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Comprehensive Treatment of Burns

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 **Mosby**

Comprehensive Treatment of Burns

The care necessary for the extensively burned patient is of an intensity, variety and duration most effectively and economically provided by the multidisciplinary staff of a specialized treatment facility."—Basil A. Pruitt Jr, MD¹

More than 2 decades have elapsed since an issue of *Current Problems in Surgery* focused on burn care.^{1,2} During that time, burn surgery has matured as a subspecialty of surgery; serious injuries are increasingly concentrated in regional centers, and public expectations for survival and long-term outcomes are at unprecedented levels. The purpose of this monograph is to define the techniques with which serious burns are now treated and the outcomes that can be expected.

Historic Overview

Untreated burn injuries are lethal for 2 principal reasons: (1) burn shock, which occurs during the first few days after injury, and (2) burn wound sepsis, which develops during the first few weeks after injury in those who have not died of burn shock. Each of these problems has been recognized and addressed systematically over the past 50 years, with a resulting profound modification of the natural history of burn injury.

Burn Shock. In the aftermath of the 1930 Rialto Concert Hall fire, the increased fluid needs of burn patients were clearly described by Underhill.³ Subsequently, clinicians began to explore methods to treat this predictably lethal problem by the administration of large volumes of intravenous fluids. The 1942 Coconut Grove fire in Boston⁴ stimulated work, which resulted in a formula for intravenous volume repletion based on body weight, the Moore Burn Budget Formula.⁵ Work performed at the United States Army Institute of Surgical Research resulted in the development of the Evans formula, the first formula that used burn size and body weight to predict fluid needs. Since then, fluid resuscitation practices have been refined to the degree that burn shock is now an infrequent cause of death.⁶

Early Excision. The next great stride in burn care had its beginnings in the 1970s when the advantages of early excision and the closure of small burn

wounds were reported to include truncated hospital stays and enhanced functional outcomes in patients with small deep dermal and full-thickness burns that were treated by early excision and immediate autografting.⁷ This approach was then taken to patients with large injuries, resulting in truncated hospital stays and enhanced survival rates in patients with large wounds (Fig 1). At that time, burns over 30% of the body surface were commonly fatal.⁸⁻¹¹ Refinement of the techniques of wound excision and closure, combined with the evolution of intensive care, has extended the ability to salvage the lives of patients with increasingly severe injuries.

Long-term Outcome Data

The increased survival rate for patients with large injuries has generated concern about the resulting quality of life and increased interest in long-term outcome research.¹² Although data are limited, among survivors of serious childhood burns, satisfaction with the quality of survival has been surprisingly good.¹³⁻¹⁵ A recent report of long-term outcomes in a large group of patients who had sustained massive burns 15 years earlier revealed that most of these patients had a satisfying quality of life.¹⁶ This review demonstrated the importance of ongoing involvement with an experienced multidisciplinary team.

It is possible for most seriously burned patients to lead happy and productive lives, but the delivery of these outcomes is not easy. It requires a multidisciplinary effort by a team of experienced burn surgeons, physical and occupational therapists, nurses, anesthesiologists, social workers, recreational therapists, psychiatrists, psychologists, and administrators who not only have extensive specific burn experience but work well together as a unit. This fact has led to the concentration of seriously burned patients into large regional units. The benefit of such regionalization is not just seen in improved clinical outcomes but in reduced costs as well.¹⁷ This volume-outcome relationship is a phenomenon that has been well documented for many complex surgical problems.¹⁸ The improved care afforded by regional burn units has led to the burn center verification process of the American Burn Association and American College of Surgeons.¹⁹

Epidemiologic Factors

In the United States each year, approximately 2 million people are burned; 80,000 are hospitalized, and 6500 lose their lives.²⁰ Approximately 70% of pediatric burns are caused by hot liquid, whereas flame injuries more often cause burns in adults of working age.²¹⁻²³ Elderly patients are at increased risk for burns that are caused by hot liquid or by flame, commonly in kitchen accidents.²⁴ Young children are also at higher risk for burn injury,²⁵⁻²⁷ and up

TABLE 1. American Burn Association burn center transfer criteria

Second- and third-degree burns over more than 10% of the total body surface area (TBSA) in patients who are less than 10 or more than 50 years of age.

