CHAPTER 57

BURNS OF THE FOOT AND ANKLE

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A burn of the foot or ankle can be an extremely disabling injury. Fortunately, 95% of all burns encountered in the U.S. are minor, and do not require hospitalization. However, proper evaluation and management are important to avoid prolonged patient morbidity. Most burns on the foot occur from scalds, contact with hot objects, and occasionally from a direct flame. It is also common for neurotrophic patients to suffer hot water immersion burns, and direct thermal injury from heating pads. Special consideration should be given to pediatric patients with scald injuries. Unfortunately, child abuse is a frequent cause of pediatric injury, making careful evaluation paramount.

PATHOPHYSIOLOGY OF THE BURN WOUND

A basic understanding of burn wound pathophysiology is necessary in order to appreciate the body's response to thermal injury. Initially, there is a tremendous increase in the net flux of fluids within the microvascular system. The function of the cell membrane becomes handicapped, and the osmotic pressure within the extracellular "third" space increases, leading to further tissue edema.

Three classic histopathologic zones exist in the burn wound. They extend outward in a concentric pattern and include the zones of hyperemia, stasis, and coagulation (Fig. 1). The zone of coagulation corresponds to the area of skin coming into direct contact with the source of heat. The zone of stasis lies in the middle, while the zone of hyperemia is furthest from the central area of injury. The zone of hyperemia lies at the periphery of the wound, appears red, and blanches on direct pressure. Complete epithelialization normally occurs within seven days. The zone of stasis is initially erythematous, but becomes mottled red and white by day five. This area initially demonstrates the ability to blanch on pressure, but during the following 24 hours will no longer blanch due to capillary sludging. This area is considered labile, having the ability

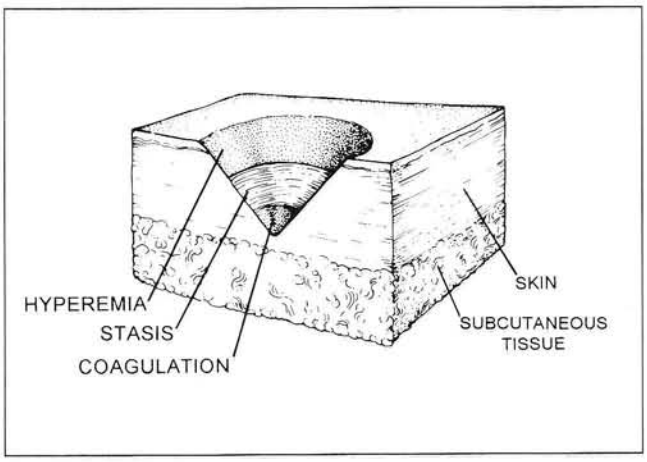

Figure 1. Zones of skin.

to survive if dermal ischemia is reduced during the first 24 hours after injury. The central zone of coagulation is white due to the destruction of capillaries and the lack of red blood cells. The expansion of this area represents the conversion of viable tissue in the zone of stasis to nonviable necrotic tissue. Although necrosis in the zone of coagulation is primarily due to vascular occlusion, local prostaglandins released by platelets, and wound dehydration, have also been shown to increase wound ischemia and lead to further necrosis.

EVALUATION OF THE BURN WOUND

Assessment of a patient with a thermal injury requires obtaining an accurate history, including the patient's general health status, the source of heat, and amount of time since the injury. A systematic approach is utilized during examination of the burned patient. The extent and depth of the wound are determined, as well as any associated injuries. The extent of the wound relates to the total body surface area (TBSA) involved and may be calculated by recording the areas burned using a chart such as the rule of nines (Fig. 2). It is helpful for the podiatric physician to remember that one entire foot constitutes approximately 3.5% of the TBSA. This holds true in children and adults.

