Continuing Medical Education

Burn Injuries of the Foot and Ankle

Proper assessment and care leads to improved results.

BY LINNIE V. RABJOHN, DPM AND KEVIN ROBERTS, DPM

Objectives

After completing this CME, the reader should be able to:

1) Understand the initial assessment of burn injuries to the foot and ankle.

2) Develop treatment plans, both short and long-term, for a burn injury involving the foot and ankle.

3) Understand the physiology of a burn injury.

4) Understand the use of topical and systemic antibiotics in the treatment of burn injuries.

5) Learn the skin's structural and functional differences in regards to the foot and ankle.

6) Understand the reconstructive aspects of a burn injury involving the foot and ankle.

7) Understand the complications of burn treatment in patients with diabetes mellitus.

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*Following this article, an answer sheet and full set of instructions are provided (pg. 206).—**Editor***

Abstract

A burn injury to the lower extremity challenges the integrity of the skin protective barrier and the structural and functional components that govern the ability to ambulate. For this reason, the foot and ankle specialist must obtain a greater understanding for the assessment of burn injuries, both in terms of initial and prolonged treatment considerations, and in terms of both the reconstructive and rehabilitative processes. Pre-acquired notions regarding the replacement of lost tissues at other anatomical sites do not apply when concerned with lower extremity coverage. The standard of care makes necessary the education for prevention of lower extremity burns in patients with diabetes mellitus who secondarily have peripheral neuropathy, impaired immune response, and/or decreased circulation.

Introduction

Human skin functions as an organ providing a protective barrier capable of dynamic responses to microenvironments. Burns represent a complex injury causing a wide range of minor, superficial to severe and extensive destruction of this skin barrier. Lower extremity thermal injuries pose a challenge to physicians due to the unique anatomical and histological components that govern one's ability to weight-bear. For this reason a burn involving the lower extremity cannot be considered minor, secondary to surface area involvement, but must be treated as a significant burn. The American Burn Association addresses this issue by classifying burns of the lower extremity as major injuries.[1,2]

It is incumbent upon foot and ankle specialists to obtain a greater base of knowledge about the assessment, treatment options, and prognosis of lower extremity burns. The ultimate goal in the treatment of a patient with a lower extremity burn injury is to maintain a plantigrade foot and ankle that is capable of unimpaired ambulation. While this goal is

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recognizable, it often will take admission to a hospital, a series of multimodality reconstructive procedures, and a long process of rehabilitation to achieve.

Further complication of the injury occurs with the underlying medical condition of diabetes mellitus. The consequences of stifled sensation and the compromises in circulation to the lower extremity make this subpopulation more prone to acquiring an injury and increases the risks of complications with that injury.

Initial Assessment of a Burn

The initial physical assessment of a lower extremity burn, occurring in the Emergency Department or on an outpatient basis, is crucial in determining an immediate treatment plan with prognosis. Understanding the two commonly used methods of classification allows the physician to more accurately describe the extent of an injury.[3,4]

The first method classifies burns into subcategories of 1st, 2nd, 3rd, and more recently 4th degrees dependent upon the clinical physical assessment and the depth of the injury (Table 1, Figure 1, Figure 2).[5]

The second approach describes a burn injury focusing more on the depth with the categories of partial or full thickness. A partial thickness burn involves full epidermis and part of the dermis. Full-thickness entails destruction of both the epidermis and dermis to include the skin appendages.[5]

Rule of Nines

The primary presentation may be misleading when initially evaluating a patient's burn injury. Secondary to the development of edema, often the full extent of the destruction cannot be fully ascertained until after 24 hours. The surface area of a burn should be determined during the initial assessment and can easily be estimated with use of well-developed methods.[5] The 'rule of nines' uses a method based on the concept that the human body can be broken into anatomical sections that equal nine percent (Table 2). If the entire foot is involved distal to the malleoli the estimated surface area is 3.5%.

The severity of a burn is directly related to the agent intensity causing the burn and the duration of contact with the agent.[5,6] Moritz and Henriques, in a series of experiments, developed an understanding of temperatures in relation to duration of exposure in the development of a burn injury.[7,8] The studies were designed to provide information on the rate of acquiring a burn in relation to temperature, including surface and air conduction of heat. They established that even contact with a lower gradient of heat for a longer duration could cause significant irreversible injury.[7] It was also proposed that with every increase in temperature by one degree in Celsius, the rate of acquiring an injury doubled, up to 51 degrees Celsius.

