ACUTE BURNS

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Abstract

With improvement in surgical technique, availability of blood bank products and improvement in ICU management, burn management has undergone a Paradigm shift from mortality as primary concern to how do we enhance the quality of life for survivors.[1] Mortality is best predicted by the size of the burn, the age of patient and the worst base deficit in the first 24 hours of hospitalization. [2] Long-term outcome 15 years most survivors of serious childhood burns have satisfying quality of life. [3]

Epidemiology

According to the National Burn Repository[4]there were 126,000 hospital admissions for burns from January 1995-2005. This information is gathered from burn centers throughout the United States and Canada in order to facilitate the collection and analysis of patient data within burn centers. From this information, we know that 62% of all burns seen in burn centers were less than 10% total body surface area (TBSA). The mean burn size was 13.4% TBSA with 62% of the full thickness burns covering less than 10% TBSA. Sixty-one percent of patients were transferred to another hospital for higher level of care. Six and a half percent of admissions had inhalation injury. The patients were 70% male with a mean age of 33 years. Flame and scald burns account for 78% of injuries.

The prognostic burn index, a sum of the patient's age and percent burn, was used as a gauge for patient mortality for many years. This Index suggested that the patient's age plus their full thickness TBSA burn plus 20% for inhalation equaled the likely percent mortality. Advances from early excision of burn eschar, skin grafting, early enteral feeding[5] and wound closure with advanced techniques (skin substitutes) have altered the simple mathematical calculation. Patients with a prognostic burn index of 90-100 now have a mortality rate in the 50-70% range with poorer outcomes at both extremes of age[6].

Treatment of Burn Injuries and Burn Centers

Treatment of thermal injuries should be stratified between simple partial thickness and small full-thickness injuries and those that require specialized care. The practicing plastic surgeon with experience and interest can reasonably, safely and effectively care for the former. The latter are best cared for with the involvement of a Burn Team (See Table 1). Treatment and management of patients with significant burn injuries is complex. The best, most successful and cost-effective treatment is in high-volume programs with a multi-disciplinary team

Transfer to a burn center is an accepted way to improve patient care. Burn injuries appropriate for transfer to a burn center include large burns, smaller burns in areas of higher morbidity or burns in patients with comorbidities. The American Burn Association has Burn Center referral criteria for patients suitable for transfer (See Table 2). Both extremes of ages have a less predictable systemic response to burns. Adherence to these criteria will improve outcome and avoid unnecessary medical expenses. Data from the National Burn Repository indicates that most burns are minor and that 80-90% of burn injuries can be treated on an outpatient basis. [7] To determine the best mechanism to deliver care, accurate communication with burn team members regarding the burn injury is essential. This is facilitated by calculating the percent burn using the Rule of Nines (See Figure 1) or using the Lund-Browder diagram and a careful review of the associated conditions. Before transferring a patient to a burn unit, communication with the accepting burn surgeon should include discussion of the following treatment issues: airway, nasogastric suction, urinary catheter and vascular access. Additionally, the calculated fluid resuscitation for transport should be confirmed. The patient should be placed in dry dressings for transport to keep the patient warm and facilitate burn assessment upon arrival to the burn center. Unless the time for transport is unusually long, antimicrobial dressings will delay transfer and obscure wound details at the receiving institution.

Pathophysiology of Burn Injury

Anatomy/Function of skin

The skin has two anatomic layers each with a separate function. The superficial, epidermal layer is a barrier to bacteria and vapor (moisture loss). The dermal layer deep to epidermis provides protection from mechanical trauma and the elasticity and mechanical integrity of the skin. Blood vessels providing nutrition to the epidermal layer run within the dermis. After skin loss, epidermal cells regenerate from deep within dermal appendages such as hair follicles or sweat glands. The skin functions of barrier to infection and fluid loss are lost with burn injury. The treating physician must compensate with appropriate fluid management and local wound care.