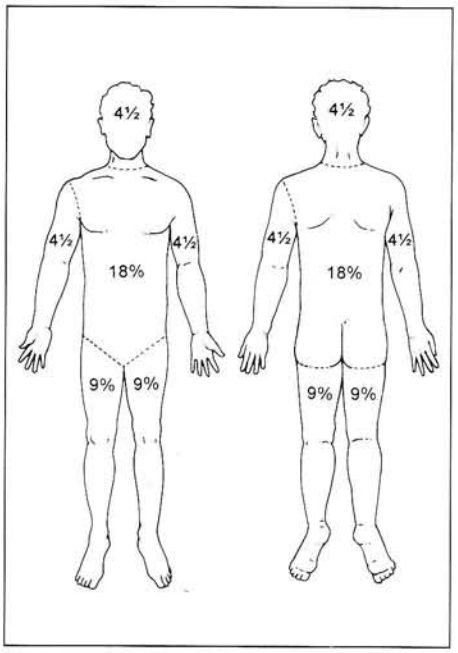

Figure 2. Rule of 9's for calculating total body surface area.

Another method of estimating extent of injury involves determining the approximate number of palms required to cover the wound; one palm constituting roughly one percent TBSA.

The determination of burn depth may prove difficult, especially in the early period. There is no easy and completely reliable method for determining wound depth. The depth of the wound is apt to change due its progressive and evolving nature. The severity of the burn has the potential to increase even after the source of heat has been removed. Post-injury treatment can potentially affect the ultimate depth of the injury. Cooling of the injured area within the first three hours of injury has been shown to limit progression of the burn wound and extent of tissue injury.

Regarding wound depth, burns may be categorized as first, second, or third degree (Fig. 3). However, in clinical practice they are many times simply classified as partial- or full-thickness injuries. First degree burns involve only the epidermis and demonstrate a locally painful, erythematous wound without blister formation. The most common cause is sunburn. Second-degree burns may be superficial or deep, depending upon the extent of dermal injury. Superficial partial-thickness burns injure the epidermis and a portion of the dermis. These wounds are moist, red, and very painful due to intact pain receptors. Blister formation is common. Deep partial-thickness burns involve the epidermis

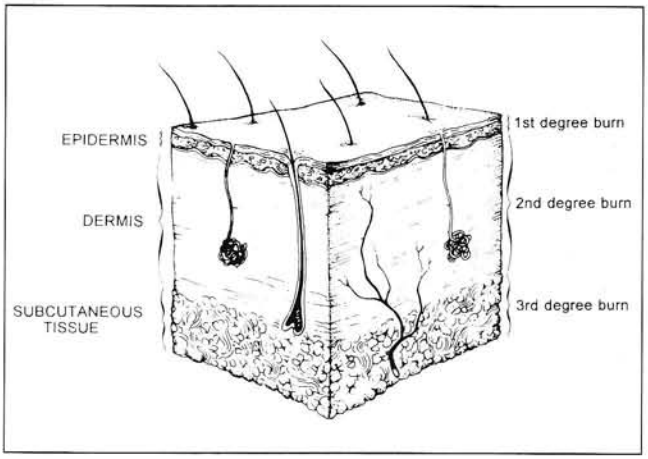

Figure 3. Burn injury depth.

and deep dermis. Only the skin appendages (hair follicles, sebaceous glands, and sweat glands) are left intact. In contrast to superficial injuries, this type of burn displays a dryer, more mottled wound, with or without the presence of blisters. Third-degree burns are full-thickness cutaneous injuries also causing destruction of the skin appendages and also involving the subcutaneous tissue. These wounds are anesthetic and may appear white, red, or black. Full-thickness burns commonly exhibit a leathery appearance. The presence of thrombosed vessels is a common finding. A helpful diagnostic test for distinguishing partial- from full-thickness injuries is performed by gently tugging on the hairs in the burned area. If the hairs can be removed without difficulty or discomfort it is most likely a full-thickness injury.