Initial Treatment on the Burn Injury

Development of a protocol for the treatment of patients with isolated lower extremity thermal injuries aids the physician in the setting of the initial presentation. While a prolonged course may not easily be ascertainable initially, necessary treatments may be started within the first minutes after the presentation of the burn. Elevation of the limb, cooling of the tissues, use of prophylactic antibiotics and the assessment of the degree of severity remain mainstays in immediate protocol of isolated lower extremity burns.

Immediate burn care focuses on the prevention of the progression of a burn

Figure 1: 38 y/o male with scalding burn to the left foot causing 2nd degree burns with characteristic serous fluid blisters.

injury. Removal of the source of heat alone does not terminate the progression of the injury.[5] Heat remains and penetrates through the deeper tissues. This progression, if unchecked, will continue for the first 24 hours after injury. Cell death continues due to the release of oxygen free radicals causing the stimulation of the arachidonic acid cycle leading to a local ischemia.[2] Cooling of the involved tissues should be done at the initial presentation of the patient using the preferred method of water at a temperature of 25 degrees C (77 degrees F). Avoid the use of ice to cool burned tissues as this could lead to a localized frostbite.

Close assessment of the circulatory status should be maintained with initial presentation. The accelerated formation of edema that occurs after injury can cause constriction and occlusion of blood flow, leading to localized gangrene of the lower extremity. This is observed more frequently in circumferential burns. Blood flow to the lower extremity may be monitored with use of Doppler ultrasound.[5] Compartmental tissue pressures should also be monitored and should remain well below 40mmHg to avoid irreversible tissue necrosis. Pulse oximetry may also be helpful when determining the oxygen saturation to tissues. With saturation less than 95%, it has been proposed that there is an indication for escharotomy.

Hospital Admission

Literature supports the early hospital admis-

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TABLE 1

Classification of Burn Injuries Based on Degree of Severity

First Degree	Superficial, painful burn that often appears as erythematous but without blisters. Will heal without scarring or discoloration.
Second Degree	Partial-thickness, painful burn associated with blisters and erythema.
Third Degree	Full-thickness, painless burn which may have a waxy, white, or necrotic appearance. Will often heal with a scar or require skin grafting.
Fourth Degree	Full-thickness, painless burn involving muscle and/or bone. Irreversible damage to deep tissues resulting in deep necrosis.

sion of patients with lower extremity burns.[1,3,4,9] A study involving 104 patients with lower extremity burns compared the development of cellulitis, length of hospital course, need for grafting, and development of scarring in patients admitted initially and those with a delayed admission.[9] The results supported the need for initial hospital admission. Those treated on an in-patient basis received three doses of prophylactic penicillin and had a zero occurrence of development of cellulitis. Admission for scald burns at a delayed date showed a 26.5% incidence of development of cellulitis. In addition, patients with delayed admission on average had a longer hospital stay, an increased incidence of need for grafting, and increased incidence of hypertrophic scarring.

Admission ensures the ability to maintain elevation of limb with strict bed rest, routine inspection with meticulous wound care to the area, and the use of IV antibiotics for prophylactic coverage. The full extent of burn progression with destruction often is not seen until after 48 hours. Admission enables monitoring of this destruction.

Circumferential burns to the lower extremity pose a direct threat on the vascular and lymph flow entering and exiting the foot. As previously mentioned, monitoring by use of Doppler ultrasound, compartment pressures, and oxygen saturation to involved areas determines the need for escharotomy/fasciotomy. Escharotomy may be performed at bedside without the need for anesthesia because the eschar is insensate. The incision made with either a 10 blade, 20 blade or electrocautery should be made proximal to distal from the margins of burned to unburned skin.[5,10] The location of incision correlates with implicated compartments and care should be taken to avoid areas where a deeper incision could cause neurovascular damage. Deeper ischemic changes compromising flow to the muscles necessitates the need for fasciatomy. In order to perform fasciatomy, anesthesia must be given.[10]

Brief Pathophysiology of a Burn

In order to fully understand the treatment needed within the first few hours and days after a burn injury, one must appreciate the pathophysiology at the burn site. An inflammatory response is initiated that leads to significant edema formation within the first six hours.[11,12] The amount of edema correlates with exposure time and is more pronounced in injuries caused at a temperature less than 55 degrees Celsius. The complete resolution of edema is typically seen after one week. Although the mechanism for the edema formation is not fully understood, the release of sensory neuropeptides plays a role.