Local tissue response

Burn injury to tissue encompasses a dynamic response to the initial insult. Damage is dependent on the temperature of the thermal energy source as well as the duration of contact. Burn injury is heterogeneous with adjacent areas showing varied levels of injury

Systemic response

When the burn exceeds 20% of the body surface, the local tissue response becomes systemic. Interstitial edema develops in distant organs and soft tissues secondary to release of vasoactive mediators from the injured tissue. Activation of complement and coagulation systems causes thrombosis and release of histamine and bradykinin leading to an increase in capillary leak and interstitial edema in distant organs and soft tissue. Secondary interstitial edema and organ dysfunction from bacterial overgrowth within the eschar can then result in systemic infection. Activation of the pro-inflammatory cascade and the counter-regulatory anti-inflammatory reaction then leads to immune dysfunction. This increases the patient's susceptibility to sepsis and multiple organ failure. [8]

The systemic response to burn injury leads to a hypermetabolic state doubling normal physiologic cardiac output over the first 48 post burn hours . [9] This response is mediated by hugely increased levels of catecholamines, prostaglandins, glucagons and glucocorticoids resulting in skeletal muscle catabolism, immune deficiency, lipolysis, reduced bone mineralization and reduced linear growth. [10] Herndon [11] has suggested that down-modulating this hypermetabolic response is beneficial. Beta-blockers have been shown to reduce the hypermetabolic response to burn in limited studies [12, 13]. However, the value of limiting this metabolic response in all burn patients through pharmacologic therapies such as antipyretics or beta-blockers is unknown.

These systemic metabolic alterations in the burn patient may be present for a year post injury. Mitigating factors in early treatment to decrease this effect are: early excision of burn and grafting, control of sepsis, maintenance of temperature, good nutrition through continuous feeding of high carbohydrate/protein diet and anabolic agents.

Tissue Injury from Burn

The multiple treatment algorithms for burn wounds and resuscitation require quantification of burns extent. Although many new modalities are becoming available to assess burn depth such as laser doppler and dielectric measurements, assessment by an experienced practitioner is currently the most reliable judge of burn depth. A simplistic description of burn type and depth is listed in Table 3.

It must be noted that burn wounds continue to mature and damage to the skin continues for 24-48 hours secondary to several factors including edema and coagulation of small vessels. Daily evaluation by a consistent team is currently the best way to achieve early recognition of full thickness loss and successful excision. The dynamic nature of burn injury means that a wound may not appear full thickness for several days post injury.

Prompt treatment and excision of deep second and third degree burn wounds has been shown to improve outcomes. However, early decisions to proceed to surgery are not always straightforward.

Initial Assessment of Burn Injuries

Plastic surgeons are consulted for burns that present to the emergency department. The first decision to be made is whether the injury may be cared for at the presenting facility or should be transferred to a designated burn center. This assessment will include size of burn, depth of burn, risk of morbidity and associated injuries (e.g. inhalation injury or trauma) as well as patient comorbidities.

Initial assessment of burn size should be performed with a standardized Lund-Browder diagram for second and third degree burns. The simpler rule of 9s is helpful for rapid assessment but is less accurate. The palm is often used to gauge 1% TBSA, however, studies of body surface area show that the adult palm *with* fingers corresponds to 0.8% TBSA in adults and 1% in children. [14] Quantifying the degree of injury is an important initial step in the treatment of burns affecting decisions for resuscitation, transfer and surgical debridement. Cone found an average overestimate of 75% by referring physicians [2]. This corresponds to a review of transfers to burn units showing air transport costs exceeding that of hospitalization in almost 10% of burns transferred to burn units.

Approximately ten percent of all burns present with concomitant trauma. Evidence of additional injuries should be evaluated where appropriate by a trauma team, orthopedic surgeon and ophthalmologist. Burns involving extremities must be checked for circumferential burns and compartment syndrome. Escharotomy involves release only of burned skin and may be performed in a monitored environment equipped with electrocautery and conscious sedation. Fasciotomy for release of edematous muscle should be performed in a more controlled environment (e.g. operating room) to allow for appropriate visualization of the anatomy. [15]

Inhalation injury

Inhalation injury is the most frequent burn-associated problem and has a great impact on survival. Aggressive diagnosis and early prophylactic intubation can be life saving. A clinical diagnosis may be based on a history of the burn occurring in an enclosed space, significant facial burns, change in voice quality, singed nasal hair or carbonaceous sputum seen on exam or in the pharynx seen with bronchoscopy. Chest x-rays are generally negative in the immediate post-burn time and are of little value in diagnosing inhalation injury. Airway edema can continue to worsen for several days post-burn; therefore, intubated patients should be closely monitored and extreme caution used when considering extubation for 48-72 hours. [16]

