell phone should suffice. The pictures should be taken from as close to the wound as possible. It is strongly suggested that a photo that clearly includes a patient’s identity label (identification tag, triage tag) be taken first because accurate identification may be difficult when many patients are being treated for burns.

E. Converting a Multidisciplinary Intensive Care Unit into a Burn Intensive Care Unit

Mass casualties may overwhelm local burn centers, and burn center expansion is not feasible in such situations. Even at the regional and national levels burn-care resources are limited: The United States has 1,900 burn ICU beds in 40 certified and 90 other burn centers. The average occupancy rate of these centers is roughly 80%, which leaves only 5 to 10 available burn beds per state. Local and regional burn centers often have agreements with larger nearby burn centers that allow secondary transfer of burn patients, but that too is often insufficient.

Staff members in a multidisciplinary ICU typically have a significant amount of the knowledge found among the staff of a burn unit. Thus it can be very efficient to have a team of burn specialists work with other ICU doctors and nurses to take care of burn patients in a multidisciplinary ICU. This extended burn care model has been set up in both civilian and military medical environments (**Figure 8-9**). The National Disaster Medical System has devised the Burn Specialists Team, and the military has B-SMART, the Burn Special Medical Augmentation Response Team. The civilian concept of the extended burn care model is aimed at doing as much as possible onsite, in the non-burn ICU, whereas the military concept is based on patient stabilization and transfer to a burn center. Under both approaches, with a minimal amount of burn expertise, teams can effectively handle patients with severe burns in remote locations. To do so requires a high level of standardization and coordination.

Figure 8-9. Extended Burn Care Model



In the extended burn care model, a team of burn specialists helps a team of nonspecialists to care for burn patients in a multi-disciplinary ICU.

MASS CASUALTY BURN CARE

- An accurate assessment of burn depth and surface area is the basis of burn care.
- Deep second-degree and third-degree burns are often less serious looking and less painful than superficial burns.
- Circular burns require escharotomy to relieve compartment syndrome and allow perfusion.
- Because burn resources are scarce, in the event of a mass casualty incident with many burn injuries, burn patients may require secondary transfer or care in a non-burn ICU.
- Patients with severe burns (>20% of body surface area) usually require 0.7 to 1.8 days in the ICU for each percent of deep burn and a total of 1.2 to 2 days for each percent of burned body surface area.



Suggested Readings

ABA Board of Trustees; Committee on Organization and Delivery of Burn Care. Disaster management and the ABA Plan. *J Burn Care Rehabil.* 2005;26(2):102-106.

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Galante JM, Jacoby RC, Anderson JT. Are surgical residents prepared for mass casualty incidents? *J Surg Res.* 2006;132(1):85-91.

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Namias N. Advances in burn care. *Curr Opin Crit Care.* 2007;13(4):405-410.



Web Sites

American Burn Association. <http://www.ameriburn.org>.

Burn Specialty Team. National Disaster Medical System. <http://www.bst2.org/>.

Educating the Burn Professionals Worldwide. Burnsurgery.org. <http://www.burnsurgery.org>.