TABLE 2
Anatomic Distribution to Determine Percentage Burn Area on an Adult

Area	Percentage (%)
Head	9
Abdomen/Chest	18
Back	18
Arm	9
Leg	18
Foot	3.5
Hand	3.5
Genitals	1

The sequestering of fluids from the vascular branches into the extravascular compartments is caused by an increase in both microvascular permeability and extravascular osmotic activity.[1,12] To date, studies with use of anti-inflammatories post-burn to decrease initial edema formation have been unable to significantly prove that these agents are effective.[12] To minimize the effects of this edema cascade, the lower extremity should be elevated immediately and the patient placed on strict bed rest at presentation.[5,9]

Microvascular Reaction

The microvascular reaction within the first minute following injury is a vasodilatory response, causing an increase in perfusion.[13] This is followed by 30 minutes of decreased perfusion. Then once again, an increase in perfusion caused by inflammatory responses. The progression of ischemia to necrosis with more advanced burns remains unclear, but involves the slowing and stopping of capillary blood flow to the involved area.

The microcirculatory effects of a burn injury can be divided histologically into three zones.[2,5,11] The zones, first described by Jackson, aid in the ability to clinically assess tissue damage. The zone of hyperemia correlates to an area of minimally injured tissue that is erythematous and blanches. Further studies concluded that there was no capillary occlusion within this area and in fact there was an increase of capillary blood flow.[11] The zone of stasis is tissue of mixed normal perfusion and areas of coagulation.

If necrosis is going to occur, it will occur within the first 24 hours. The tissue at initial presentation is likely to blanch and later with occurrence of ischemic coagulopathy will not. The zone of coagulation represents an area of dead, necrosed tissue requiring debridement. This zone was found to increase by a factor of ten within the first 48 hours.[11] After 48 hours no further occlusion is seen. Edema within this zone is limited due to the destruction of blood vessels.[12]

Red cell aggregation, white cell adhesion and platelet microthrombi and microemboli are all implicated in the partial to full occlusion of the vascular branches. Partial occlusion usually occurs within 8-24 hours caused by the adhering of leukocytes to the endothelium of venules. This has never been found to cause complete occlusion.

Infection

The increased susceptibility of a thermal injury to infection results from alteration within the immune function.[14] A burn injury creates an excellent medium for the colonization and invasion of pathogens.[15] If the patient presents within the first few hours after injury, the wound is likely sterile. This does not, however, negate the need for prophylactic antibiotic coverage at initial treatment. Systematic prophylaxis with use of penicillin guards against beta-hemolytic streptococci, a bacterial threat during the first few days after injury.[2] The development of a burn wound infection implies serious risks of septicemia, bacteremia, and/or a limb-threatening infection.

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Topical Agents

Topical agents alone can not ensure the prevention of infection or reduce the microbial count sufficiently of a burn wound. Local benefits do necessitate their use. Topical agents have shown to increase the duration of wound sterility in full-thickness burns, allowing for time to stabilize the patient before debridement. In the subpopulation of patients with poor vascularity to the lower extremity, a topical agent gives some form of coverage at the surface-air interface. Three topical agents are commonly recognized for their activity at a burn site: silver nitrate 0.5% solution, mafenide acetate, and silver sulfadiazine.[2,5,9,16,17]

Silver nitrate solution may be used on burn wounds wherein no colonization of the eschar is present due to its inability to penetrate the eschar.[9,17] This makes it a viable initial choice within the first 48 hours after injury. The agent provides a broad-spectrum gram negative coverage. Its application is a 0.5% solution and must be kept in a saturated state on the wound. Its use has been described with both occlusive dressings and loose gauze dressings.[15,17] Regardless, the full dressing should be changed every 12 hours.

Although the solution draws sodium and chloride out of the blood, the surface area of a lower extremity burn should not be large enough to compromise metabolic needs. One noted disadvantage to its use is the black discoloration that it causes with contact.[17] This can make it difficult to accurately assess the state of the wound.