MANAGEMENT OF THE BURN WOUND

After careful evaluation, a decision is made as to whether the patient can be managed as an outpatient, or if hospitalization is necessary. In general, relatively minor, superficial burns can be managed on an outpatient basis. It is commonly accepted that partial-thickness injuries involving less than 15% of the TBSA in adults or less than 10% TBSA in children can be managed on a outpatient basis. However, injury to greater than 5% TBSA with involvement of a critical area (eyes, ears, face, hands, feet, or perineum) require hospitalization. Regarding full-thickness burns, injuries less than 2% TBSA, excluding critical areas, may be managed on an outpatient basis. Burns isolated to the feet require very limited systemic treatment, obviating the need for formal intravenous resuscitation.

Systemic resuscitation becomes necessary when the burns are greater than 10% of the TBSA.

The goals of local burn wound management are to prevent progression of the wound, avoid infection, and promote wound healing. Progression of the injury can be prevented by applying cool water to the wound for 30-45 minutes. Equally important is not allowing the wound to dry out. Traditionally, blisters have been left intact unless tense. In this instance, they are aspirated leaving the epidermal covering intact as a biologic dressing. Although this is still a common form of treatment, some recent literature supports the debridement of blisters based on the identification of certain opsonins and plasmin inhibitors in blister fluid which have been shown to interfere with wound healing.

Superficial Burns

No treatment is required for first-degree burns unless the injury involves a large area of skin on an infant or an elderly patient. However, topical lotions or ointments that decrease the exposure of the burn to air may provide significant relief. Healing will normally take place within 5-7 days.

Superficial second-degree injuries are considered minor burns and should be managed similar to abrasions. The wound should be kept clean by washing with mild soap and water, and moist by applying a light coating of a bland ointment. The injured area should be covered with a non-adherent dressing such as Xeroform® or Adaptic® and wrapped with a bulky bandage such as Kerlex®. It is recommended that dressing changes be performed twice daily. Standard tetanus prophylaxis should be instituted if more than 5 years have passed since the patient's last booster. These injuries normally heal within three weeks with no subsequent hypertrophic scarring. Using a topical antimicrobial such as Silver Sulfadiazine is not mandatory, and has even been discouraged in more recent medical literature. Although topical antibiotics are effective in preventing wound sepsis in patients with severe burn injuries, they may produce complications such as delayed wound healing and the development of later opportunistic infections if used inappropriately.

A recent advancement in the treatment of partial-thickness burns has been the development of semisynthetic wound dressings. The most well known product in this category is Biobrane® (Woodroof Laboratories, Santa Anna, California). It is a biocomposite of a thin semipermeable silicon membrane bonded to a flexible nylon fabric. It is directly applied to the wound (or donor site) and anchored to the surrounding normal skin with adhesive strips or skin staples. In approximately 24 hours, the dressing becomes adherent to the wound, and the periphery of the dressing may be trimmed. It is left in place until epithelialization occurs.

Deep Partial- and Full-Thickness Burns

The standard treatment for deep partial-thickness and full- thickness burns is early excision of the eschar and auto-grafting. Although deep partial-thickness injuries may heal in 4-6 weeks, they often result in hypertrophic scarring, wound contracture, and unstable epithelium. Early excision and grafting has been shown to result in less time missed from work, and decreased expense for the patient. Other advantages include a decrease in the number of painful debridements in addition to a lower rate of infection in patients with burns covering less than 20-40% TBSA who undergo early excision and grafting.