Second- and third-degree burns over more than 20% TBSA in other age groups.

Second- and third-degree burns that involve the face, hands, feet, genitalia, perineum, and major joints.

Third-degree burns over more than 5% TBSA in any age group.

Electrical burns, including lightning injury.

Chemical burns.

Inhalation injury.

Burn injury in patients with pre-existing medical disorders that could complicate treatment, prolong recovery, or affect mortality.

Any patients with burns and concomitant trauma (such as fractures) in whom the burn injury poses the greatest risk of morbidity or death. In such cases, if the trauma poses the greater immediate risk, the patient may be treated initially in a Trauma Center until a stable condition is achieved before being transferred to a Burn Center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.

Hospitals without qualified personnel or equipment for the care of children should transfer children with burns to a Burn Center with these capabilities.

Burn injury in patients who will require special social/emotional and/or long-term rehabilitative support, including cases that involve suspected child abuse and/or substance abuse.

to 20% of injuries in this age group involve abuse or neglect.²⁸ All suspicious injuries should be reported to the proper state authorities.

Extensive efforts have been made to diminish the incidence of burn injury through public education and legislation, with mixed results.²⁹⁻³² Legislation that required lower temperatures for hot water heaters has been successful.³³ Legislation regarding the mandatory installation of smoke detectors also has been successful.³⁴ In our highly industrialized society, burn injuries will continue to occur, despite prevention measures.

Organization of Burn Care

There is a growing body of evidence that suggests complex surgical problems are most successfully and cost-effectively treated in high-volume programs, a so-called volume-outcome effect.³⁵⁻³⁷ Similar data exist for burn care^{16,17} and trauma care.¹⁸ It has been recognized that burn care requires a set of personnel and equipment resources that are not maintained cost-effectively in many low-volume programs. These issues have led to the formation of the burn center verification program, a combined effort of the American Burn Association and American College of Surgeons. Patients with serious burns are increasingly sent to regional programs for comprehensive care (Table 1).

Physiologic Factors

“There resulted, however, from this local injury a great constitution-

al disturbance..."—Daniel Drake, MD (describing his own burn injury in 1830)³⁸

Our survival as individuals depends on the vapor and bacterial barriers afforded by normal skin. The epidermal layer provides these 2 essential functions; the dermis provides the flexibility and strength of the skin. The durable bonding between these 2 layers is crucial, as demonstrated by those disease processes (such as toxic epidermal necrolysis and epidermolysis bullosa) in which this function is impaired. Dermal appendages prevent desiccation of the skin by producing oils, and the reactive dermal microvasculature facilitates heat dissipation and conservation that allows us to adapt to changes in environmental temperature. These functions are compromised when substantial areas of the skin are burned, which explains in large part the fluid and electrolyte losses and increased incidence of infection that characterizes the burn disease process.

Local Response to Burn Injury

The local response to thermal injury involves not only direct coagulation of burned tissue, but microvascular reactions in the surrounding dermis, where progressive vasoconstriction and thrombosis vary directly with the severity of the primary injury.³⁹ In animal models, the secondary injury that accrues from these microvascular changes has been truncated by cyclo-oxygenase inhibitors,⁴⁰ lazaroids,⁴¹ and fibrinogen depletion,⁴² which may lead to therapeutic interventions that minimize the depth of burn injury in the future. Antioxidant use during resuscitation may also favorably impact this physiologic process.⁴³⁻⁴⁸

Systemic Response to Burn Injury

The systemic response to burning is driven by the loss of the skin's barrier functions with associated fluid loss and decreased resistance to infection, by the release of vasoactive mediators from the injured tissue with secondary interstitial edema and organ dysfunction, and from bacterial overgrowth within the eschar with resulting systemic infection. When the burn size exceeds 20% of the body surface, interstitial edema develops in distant organs and soft tissues as the result of a combination of wound released mediators⁴⁹ and hypoproteinemia.⁵⁰ These distant microvascular effects also have the ability to interfere with the function of organ systems that are not directly injured by the burning process,^{49,51} which explains the frequent occurrence of pulmonary and other organ dysfunctions in patients with large burns.⁵²