Of the three topical agents commonly used, only one is capable of penetrating eschar. Mafenide acetate has broad-spectrum coverage against gram negative organisms.[17] It is limited in its activity against Staphylococcus species. This topical is also a solution consisting of 5% mafenide acetate. The dressing should consist of gauze that is saturated with solution every 6-8 hours. The dressing may be kept intact for up to five days. Although it can penetrate eschar, it does cause a transient burning sensation with contact.

Silver sulfadiazine is the third topical agent used to superficially control micro-density of a wound with activity against both bacteria and fungus. Although no penetration through a wound will occur, therefore strictly prophylactic, this agent is commonly used for topical burn care due to its soothing nature for patients.[17] The cream is applied to the burn wounds in a 1/16 thickness and covered with gauze. The dressing should be changed every 12 hours.

Routine Inspection of Burns

Systemic and topical anti-microbials do not eliminate the need for routine inspection of burn wounds. Bacterial colonization or invasion into viable tissue should be considered if one of the following is observed: tissue hemorrhage, rapid eschar separation, green discoloration of the eschar, or presence of subeschar fat.[16,17] Suspicion of infection should be raised if a partial thickness injury converts to full thickness. Blackened discoloration of a burn caused by a rapidly expanding ischemic necrosis indicates a possible fungal infection, most likely caused by mucormycosis. This type of fungus is aggressive and quickly crosses fascial planes. If this is suspected add the topicals sulfamylon and nystatin to the treatment plan.[17]

Figure 2: Third degree scalding burn with superficial skin necrosis of the plantar foot with fourth degree complete necrosis of digits 2-5.

To more accurately ascertain the presence and extent of infection at a burn site, histological biopsies should be taken.[16,17] Viable tissue will show the presence of microorganisms if an invasive infection is present. Soft tissue cultures of a wound prove to be helpful in the determination of microorganisms and the sensitivities of antibiotics.

Gram negative infections tend to be diffuse in nature and may vary dependent on the treatment facility. Pseudomonas is a common causative organism.[16]

Gram positive infections tend to be more localized with the presence of microabcesses.

Candida typically is localized to only the burn tissue. Its tendency to be non-invasive means that no specific treatments are needed. The most common fungal species apparent in burn wounds is Aspirgillus. Topical treatment with clomitrazole and systemic treatment with Amphotericin B is warranted if Aspergillus is suspected.

Structure of the Lower Extremity Skin

The histology of skin structure varies in regards to the different anatomical components of the foot and ankle. The dorsal skin in comparison to the sole of the foot is relatively thin with minimal subcutaneous tissue and must allow for the gliding motion of the anterior compartment tendons.[3,18] A burn injury causing distortion of the skin could cause adhesions jeopardizing the function of the tendons.

In more serious injury, exposure of the tendons could lead to infection and/or necrosis. Likewise the skin structure overlying the malleoli lacks a considerable amount of subcutaneous tissue with which injury could easily expose the structures composing the ankle joint. Reconstructing these regions requires the use of skin, which can function in the same capacity in regards to suppleness and the allowance of unrestricted motion.

The trauma that is imposed during ambulation is counteracted by the special properties of the weight-bearing surface of the foot. Spiral patterns of the subcutaneous tissue allow for a safe transmission and absorption of shock beneath the calcaneus. This tissue, along with the fat pad underlying the metatarsal heads, is tightly attached to the overlying plantar skin.[3] This allows for the durability and stability needed to withstand the shearing forces of ambulation. The plantar skin of the foot in relation to the dorsal skin has thicker epidermal layer with a more solid stratum corneum.[19]

The dermal thickness of the skin does not vary widely throughout the body; however, the connective tissue component is less elastic at the sole of the foot. The plantar skin also lacks hair, sebaceous glands, melanocytes and has a sparse amount of pigment cells. In many

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of these respects, the plantar skin of the sole of the foot resembles that of the palmar surface of the hand. For this reason, literature regarding reconstruction of the palm of the hand after burn injury addresses the use of replacing this skin with like tissue of the sole of the foot.[19-22]

Reconstruction of the Lower Extremity

With regard to reconstruction, the physician must assess and evaluate the extent of injury, depth, location, and the involvement of deeper structures. Reconstructive concerns with involvement of the lower extremity are complicated due to the different soft tissue structures and functions at the different regions of the foot and ankle. From the development of blisters with partial-thickness injuries to the wide destruction of the foot, procedures may vary from simple aspiration and local wound care to amputations due to the inability to salvage a limb. A multi-specialty team approach to the reconstructive and rehabilitative aspects may be needed to obtain the ultimate goal of unimpeded ambulation.