The standard technique of managing a full-thickness burn is as follows. Prior to surgery, topical antibiotics and saline dressings are applied to the wound twice daily. This is carried on for several days while the wound has a chance to form some degree of demarcation. Wound cultures may be obtained at this time if desired. The patient is then taken to the operating room where tangential debridement of the wound is performed by shaving multiple, thin layers of burned tissue with a Goulian knife or a pneumatic powered dermatome, until viable dermis is encountered (Figs. 4A, 4B). Significant bleeding may be encountered, necessitating control of hemostasis

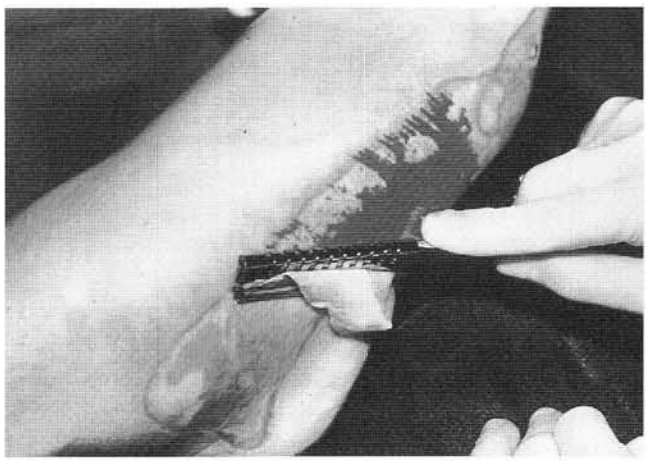

Figure 4A. Goulian knife.

Figure 4B. Pneumatic dermatome.

with a dilute solution of epinephrine (1:500,000) or topical thrombin. Debridement may also be performed under tourniquet. A split-thickness autograft is obtained from the thigh or buttock region. It may be applied directly as either a sheet or meshed graft. If the graft is meshed, it may be directly applied to allow for drainage or expanded if necessary to cover a large wound. However, expansion is discouraged due to the formation of an ugly scar with a corrugated appearance. The donor site may be covered with a semisynthetic dressing such as Biobrane® or a synthetic material such as Xeroform® (Sherwood Medical, St. Louis, Missouri), or Op-cite (Smith Nephew {United}, Largo, Florida).

Although the graft can be obtained at the time of debridement, it should not be applied if absolute hemostasis has not been obtained, or the quantitative bacterial count is greater than 100,000 per gram of tissue. In this instance, the donor graft may be rolled in a moistened saline gauze and stored in a refrigerator. It may then be applied at a later time when the status of the wound is felt to be satisfactory. The patient may be taken back to the operating wound, or the graft may be applied to the wound at bedside. If the graft is applied to the wound in the operating room, it can be tacked with sutures or staples. However, this is not mandatory and may simply be covered with petrolatum gauze and a sterile dressing. The graft is inspected 4-5 days after its application. Another option for graft management is leaving it uncovered, in order to inspect the wound daily.

ANTIBIOTIC ADMINISTRATION

Physicians are frequently tempted to administer prophylactic antibiotics to all burned patients realizing that the wounds are extremely hospitable for the growth of bacteria, including the normal skin flora. However, a common outcome is selective pressure resulting in virulent resistant microbes. Antibiotics should be instituted based on severity of the wound, medical status of the patient, and taking into account the mode of injury.

Although routine prophylactic systemic antibiotic administration is not recommended in the burn patient, there are several clinical situations in which administration may be indicated. Burn-wound excision frequently results in bacteremia, and therefore, warrants a short course of antibiotics. In autografting techniques it is usually mandatory to keep the wound covered for several days after surgery, especially when using meshed grafts. During this time the graft can be destroyed by gram-positive skin flora (usually streptococcal species) without significant systemic manifestations. It is common practice to administer a short course of prophylactic antibiotic therapy against streptococcal infections in the pediatric burn patient during the immediate post-injury period. In addition to the above listed indications for prophylactic administration, systemic antibiotics should be administered if there is any clinical sign of infection or if a pathogenic organism has been identified. There are several general guidelines to consider when administering systemic antibiotics in the burn patient. If an antibiotic has been chosen to destroy a particular organism it should be administered for a minimum of five to seven days to achieve a clinical response. During this time period routine cultures are obtained to confirm the pathogen and monitor antibiotic sensitivity. If a clinical response is achieved, the antibiotic should be continued until the pathogen is eradicated (usually 10-14 days).