A burn wound is initially clean but is rapidly colonized by endogenous bacteria. As these bacteria multiply in the avascular eschar over the suc-

ceeding days, proteases liquefy the eschar, which then separates and leaves a bed of granulation tissue or healing burn, depending on the depth of the original injury. In healthy patients with small burns (<20% of the body surface), this septic process is generally well tolerated. However, when injuries are larger, systemic infection results, which explains the rare survival of patients with deep burns in excess of 40% of the body surface who are treated without early wound excision.^{53,54}

The Hypermetabolic Response

Patients with large burns demonstrate an initial decrease in the cardiac output and metabolic rate. Subsequently, in those patients who are resuscitated successfully, a hypermetabolic response develops with a near doubling of the cardiac output and resting energy expenditure over the next 24 to 48 hours; the magnitude of this response peaks in patients with injuries of 60% or more of the body surface at as high as twice the normal basal metabolic rate.^{55,56} The associated enhanced gluconeogenesis, insulin resistance, and increased protein catabolism that is associated with this response have major implications for the support of burn patients and are the focus of numerous research efforts. The cause of this physiologic reaction is not well understood but is assumed to involve a combination of factors that include a change in hypothalamic function with coincident increases in glucagon, cortisol and catecholamine secretion,⁴⁹ deficient gastrointestinal barrier function with translocation of bacteria and their byproducts,⁵⁷ bacterial contamination of the burn wound with systemic release of similar products from this source,^{58,59} and some element of enhanced heat loss through transeschar evaporation of fluid.⁶⁰ An important element of the treatment of patients with large burns is support of the hypermetabolic state through the provision of adequate nutritional support.

Modification of adverse components of the hypermetabolic response, particularly protein catabolism, seems desirable. Although a modest modification of the response, in the form of antipyretics,⁶¹ has been practiced widely, the elimination of hypermetabolism has unknown value and may even be harmful. Beta-adrenergic blockade,^{62,63} beta-adrenergic supplementation,⁶⁴ nonsteroidal anti-inflammatory agents,⁶⁵ recombinant growth hormone,⁶⁶⁻⁶⁸ and insulin-like growth factor-1⁶⁷ are under active investigation. The goal is to eliminate unfavorable aspects of the hypermetabolic response without inadvertently harming the patient. At the present time, the data are inadequate to support the routine use of such therapies outside clinical trials.

Pediatric Considerations

Approximately one half of all burn injuries occur in children.⁶⁹ Young

TABLE 2. Essential pediatric considerations

The much smaller pediatric upper airway is rapidly occluded by progressive edema.
The trachea of the young child is short, which makes main stem intubation common.
Bronchospasm is commonly a problem for young children after inhalation injury.
Young children have less mature renal concentrating ability.
Young children are easily fluid loaded.
Young children are particularly susceptible to hyponatremia and secondary cerebral edema.
Young children have higher energy needs per unit body weight.
Children tolerate long periods of inadequate nutrition poorly.
The large surface area-to-mass ratio makes temperature control more difficult.
Children have a thinner skin than adults.
Burns are relatively deeper, and donor sites are more unforgiving.
Children have smaller vessels than adults.
Children grow and will predictably outgrow good surgical results.
Children seem to form hypertrophic scar with greater intensity.
Pain and anxiety are more difficult to access.
School age children have schooling needs.
Children need strong families.

children especially have unique physiologic, medical, surgical, and psychosocial issues that must be addressed by the burn team (Table 2).^{70, 71} Injury mechanisms are weighted toward scalding, particularly in younger children. The possibility of abuse must always be considered; if conditions are suspicious, children should be admitted for further evaluation, and the appropriate state authorities should be notified.

There are several important airway and respiratory issues that must be considered. The much smaller pediatric upper airway is rapidly occluded by progressive edema. Stridor and retractions should trigger careful airway evaluation and possible intubation. The trachea of the young child is short, which makes main stem intubation common. Bronchospasm is commonly a problem for young children after inhalation injury and should be treated aggressively to avoid dynamic hyperinflation.