Blister formation is characteristic of a second degree, partial thickness burn. The blister, or larger bullae, is the accumulation of fluid between the dermal-epidermal junction. The fluid contained within this space is the byproduct of the arachidonic acid cycle and should be aspirated.[2] Upon aspiration of the fluid, the epidermis should be left intact, functioning in the prevention of dessication and the protection of underlying tissue.[5] As with any bedside needle aspiration, the area should be prepped with Betadine and allowed to dry. Then the fluid should be aspirated with a sterile 18-22 gauge needle. Multiple aspirations may be needed due to the re-accumulation of fluid within this layer.

Involvement of the deeper layers of tissues seen with more involved partial thickness or full-thickness burn injuries necessitates surgical intervention in most situations. The most simple primary procedure is early excision of the burned tissue with immediate closure.[3,23] Although this is a preferred primary procedure, burns involving a larger surface area or complicated with infection are unable to be closed in this manner. Often other methods of coverage are pursued and include skin grafts, plastic surgical techniques, and flaps. Appropriate coverage for the lower extremity is based on the soft tissue structure and the function of specific areas. The physician must have knowledge in the biomechanical aspects of the lower extremity, as well as the anatomical components on both micro and macro levels.

Replacing tissue with like-tissue is a fundamental concept concerning coverage of burn wounds. Autogenous skin grafts placed on the lower extremity from traditional sites pose risks of hyperpigmentation, scarring, and hyperkeratosis. In order to best understand treatment considerations available for coverage, the lower extremity is divided into the previously mentioned areas; dorsum, plantar sole, and posterior heel/Achilles tendon region.

Split-Thickness Grafts

A split-thickness autogenous skin graft may be placed on the dorsum of the foot if subcutaneous tissue is unaffected. Adequate blood supply to the area must be present to ensure ischemic changes will not cause tissue breakdown. The preferred split-thickness skin graft for this area is sheet rather than mesh, avoiding a more pronounced wound contraction that occurs with meshed grafts.[3]

A skin graft will not incorporate over eschar or areas of coagulation necrosis, or with any presence of infection; however, with preparation, it may be placed over bone. The formation of granulation tissue after decortication of dorsal bone provides a suitable bed for the skin graft. The graft must be able to conform to the structure of the dorsal foot. Sensation restoration to this area is not necessary. Another option, other than the decortication of bone with the application of a split-thickness skin graft, is the use of free skin or muscle flaps.

More pronounced injuries result in extensive scarring, exposure of tendon or joint capsules, to the development of soft tissue contractures. Initially, scar formation is limited to the epidermis and dermal layers.[10] With time, however, the contractures may involve neurovascular structures, ligaments, and tendons causing permanent deformations. Contractures involving the extrinsic anterior tendon complex will cause a dorsi-flexed position of the ankle and/or hammering of the digits due to shortening of the tendons. Tendon releases or lengthening should be performed in order to correct the contractures.

The plantar sole of the foot has innate qualities within the epidermis, dermis, and subcutaneous tissues to sense position, and for protection against the environment and shearing forces of ambulation. The inability to replace lost tissue in this region with tissue maintaining the same qualities may cause long-term sequelae affecting the ability to ambulate. If adequate subcutaneous tissue is present, split-thickness or full-thickness skin grafts may be used for coverage, taking note that the previous complications remain with the added loss of needed sensation.[3]

Sommerland, et al. compared the long-term functional capabilities with split-thickness, full-thickness skin grafts, and flaps to the weight-bearing and non-weight-bearing areas of the foot.[24] No significant difference was noted between the use of these three techniques. Furthermore, the patients in whom resurfacing of the plantar sole had occurred, avoided weight-bearing on the resurfaced areas.

Muscle Flaps

In patients where skin grafts may not suffice due to the lack of subcutaneous tissue, use of fasciocutaneous or muscle flaps is advocated.[3,10,25] The use of pedicle fasciocutaneous flaps is dependent upon the viability of the posterior tibial, anterior tibial, and peroneal arteries.[3] Local muscle flaps involving the use of the abductor hallucis, abductor digiti minimi, and flexor digitorum brevis have been described.[3,25] Due to the limitation of these muscles with regard to arcs of rotation, their scope of use is primarily for small burn wounds.[25]

The abductor hallucis is generally useful in coverage of the plantar heel and the medial heel inferior to the malleoli. The abductor digiti minimi has the same coverage on the lateral aspect of the heel. The flexor digitorum brevis may be used solely for plantar heel coverage. The local muscular flaps do maintain some pressure sensibility beneficial for ambulation. Flap stability is compromised due to the lack of fibrous connections that help resist damaging effects of shear forces.[3] After the muscle has been transposed, skin grafting is necessary over the flap.