Acute physiologic deterioration secondary to carbon monoxide (CO) results from competition for oxygen binding sites on the hemoglobin molecule. Suspected or significant exposure to CO should be treated with administration of 100% oxygen continued for several half-lives (45minutes). In the ten percent of burns that present with inhalation injury, ventilation to minimize barotrauma in the damaged, non-compliant lungs is critical. One such method is high frequency oscillatory ventilation. [17-20] This modality allows for oxygenation of stiff pulmonary tissue through higher inspiratory pressures while minimizing barotrauma by allowing leakage of air around the endotracheal tube cuff [17] .

Burn Treatment

Treatment of Minor burns

A careful examination of the criteria for transfer to a burn center will allow for safe treatment of most burns outside of regional burn centers. Many minor burns can be treated as an outpatient with careful treatment to avoid progression of the burn and thorough follow-up to avoid post-burn morbidity.

The burn should be debrided at bedside or hydrotherapy on initial assessment to allow determination of burn depth. This requires pain management and a surgical tray for removal of sloughing tissue. The raised epidermis of bullae may be removed with warm water, soap and abrasive gauze followed by excision of sloughed tissue during evaluation. For best healing, the burn wound should be debrided daily and dressed with a topical antibiotic. Patients who are unable to tolerate daily wound care at home may need inpatient care to encourage good healing. Patients need to maintain good nutrition, use adequate pain control for continued debridement and to return with any signs of infection. Because burn wounds evolve over several days, burn wounds should be evaluated again by the treating surgeon within 3-5 days. Evaluation should confirm that the burn wound is progressing toward healing, range of motion at involved joints is maintained, patient nutrition is adequate and no signs of infection are present.

Related decisions to be made at follow-up include whether the burn needs surgical excision, if the patient is doing an adequate job of wound care, whether or not the patient needs physical or occupational therapy, nutritional counseling or supplemental feeding and whether there is a need for systemic antibiotic therapy. (See Table 4) Failure in these areas as an outpatient may necessitate inpatient care.

Burn wound management

Whether or not a burn needs surgical debridement, the wound will need a dressing placed to keep the wound moist and clean.

Topical treatments

Although topical antibiotics are the choice in most burn centers, treatments include everything from honey to silver sulfadiazine to duoderm. [21-26] Topical antibiotics are used to keep the wound moist, control pain, and slow bacterial growth. Silver is found in many burn wound dressings including silver sulfadiazine (cream), acticoat (fabric) and silver nitrate (solution). Silver has bactericidal activity that reduces inflammation and promotes healing. [23]

Treatment of Major Burns

Resuscitation

Monitoring resuscitation is most commonly done using clinical end points for volume status, such as peripheral temperature, blood pressure, heart rate and urine output. Minor burns (less than 15-20%) need 150% of normal maintenance IV fluids. [27-29]] The goal of resuscitation is enough volume to ensure end-organ perfusion while avoiding intracompartmental edema and joint stiffness. Patients with preexisting conditions that may affect correlation between volume and urine output require invasive monitoring. [30] Central venous pressure or pulmonary capillary wedge pressure should be considered in patients with known myocardial dysfunction, age greater than 65 years, severe inhalation injury or fluid requirements greater than 150% of that predicted by Parkland formula. [28]

Initial fluid rate may be calculated using the Parkland formula (See Table 5). Multiple studies have reported inadequacy of standard fluid resuscitation formulas with needs routinely exceeding the calculated need. [31] This may be attributed to variation in body mass index, accuracy of calculated size of burn and differences in mechanical ventilation. Resuscitation fluids should be isotonic (lactated ringers) for the first 24 hours then colloid solutions after 24 hours when capillary integrity returns. Vascular access for these fluids should be two large bore peripheral iv or a central line.

Infection prophylaxis

Treatment of burns with topical antibiotics has been shown to decrease the bacterial overgrowth and incidence of burn wound sepsis. Current treatment regimens include, silver sulfadiazine, Bactroban or Sulfamylon in conjunction with daily cleaning and debridement. Acticoat is a silver impregnated material dressing that provides antibiotic coverage for 3-7 days.