There are several important fluid and electrolyte issues. Young children have less mature renal concentrating ability and may require more fluid per unit body weight than predicted by common formulas for successful resuscitation.⁷² However, they are very easily fluid overloaded, especially if all administered fluids (including arterial and central venous line flushes and medications) are not considered. Young children are particularly susceptible to cerebral edema if they become hyponatremic. This can result in seizures^{73,74} or even herniation.

Nutritional and metabolic issues include the higher energy needs of children per unit body weight, which makes nutritional support even more essential. Children tolerate long periods of inadequate nutrition poorly

and should be supplemented parenterally if they are not tolerating enteral feedings. Their large surface area-to-mass ratio makes temperature control an important issue. Children should be kept warm throughout their hospitalization.

Children have a thinner skin than adults. Burns are relatively deeper, and donor sites are more unforgiving of a deep pass with a dermatome. Intraoperative hypothermia must be avoided by operating room heating. Children have smaller vessels than adults. Central venous and arterial lines should be of the smallest possible caliber and placed with great care.

Children grow. They will predictably outgrow the best surgical result. They will fare better in the long term if they have prolonged and regular contact with a multidisciplinary burn clinic that can ensure that they receive adequate reconstruction and revisional surgery as they grow. Children also seem to form hypertrophic scar with greater intensity and will predictably need prolonged scar treatment efforts.

Finally, children have unique developmental and psychosocial needs that are ideally met by a knowledgeable team. Their pain and anxiety should be anticipated and treated in a compassionate way. Integrating recreational therapy with rehabilitation needs is tremendously effective. School-aged children should have their schooling needs supported and, whenever possible, should receive assistance in reintegrating with their peers in school. Children need their families. They will have better outcomes if their families are supported, both during the acute hospitalization and in the years that follow.

Geriatric Considerations

Older adults with burn injuries also have special issues (Table 3). Injury mechanisms may involve compromised mobility or dexterity⁷⁵ and may sometimes reflect an inability to live alone safely. Sometimes injuries occur during syncopal episodes that should be evaluated concurrently.

Resuscitation should be considered carefully if burns are large, particularly in the presence of inhalation injury. Data suggest that the mortality rate is high in patients older than 60 years of age with burns covering more than 40% of the body surface and concomitant inhalation injury.⁷⁶ Patients may have advanced directives, interested families, or health care proxies that should be consulted as early as possible.

Older adults often do not have the physiologic reserve of the young. Their pulmonary function may be compromised by years of smoking. Occult or overt coronary artery or peripheral vascular disease may be present. Muscle strength, including respiratory muscles, may be reduced. Renal function may be reduced with greater sensitivity to nephrotoxic drugs or hypotensive

TABLE 3. Essential geriatric considerations

Injury mechanisms more often involve compromised mobility or dexterity.
Injuries may reflect an inability to live alone safely.
Injuries occur during syncopal episodes.
Resuscitation should be considered carefully if burns are very large, particularly in the presence of inhalation injury.
Patients may have advanced directives, interested families, or health care proxies who should be consulted as early as possible in their care.
Older adults often do not have the physiologic reserve of the young.
Pulmonary function may be compromised by years of smoking.
Occult or overt coronary artery or peripheral vascular disease may exist.
Muscle strength, including respiratory muscles, may be reduced.
Renal function may be reduced, with resulting greater sensitivity to nephrotoxic drugs or hypotensive insults.
Nutritional needs of the elderly patients are poorly predicted by standard predictive equations.
The skin of the elderly person is thin and therefore sustains full-thickness injury more readily and tolerates repeated donor harvest less well.
Older adults may live alone or have a spouse who cannot reasonably meet postdischarge needs.
Discharge planning may be very involved and must be started early.

insult. The nutritional needs of the elderly patient may not be as well predicted by standard predictive equations.⁷⁷ The skin of the elderly person is thinner than the younger adult and therefore sustains full-thickness injury more readily and tolerates repeated donor harvest less well.

Finally, elderly adults also have unique psychosocial needs. They may live alone or have a spouse who cannot reasonably meet their needs after discharge for wound care, transportation, or general support. Their children may live far away. Discharge planning may be very involved and must be started early.