Free flaps involve the transferring of either fasciocutaneous or muscular elements from distant sites to the burned area. Both forms of free flaps maintain

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sensitivity through original innervations and contour well to the plantar sole. Studies have shown, however, that the acquired protective sensation may not be enough to prevent ulcerations.[3,10,25] Free muscle transfers, as with the use of the latissimus dorsi, may provide more durability in comparison, but provide less sensation.[25]

The goal of reconstruction is the provision that the lower extremity can not only weight-bear but can do so with minimal long-term risks of tissue and bone breakdown. Even in the most skilled of hands, reconstruction is limited to the extent of destruction and the availability of necessities to rebuild a limb capable of ambulation. Recognizing a limb that is not salvageable and needs amputation eliminates the long process and risks of multiple surgical procedures and a rehabilitative process with no achievable end.

Diabetes Mellitus and Burn Injuries

Special attention should be allocated in cases of lower extremity burns involving patients with diabetes mellitus. A combination of impaired sensation secondary to peripheral neuropathy and decreased vascularity lends this subpopulation not only to an increased incidence of preventable burn injuries, but also compromises their ability to heal.[18,26,27,28,29,30,31] Patients with diabetes mellitus have a pre-existing vascular compromise to the lower extremity.

This reduced circulation changes the threshold values for the relationship of duration of contact and the source of damage.[32] The temperature to cause injury is lower than normal due to the decreased ability of the heated tissues to transfer heat. This leads to a slower progression of heat through the tissues, resulting in an accelerated rise in temperature within the area involved. Often these patients require a longer hospitalization.[30]

The responsibility of education of diabetic patients about their risks of lower extremity burns lies with the physician. The dangers of hot water scalding or exposure to other heating devices placed on the lower extremities should be explained.[28,30,31] PM

References

[1] Grube B, Engrav L, Heimbach D. Early ambulation and discharge in 100 patients with burns of the foot treated with grafts. J Trauma 1992; 33:662.

[2] Phillips L, Robson MC, Heggers J. Treating minor burns: Ice, grease, or what? Postgrad Med 1989; 85:219.

[3] Kucan JO, Bash D. Reconstruction of the burned foot. Clin Plast Surg 1992; 19:705.

[4] Schoen N, Gottlieb L, Zachary L. Distribution of pedal burns by source and depth. J Foot Surg 1996; 35:194.

[5] Jahss MH. Disorders of the Foot and Ankle: medical and surgical management (2nd ed). Philadelphia, W.B. Saunders Company, 1991.

[6] Arturson G, Jakobsson OP. Oedema measurements in a standard burn model. Burns 1985; 12:1.

[7] Moritz AR, Henriques FC. Studies of thermal injury; the relative importance of time and surface temperature in the causation of cutaneous burns. Arch Pathol 1947:695.

[8] Moritz AR, Henriques FC, Dutra FR, Weisiger JR. Studies of thermal injury: An Exploration of the casualty-producing attributes of conflagrations; local and systemic effects of general cutaneous exposure to excessive circumambient (air) and circumradiant heat of varying duration and intensity. Am J Pathol 1947; 23: 695.

[9] Zachary LS, Heggers JP, Robson MC, Smith DJ, Maniker AA, Sachs RJ. Burns of the feet. J Burn Care Rehabil 1987; 8:192.

[10] Mani MM, Chhatre M. Reconstruction of the burned lower extremity. Clin Plast Surg 1992; 19:693.

[11] Boykin JV, Eriksson F, Pittman RN. In vivo microcirculation of a scald burn and the progression of post burn dermal ischemia. Plast Reconstr Surg 1980; 66:191.

[12] Lund T, Onarheim H, Reed RK. Pathogenesis of edema formation in burn injuries. World J Surg 1992; 16:2.

[13] Lofgren O, Gazelius B, Lundeberg T. Acute microcirculatory changes after scalding of the rat paw. Acta Physiol Scand 1997; 161:289.