Patients who show signs of sepsis should receive a complete work-up with special focus on the most commonly encountered bacteria in burn units including *staph aureus, pseudomonas aeruginosa* [32] and *acinetobacter*. The compromise to the skin barrier and overgrowth of bacteria in burn eschar leading to sepsis has led to a high rate of antibiotic resistance in these common organisms.

Surgical Debridement

The timing of surgical debridement has a significant impact on long term results of burn wounds. Early identification, excision and closure of full-thickness burn wounds help avoid wound sepsis, decrease systemic inflammation and improve outcomes in wound healing. For mixed-depth wounds, topical therapy for 5-7 days will facilitate any spontaneous wound healing that may occur.

Declaration of the depth of injury during that time with frequent assessment of wound progression should guide surgical planning.

Blood loss for surgical debridement of burns is estimated at 3.5-5% of blood volume for every 1% TBSA burn excised. [33] The systemic response to burn injury is responsible for the significant blood loss secondary to an alteration in the coagulation cascade. Operative methods to minimize blood loss during surgical debridement include injection of dilute epinephrine below the eschar, using cautery for fascial excision, excising extremities under tourniquet, and performing excisions early in the post-burn period before significant wound angiogenesis develops.

Surgical debridement is performed using a Goulian blade for small areas or those with multiple irregular contours (e.g. hand or knee) and a Watson blade for larger areas. Burned tissue is excised tangentially and sequentially until the wound has been excised down to healthy dermis, fat, muscle, peritenon or periosteum. The wound may then be covered with autografts, allograft or synthetic skin substitute. If a healthy recipient bed is not available, other reconstructive options should be considered.

Burn Wound Coverage

Autografts include full thickness skin graft, split thickness skin graft and cultured epithelial cells; each with their own set of advantages and disadvantages (see Table 6). Full thickness skin grafts are rarely used in burn surgery because of the added tissue loss. Split thickness skin grafts allow for regrowth of the donor site with minimal scarring. Average depth of graft is 8-14/1000ths of an inch. Thinner grafts heal the donor site faster with less scarring while thicker grafts provide more durable coverage but will have more significant scarring at the donor site Graft depth should be adjusted in pediatric and geriatric populations for thinner reticular dermis layer. Meshing of the skin graft has several advantages including expanding the square centimeters of coverage, allowing for drainage of fluid from under the graft and allowing for placement of graft over contoured areas such as the knee or ankle. The disadvantage of meshed skin graft include a permanent weave-look of the healed scar site. Sheet skin grafts have a smoother healed appearance but need to be checked frequently for hematoma and seroma formation and cannot be used for large burns where donor sites are scarce. Recently fibrin spray has been used to improve adherence of both sheet and mesh skin grafts. Cultured epithelial autografts are grown from patient skin samples. Seventy-five square meters may be grown from a one-centimeter square specimen. Few centers have large success with CEA secondary to lack of take and poor long-term durability. [34]

Alternatives to autografts

Several available substitutes for coverage of partial thickness wounds are available. The main purpose of these products is to provide a moist environment that stimulates epithelialization for faster healing. Synthetic products are best reserved for “clean” wounds. An excellent, comprehensive review of biological skin substitutes can by found by Jones. [35]

Full thickness skin substitutes act to replace the dermis. They provide wound closure, protection from mechanical trauma and a barrier to vapor and bacteria. Integra has a collagen proteoglycan matrix that acts as a scaffold for infiltration by fibroblasts and capillaries. Once the neodermis is created, the temporary silicone “epidermis” is removed and a thinner (6-8/1000ths of an inch) STSG may be placed. Disadvantages of using Integra include the need for a second stage surgery with a minimum interval of three weeks, dressing changes during this maturation phase, possible prolonged hospitalization and a product cost. Integra has recently been used with success for deep skin defects with partial exposure of bone or muscle. [35, 36]

Donor site dressings

Donor sites are partial thickness wounds. Coverage may be with a dressing that will dry such as xeroform, beta-glucan or Scarlet Red impregnated gauze. These dressings should be covered with an absorbent gauze for 24-48 hours, then removed and allowed to dry. Edges may be trimmed by staff or the patient to avoid painful snaring of firm edges. Dressings that create a moist wound environment such as hydrocolloid or Tegaderm facilitate re-epithelialization and decrease pain. Monitoring of wound is required to drain fluid collections under the dressing and watch for infection

Post-operative care

The success of skin grafts depends not only on surgical technique but post-operative care including post-operative dressings, frequent assessment of graft viability and close involvement of occupational and physical therapy teams. Viable graft may be mobilized on post-op day four or five. Grafts to the lower extremities should be protected from venous hypertension by double ace-wraps. Grafts to the upper extremities, especially the fingers should be protected with an elastic wrap such as Coban.