Initial Evaluation

*“The patients who lay quietly at rest on arrival were in the minority.”—
H.K. Beecher, MD (on initial evaluation of victims of the Coconut Grove
Fire, 1943)⁷⁸*

Who should be referred to a burn center, who should be treated in a local general hospital, and who should be treated as an outpatient can be difficult decisions to make, and these decisions can have a profound impact on outcome.⁷⁹ A reasonable set of guidelines that have stood the test of many years are the American Burn Association criteria for transfer of a patient to a burn center (Table 1).

Prehospital and Interhospital Transportation

Several concepts should be stressed when making arrangements for pre-

TABLE 4. Acute burn transfer advice

It is critical that the airway be adequately controlled before transport. If there is any question of airway compromise, the patient should be intubated prophylactically before transport.

Patients with serious burns should be transported with a nasogastric tube, bladder catheter, and 2 well-secured intravenous lines.

Outlying facilities should be given advice regarding fluid administration. A reasonable starting point would include the following items:

For a child who weighs less than 30 kg:

Ringer's lactate with 5% dextrose (D5RL) at maintenance rate (approximately, 4 mL/kg/h for the first 10 kg, 2 mL/kg/h for the next 10 kg, and 1 mL/kg/h for remaining weight) plus Ringer's lactate (RL) at 2-3 mL/kg/% burn over the first 24 hours, the first half in the first 8 hours after the burn injury.

For a child over 30 kg or for an adult:

RL at 4 mL/kg/% burn over the first 24 hours, the first half in the first 8 hours after the burn injury.

These are starting rates and should be modified based on urine output and vital signs.

Make every effort to keep the patient warm during transport.

Vital signs should be monitored. Pulse oximetry is ideal. Attendant skill level should be appropriate to the severity of the injury.

hospital and interhospital transfers (Table 4). In addition to control of the patient's airway, these include the achievement of secure venous access, the placement of bladder and nasogastric catheters, maintenance of body temperature, fluid administration if the transport time will be more than 1 hour, documentation of the events of the injury from personnel who will not be available to the receiving facility, efforts to notify family members and to define the legal custodian of children, and clear documentation of all interventions.

It is far easier to prevent hypothermia from developing than it is to treat it once it is established. Transporting vehicles and emergency department receiving areas should be heated before the patient's arrival. Most authorities recommend clean dry coverings to wounds (clean sheets). However, moist dressings may be acceptable as long as evaporative heat loss and hypothermia are strictly avoided. Although immediate cooling of a wound that involves less than 15% of the body surface may help limit burn depth without causing systemic hypothermia, by the time emergency response personnel have arrived, this brief window of opportunity has usually passed.

The value of prehospital fluid administration depends on the transport time. For patients with extensive burns, safe and reliable vascular access can be technically challenging. Delaying a transport that is anticipated to be less than 1 hour to achieve venous access for fluid administration is probably not justified in many cases. In circumstances in which longer transport times are anticipated, venous access should be obtained unless an inordinate delay will result.



FIG 1. The natural history of burn wounds is progressive colonization and liquefaction of devitalized tissue with local granulation in patients who do not die of systemic sepsis. Burns such as those pictured here were always lethal before early excision was practiced.

Primary Survey

Serious burns are often accompanied by nonthermal injuries; therefore, all burn patients should be approached initially as multiple trauma patients, by following the guidelines of the American College of Surgeons Committee on Trauma and the Advanced Trauma Life Support Course.¹⁹ A similar course, directed at the unique needs of the burn patient, is available from the American Burn Association (Advanced Burn Life Support Course). Injuries missed during the initial evaluation can be a source of significant morbidity later. Liberal use of computed tomographic (CT) scanning of the head, chest, and abdomen is justified if the mechanism of injury is consistent with head or abdominal trauma.

Security of the airway is the highest priority issue during the initial evaluation. Fortunately, the urgency is rarely such that a few minutes are not available to approach control of the airway in a studied manner. The airways of burn patients are among the most challenging of airways to control. Hot liquid is infrequently aspirated and can result in the need for urgent intubation because of rapidly progressive swelling⁸⁰ (Fig 2).