Indications for topical antibiotic administration include deep partial-thickness and full-thickness wounds, burn infection, or wounds older than 24 hours when first treated. Other relative indications include the elderly, and certain systemic illnesses (e.g. diabetes mellitus). If antibiotics are to be

administered, wound cultures should be obtained prior to beginning therapy. Although successful topical therapy can delay microbial proliferation and maintain a more homogenous wound flora, it is not mandatory that all burns be treated with topical antibiotics.

Due to colonization of the wound by the host's skin flora, the majority of microorganisms in the burn wound after the first 24 hours are gram-positive cocci. However, within the next 3-7 days bacteria from the host's surrounding environment may invade the burn wound, with infection most often resulting from the growth of aerobic gram-negative rods. The burn eschar present in full-thickness burns is considered an avascular entity and, therefore, may preclude the ingress of systemic medications, as well as host-mediated defense factors. The burn eschar also provides a very suitable environment for the proliferation of microorganisms. In full-thickness burn injuries, the necrotic eschar sloughs secondary to bacterial enzymatic degradation. Therefore, the less effective the control of bacterial growth, the quicker the eschar will slough. In contrast, sloughing associated with partial-thickness eschars is not related to bacterial growth or enzyme production, but rather the rate of wound epithelialization.

When choosing antimicrobial preparations, one should select an agent that has broad-spectrum in vitro activity against *staphylococcus aureus*, aerobic gram-negative rods, enterococci, and *pseudomonas aeruginosa*. These organisms are frequently cultured in burn wound infections and should, therefore, be covered. The presence of anaerobic bacterial proliferation in burn wounds is uncommon. However, in cases where the patient has sustained an injury such as a high-voltage electric shock, a significant amount of necrotic muscle tissue can be present which predisposes to anaerobic colonization. *Pseudomonas* and Enterobacteriaceae species are reported to be the most likely organisms to acquire resistance.

TOPICAL PREPARATIONS

Topical antibiotics have not proven to be significantly useful in burn wound prophylaxis. However, when used cautiously they do have a place in the treatment of infections against microorganisms having demonstrated resistance to other agents. Because the topical antibiotics are not particularly effective in controlling infections that continue over an extended period, they should only be administered for a short period of time and over a limited area of the wound. These medications act at specific steps in metabolic pathways resulting in intense selective pressure against microbial growth. Frequently, superinfections with more virulent bacteria and fungi arise and further complicate treatment. Although there are many compounds which have been used in the topical treatment of burns, there are only a few in routine use that are low in toxicity, have effective antimicrobial activity, and are easy to apply.

Silver Sulfadiazine 1%

This product is the most commonly used topical preparation in burn treatment. It is a broad spectrum antibiotic with intermediate ability to penetrate escharotic tissue. It is easy to use and not particularly painful on application.

Silver Nitrate 0.5%

Silver nitrate is a broad-spectrum antiseptic with poor eschar penetrativeness, and therefore, is most often reserved for early burn management. Although quite effective, clinical failure is common if the burn covers greater than 50-60% TBSA. Potential complications include methemoglobinemia and argyrosis (brown discoloration of the conjunctiva). Another disadvantage is the black staining of everything it comes in contact with.

Mafenide Acetate 10%

Mafenide is a broad spectrum methylated sulfonamide with particularly good activity against gram-positive and gram-negative organisms. It is also quite effective against *Clostridia sp.* This medication has the greatest eschar penetrativeness of the topical products, but is painful on application. The most severe potential side-effect is hyperchloremic metabolic acidosis secondary to alkaline diuresis and excessive polyuria.

SUMMARY

There are many treatment options in the management of burn injuries to the foot and ankle. The key point in the treatment of burns is the formation of an accurate wound assessment based on clinical evaluation. Many decisions must be made regarding

possible hospital admission, need for resuscitation, surgical intervention, wound care, and rehabilitation. However, with a systematic, common-sense approach to burn wounds, patient morbidity can be greatly diminished.

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