[14] Heideman M, Bengtsson A. The immunologic response to thermal injury. World J Surg 1992; 16:53.

[15] Fitzpatrick TB, Eisen AZ, Wolff K, Freedberg IM, Austen KF. Dermatology in General Medicine (3rd ed). New York, McGraw-Hill Book Company, 1987.

[16] Gorbach SL, Bartlett JG, Blacklow NR. Infectious Disease. Philadelphia, W.B. Saunders Company, 1992.

[17] Mandell GL, Bennett JE, Dolin R. Principles and Practice of Infectious Disease (5th ed). Philadelphia, Churchill Livingstone, 2000.

[18] Balakrishnan C, Rak TP, Meininger MS. Burns of the neuropathic foot following use of therapeutic foot baths. Burns 1995; 21:622.

[19] Bunyan AR, Mathur BS. Medium thickness plantar skin graft for the management of digital and palmer flexion contractures. Burns 2000; 26:575.

[20] LeWorthy GW. Sole skin as a donor site to replace palmer skin. Plast Reconstr Surg 1963; 30:32.

[21] Tanabe HY, Aoyagi A, Tai Y, Kryokaiwa K, Inove Y. Reconstruction for plantar skin defects of the digits and using plantar dermal grafting. Plast Reconstr Surg 1998; 101:992.

[22] Webster JP. Skin grafts for hairless areas of the hands and feet. Plast Reconstr Surg 1995; 15:83.

[23] Zuker RM, McLeod ME, Vaz H, Thomson HG. Effective management of deep scald burns to the feet. J Burn Care Rehabil 1984; 5:288.

[24] Sommerland BC, McGrowther DS. Resurfacing the sole: long term follow-up and comparison techniques. Br J Plast Surg 1978; 31:107.

[25] McGraw JB, Arnold PG. McGraw and Arnold's Atlas of Muscle and Musculocutaneous Flaps: lower extremity reconstruction. Norfolk, Hampton Press Publishing Company, 1987.

[26] Hwang JCF, Himel HN, Edlich RF. Bilateral amputations following hydrotherapy tank burns in a paraplegic patient. Burns 1995; 21:70.

[27] Saffle JP, Davis B, Williams P. Recent outcomes in the treatment of burn injury in the United States: a report from the American Burn Association patient registry. J Burn Care Rehabil 1995; 16:219.

[28] Weaver AM, Himel HN, Edlich RF. Immersion scald burns: strategies for prevention. J Emer Med 1993; 11:397.

[29] Katcher ML, Shapiro MM. Lower extremity burns related to sensory loss in Diabetes Mellitus. J Fam Pract 1987; 24:149.

[30] Thng P, Lim RMC, Low BY. Thermal burns in diabetic feet. Singapore Med J 1999; 40:362.

[31] Valdes VG, Fornells MG, Gonzalez RFG, Guijon del Castillo AJ, Gutierrez AM, Bou JE. Hot sand burns on the sole of a patient with Diabetes. J Wound Care 2002; 11:170.

[32] Ovesen O, Wildfang IL. Foot spas as a cause of burns. Burns 1990; 16:211.

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CME EXAMINATION

Continuing Medical Education

SEE ANSWER SHEET ON PAGE 207.

1) The full extent of injury following a burn can be fully ascertained:
   A) Immediately following injury
   B) After two hours following injury
   C) After 24 hours following injury
   D) After 72 hours following injury

2) What is the appropriate method for cooling of involved tissues following a burn injury?
   A) Apply ice to the involved area
   B) No cooling is necessary once the source of the burn has been removed
   C) A water bath at room temperature (approximately 80 degrees Fahrenheit)
   D) A water bath at 50 degrees Fahrenheit

3) Which of the following could be necessary in assessment of blood flow to the lower extremity following a burn injury?
   A) Doppler ultrasound
   B) Pulse oximetry
   C) Compartmental pressures
   D) All of the above

4) What protocol must be followed in order to perform an escharotomy?
   A) General anesthesia with sterile OR environment
   B) Local monitored anesthesia care (conscious sedation) with block to the involved extremity
   C) No anesthesia necessary, but must have sterile field
   D) No anesthesia or sterile field is necessary

5) The amount of edema present following a burn injury is directly related to which of the following?
   A) Exposure time
   B) More edema is present at temperatures above 55 degrees Celsius.
   C) More edema is present at temperatures below 55 degrees Celsius.
   D) Both a and c

6) Which of the following describes the zone of stasis related to a burn injury:
   A) Area of minimally injured tissue that is erythematous and blanches
   B) Area of dead, necrosed tissue that requires debridement
   C) Area of mixed normal perfusion and areas of coagulation.
   D) Area of complete coagulation.