FIG 2. Hot liquid aspiration will cause catastrophic acute upper airway edema. The examination of this child suggested the aspiration of hot liquid.



FIG 3. Progressive facial and oropharyngeal edema can render reintubation after an accidental extubation very difficult. Therefore, endotracheal tube security is very important.

All patients who display signs of impending upper airway obstruction (such as hoarseness and retractions) or who are obtunded from drugs, alcohol, or shock should be intubated. Commonly, a few minutes exist for experienced help to arrive, which is advisable because these edematous airways can be difficult to intubate. It is critical to secure the endotracheal tube with a carefully constructed tie harness⁸¹ to avoid the potential catastrophe of an accidental extubation (Fig 3).

It is important to achieve reliable vascular access to support resuscitation needs. Peripheral vascular access can be difficult to secure in hypovolemic burn patients, especially young children, in whom intraosseous access may be useful (Fig 4). A commercially available catheter or a heavy spinal needle can be placed below the tibial tuberosity (the needle should be directed distally away from the epiphysis).



FIG 4. Intraosseous infusion can be useful in the initial resuscitation of young children with hypovolemia.

Secondary Survey

The burn-specific secondary survey complements the trauma secondary survey and includes points specific to neurologic, otolaryngologic, chest, cardiac, abdomen, genitourinary, and extremity issues and radiographs and laboratory studies (Table 5). Important neurologic issues include assessments for intracranial trauma, significant anoxic or carbon monoxide injury, and control of pain and anxiety. Intracranial trauma is excluded by history, supplemented by liberal use of CT scanning. Patients with large injuries commonly become obtunded later, and it is good to know that this change does not represent a missed intracranial injury.

During the initial evaluation of patients who were injured in structural fires, the possibility of serious carbon monoxide exposure should be evaluated. This is always a difficult diagnosis to establish because a depressed sensorium can be due to drugs, alcohol, pain medications, hypoxia and hypotension in this setting, as well as carbon monoxide. Prompt administration of 100% oxygen to such patients will generally quickly clear the blood of carboxyhemoglobin (half-life, 2.5 hours on room air and 40 minutes on 100% oxygen). However, carbon monoxide also binds to mitochondrial cytochromes and thereby interferes with oxygen usage. Patients with serious carbon monoxide poisoning may be at risk for delayed neurologic sequelae, such as ataxia and choreiform movement disorders. The ability of hyperbaric oxygen treatment to reduce the risk of these sequelae is not known with certainty.⁸² However, if it can be administered safely, it may be considered in selected patients with carboxyhemoglobin levels over 30% and with overt neurologic dysfunction not caused by trauma, shock, or drugs.⁸³ Hemodynamic instability, wheezing or air trapping, or the need to effect transports that are inconsistent with good general burn care are contraindications to treatment.⁸⁴

TABLE 5. Important aspects of the burn-specific secondary survey

History

Document mechanism of injury, closed space exposure, extrication time, delay in seeking attention, fluid given during transport, and previous illnesses and injuries.

Head, ear, eyes, nose, and throat

The globes should be examined, and the corneal epithelium should be stained with fluorescein before adnexal swelling makes examination difficult. Adnexal swelling provides excellent coverage and protection of the globe during the first days after injury, so tarsorrhaphy is virtually never indicated acutely.

Corneal epithelial loss can be overt, giving a clouded appearance to the cornea, but is more often subtle, requiring fluorescein staining for documentation. Topical ophthalmic antibiotics constitute optimal initial treatment.

Signs of airway involvement include perioral and intraoral burns or carbonaceous material and progressive hoarseness.

Hot liquid can be aspirated in conjunction with a facial scald injury and result in acute airway compromise that requires urgent intubation.

Endotracheal tube security is crucial and is best maintained with an umbilical tape harness, rather than adhesive tape, on the burned face.

Neck

Radiographic evaluation is driven by the mechanism of injury.

Rarely, in patients with very deep burns, neck escharotomies are needed to facilitate venous drainage of the head.

Cardiac

The cardiac rhythm should be monitored for 24-72 hours in patients with electrical injury.