Nutritional support

In recent decades the need for early feeding in burn patients been substantiated with studies. A huge rise in metabolic rate occurs following a burn injury. [9, 37] as well as enhanced gluconeogenesis, insulin resistance, and increased protein catabolism. Patients with minor burns that are able to tolerate a diet should be encouraged to eat healthy foods high in protein. Patients with minor burns that are unable to eat because of age, pain medication or non-compliance should be followed by a dietician and intake supplemented by tube feedings as necessary. Pre-albumin provides a contemporary measurement of nutritional state more useful in acute care of burns than albumin alone. In critically ill burn patients, beginning tube feedings immediately upon admission can prevent atrophy of the gastrointestinal mucosa and bacterial translocation in the gut. Duodenal tube feeding may be superior to gastric feeding but is usually reserved for those patients intolerant of gastric feeding. [38]

Pharmacotherapy

Multiple advances in pharmacotherapy have been achieved for burn patients. Burn patients show significant inter- and intra-patient variation in distribution of medications. [39] Pharmacist help in ensuring correct dosing based on blood levels and blood volume are invaluable. Horton showed that anti-oxidants reduced burn and burn-sepsis related mortality by inhibiting free radical formation and scavenging free radicals. [40] The anabolic steroid oxandrolone has been shown to decrease acute phase proteins and long term administration improved lean body mass and bone mineral density in pediatric burn populations. [10]

Judicious use of topical and systemic antibiotics is recommended to avoid development of opportunistic nosocomial bacterial resistance. [10] Because of increasing multi-drug resistance nosocomial pathogens [41] (Pseudomonas aeruginosa, MRSA and VRE) antibiotic usage in burn units is discouraged in the absence of sepsis or identification of a specific pathogen. Patients receiving antibiotics should be closely monitored to ensure therapeutic levels, thereby preventing the development of more drug resistance.

Burn outcomes

Long Term Data

Data from the 2005 Burn Repository show decrease in mortality among all burns from 6.2% in 1995 to 4.7% in 2005[4]. The biggest factor in burn mortality is inhalation injury. In the six and a half percent of burns admitted with inhalation injury, mortality increases to 26.3%. Thirty-eight percent of all burn deaths were due to multiple organ failure and only 4.1% from burn wound sepsis. Mortality was much greater at both ends of the age spectrum. Factors previously thought to influence time to wound healing such as percent burned, gender, age, graft type, and infection were not found to be significant in a study by Jewell, et al. [42]

The significant increase in survival from burns over the last several decades[6, 43] generates important questions about quality of life issues. Studies of the quality of life among those surviving serious childhood burns have been surprisingly good. [44] Additionally, a recent study of patients who suffered massive burns shows that they have a satisfying quality of life 15 years post burn.[1, 45] A 1995 study showed that the most significant predictors of return to work are hand involvement, grafting and size of the burn;[46] a 1989 study shoed that the most significant variables influencing return to work after injury are the degree of burns, hand burns, age (those younger than 45 have a higher return to work rate), and the type of work done before injury. The length of time a patient is off work, their burn size, and their pre-injury employment are the best predictors of eventual return to work status. The Burn Specific Health Scale (BSHS) quantifies quality of life issues specific to burn injury. An abbreviated form was developed and validated by Kilda [47] to improve clinical use and gather more data that will help burn centers care for patients.

On average, burn patients with a mean TBSA burn of five percent returned to work within one month, patients with a mean TBSA burn of ten percent returned to work within one to six months, patients with mean TBSA burn of twenty percent returned to work within six months to a year and patients with a mean TBSA burn of 35 percent returned to work more than a year later. [43]

Summary

Interdisciplinary involvement with members of the burn team and counseling groups are very important in maximizing a patient's clinical outcome. Interventions designed to aid adjustment, work hardening, and other rehabilitation services and marital/family therapy are also important.

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