7) Appropriate antibiotic prophylaxis following a burn injury includes:
   A) No antibiotic prophylaxis is needed if there are no clinical signs of cellulitis.
   B) Topical antibiotic treatment alone is acceptable for prophylaxis.
   C) Systemic antibiotics are necessary for appropriate antibiotic prophylaxis.
   D) Avoid systemic antibiotics because of the threat of development of resistance.

8) Which one of the following describes a third degree burn?
   A) Superficial, painful, no scarring, erythematous, no blisters
   B) Burn involves muscle, bone, complete necrosis
   C) Full-thickness, painless, may need skin grafting
   D) Partial-thickness, blisters that are painful

9) Based on the "Rule of Nines," a burn involving the entire foot encompasses what percentage?
   A) 1%
   B) 3.5%
   C) 10%
   D) 15%

10) Which of the following should not be done upon initial assessment?
   A) Maintain dependent position of limb
   B) Cool limb
   C) Escharotomy, if applicable
   D) Pain management

11) What should the compartmental pressures be to avoid irreversible damage?
   A) Less than 75 mm. Hg.
   B) Less than 40 mm. Hg.
   C) Less than 50 mm. Hg.
   D) Less than 100 mm. Hg.

12) What is the acceptable method for estimation of the percentage of burn involved in an injury?
   A) Estimate based on the trunk being 50% of body area
   B) "rule of nines"
   C) should not try to estimate the percentage burn within the first 24 hours after injury
   D) "rule of eights"

13) Which one of the following will cause the most severe burn injury?
   A) Lower gradient of heat for a short duration
   B) Higher gradient of heat for a short duration
   C) Lower gradient of heat for a long duration
   D) The duration and gradient of heat does not influence the severity of a burn

14) When performing pulse oximetry on involved burn tissues, at which oxygenation saturation levels should one consider an escharotomy?
   A) 90-95%
   B) 95-97%
   C) 97-99%
   D) all levels below 100%

Continued on page 206

Continuing Medical Education

CME EXAMINATION

15) Within the "zone of hyperemia" the capillary blood flow is:
- A) Occluded
- B) Partially occluded
- C) Unchanged
- D) Increased

16) Which one of the following topical agents used for burn injuries is capable of penetrating an eschar?
- A) Silver nitrate 0.5% solution
- B) Mafenide acetate
- C) Silver sulfadiazine 1%
- D) Triple antibiotic ointment

17) The thickness of which layer of skin is different between the dorsal and plantar skin of the foot?
- A) Papillary dermis
- B) Reticular dermis
- C) Epidermis
- D) hypodermis

18) A blister is characteristic of which degree of burn?
- A) First
- B) Second
- C) Third
- D) Fourth

19) Which one of the following type of skin graft will cause the most skin contracture?
- A) Split, meshed
- B) Split, non-meshed
- C) Full thickness
- D) A skin graft will not contract if applied correctly

20) Which of the following is a fundamental concept concerning the reconstruction with skin coverag of burn wounds?
- A) Replacing tissue with like tissue increases the likelihood that breakdown in the future will not occur.
- B) The physician must eradicate infection prior to application of skin graft.
- C) Adequate blood supply must be present in order for a skin graft to incorporate.
- D) All of the above.

See answer sheet on page 207.

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ENROLLMENT FORM & ANSWER SHEET *(continued)*

EXAM #3/12
Burn Injuries of the Foot and Ankle
(Rabjohn and Roberts)

Circle:

1.	A	B	C	D	11.	A	B	C	D
2.	A	B	C	D	12.	A	B	C	D
3.	A	B	C	D	13.	A	B	C	D
4.	A	B	C	D	14.	A	B	C	D
5.	A	B	C	D	15.	A	B	C	D
6.	A	B	C	D	16.	A	B	C	D
7.	A	B	C	D	17.	A	B	C	D
8.	A	B	C	D	18.	A	B	C	D
9.	A	B	C	D	19.	A	B	C	D
10.	A	B	C	D	20.	A	B	C	D

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