If intravascular volume and oxygenation are supported adequately, significant arrhythmias are unusual in otherwise healthy patients.

Pulmonary

Optimize chest wall compliance by performing liberal chest escharotomies when needed.

Severe inhalation injury may lead to the slough of endobronchial mucosa and thick endobronchial secretions that can occlude the endotracheal tube, so one should be prepared for sudden endotracheal tube occlusions.

Vascular

The perfusion of burned extremities should be monitored vigilantly by serial examinations.

Indications for escharotomy include decreasing temperature, increasing consistency, slowed capillary refill, and diminished Doppler blood flow in the digital vessels. One should not wait until blood flow in the named vessels is compromised to decompress the extremity.

Fasciotomy is indicated after electrical or deep thermal injury when distal blood flow is compromised on clinical examination. Compartment pressures can be helpful, but clinically worrisome extremities should be decompressed regardless of compartment pressure readings.

Abdomen

Nasogastric tubes should be in place, and their function should be verified, especially before air transport in unpressurized helicopters.

An inappropriate resuscitative volume requirement may be a sign of an occult intra-abdominal injury.

Torso escharotomies may be required to facilitate ventilation in the presence of deep circumferential abdominal wall burns.

Immediate ulcer prophylaxis with histamine receptor blockers and antacids is indicated in all children with serious burns.

Genitourinary

Bladder catheterization facilitates the use of urinary output as a resuscitation endpoint and is appropriate in all patients who require a fluid resuscitation.

It is important to ensure that the foreskin is reduced over the bladder catheter after insertion, because progressive swelling may otherwise result in paraphimosis.

TABLE 5. Important aspects of the burn-specific secondary survey (continued)

Neurologic
An early neurologic evaluation is important, because the patient's sensorium is often progressively compromised by medication or hemodynamic instability during the hours after injury. This may require computed tomography scanning in patients with a mechanism of injury that is consistent with head trauma.
Pain and anxiety medication should be administered within the bounds of safety.
Those who require neuromuscular blockade for transport should also receive adequate sedation and analgesia.
Extremities
Extremities that are at risk for ischemia, particularly those with circumferential thermal burns or those with electrical injury, should be dressed so they can be examined frequently.
Tense extremities should be decompressed promptly by escharotomy and/or fasciotomy when clinical examination reveals increasing consistency, decreasing temperature, and diminished Doppler blood flow in digital vessels.
The need for escharotomy usually becomes evident during the early hours of resuscitation.
Therefore, most escharotomies can be delayed until transport has been effected, if transport times will not extend beyond 6 hours after injury.
Burned extremities should be elevated and splinted in a position of function.
Wound
Wounds, although often underestimated in depth and overestimated in size on initial examination, should be evaluated for size, depth, and presence of circumferential components.
Burn wounds are potentially tetanus prone, and tetanus immune status should be determined and supplemented appropriately.
Laboratory
Arterial blood gas analysis is important when airway compromise or inhalation injury is present.
A normal admission carboxyhemoglobin concentration does not eliminate the possibility of a significant exposure because the half-life of carboxyhemoglobin is 30 to 40 minutes in patients ventilated effectively with 100% oxygen.
Baseline hemoglobin and electrolyte levels can be helpful later during resuscitation.
Radiography
The radiographic evaluation is driven by the mechanism of injury and the need to document the placement of supportive cannulae.

Important otolaryngologic issues include documentation and proper initial treatment of burns to the corneal epithelium and the external ear. If one waits until facial and ocular adnexal edema is advanced, it can be difficult to evaluate the globes. Although deep corneal stromal burns are usually obvious by the cloudy appearance they impart (Fig 5), the eye evaluation should also include fluorescein staining to detect more subtle injury to the corneal epithelium. Burns of the external ear are often complicated by suppurative chondritis, unless they are treated with topical mafenide acetate. The routine use of 11.1% mafenide acetate cream on such injuries has virtually eliminated this complication.⁸⁵

The focus of the initial evaluation of the chest is ensuring that both hemithoraces are well ventilated. Decreased chest wall compliance (as the result of circumferential deep eschar) and bronchospasm (as the result of