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Thermal Burns

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Introduction

Thermal burns are a significant cause of worldwide morbidity and mortality. They can lead to debilitating, life long injuries and have serious psychological and economic impact. With proper treatment, successful functional and emotional recovery is possible. After reviewing this chapter, the reader should be familiar with basic approaches to burn care, underlying pathophysiology of thermal injuries, and the multidisciplinary effort required for successful post operative care.

Etiology

Thermal burns result from tissue exposure to an external heat source. Burns that occur at higher temperatures or for extended contact times result in deeper, more severe injuries. There are three main thermal burn mechanisms. Flash and flame burns occur due to direct or indirect exposure of a patient to a flame source. These flames result from a triad of ignition source, oxidizing agent, and a fuel source. Inhalation injuries may occur if patients are exposed to open flames in a closed setting. Scald burns result from exposure of the patient to high temperature liquids. Grease burns and those due to hot oils are often much deeper than the initial examination suggests. Finally, contact burns occur from direct contact with a high temperature object. Individuals with medical conditions such as epilepsy or habits like alcoholism that predispose them to periods of incapacitation are at higher risk of this mechanism of injury.

Epidemiology

According to the World Health Organization, thermal burns account for an estimated 6.6 million injuries and 300 thousand deaths each year worldwide. An estimated 95% of these deaths occur in low income countries due to lack of education and access to medical care as well as more common use of open fires for heating, lighting, and cooking. The 2014 World Fire Statistics showed fire related burn injuries have a significant economic impact with an estimated 0.02-0.22% of average Gross Domestic Product (GDP) attributed to direct losses and 0.002-0.95% to indirect losses. Approximately two thirds of fire related costs were attributed to males. Deaths per 100 thousand ranged from 0.02 (Singapore)-2.03 (Finland) with USA in the middle at 1.11. Flash and flame burns accounted for the majority of adult burn admissions while scald burns accounted for the majority of pediatric burns.

Pathophysiology

The skin is the largest organ in the body and is composed of the superficial epidermis, the underlying dermis (further divided into the upper papillary dermis and lower reticular dermis), and the hypodermis, composed of subcutaneous fat and connective tissue.

Thermal burn pathophysiology can be broken into local and systemic response. When excessive heat is transferred to the skin, it radiates outward from the point of initial contact and forms a local response with three zones in all directions. The zone of coagulation is the central contact point of maximal damage in which cell death, denaturation of proteins in the extracellular matrix, and damage to the circulation occur. Damaged circulation near the zone of coagulation results in a second surrounding zone of stasis. The peripheral third zone of hyperemia results from increased circulation as the body responds to injury. The zone of stasis can recover with a proper resuscitation and adequate wound care. On the contrary, prolonged periods of hypotension and inadequate wound care can convert the zone of stasis and even the zone of hyperemia into wider and deeper tissue damage.

The systemic response following a burn can be massive. In a large burn, two clinically significant processes occur. The release of systemic inflammatory mediators and cytokines result in increased capillary permeability and wide scale extravasation of fluid and proteins from the intravascular to the extravascular space. This can result in life threatening hypotension, pulmonary edema, and decreased circulation to end organs and the already stressed integument in a response similar to that of severe sepsis and septic shock. The second process is a due physical skin loss. The skin plays several important roles in homeostasis including temperature control, fluid regulation, and it serves as a physical barrier to infection as well as a point of contact to mediate interpretation of our environment. Large surface area loss of this vital organ interrupts these important processes.

With a flash and flame burn in an enclosed setting one can be exposed to high levels of carbon dioxide. Carbon dioxide, which has 40 times higher affinity for Hemoglobin than oxygen, causes intracellular and extracellular hypoxia by displacing oxygen from hemoglobin as well as interrupting oxidative respiration by binding to proteins in the cytochrome oxidase pathway. Inhalation of smoke can also result in facial and supraglottic burns, but true subglottic and lower respiratory tract burns are rare due to the protective mechanism of reflexive vocal chord closure. The products of combustion can travel deep into the respiratory tract and cause mucosal irritation, leading to bronchospasm and local or systemic inflammation and capillary leak. True inhalation injury causes a significant increase in mortality.

A burn wound is considered fully healed after final epithelialization. Open wounds epithelialize two ways, circumferentially inward from the intact epithelium at the periphery and from basal cells in underlying dermal appendages such as hair follicles and sebaceous/sweat glands. Therefore, the depth of a burn will largely dictate the healing process as deeper burns will no longer have dermal appendages and epithelialization will depend solely on circumferential growth from the wound periphery, a much slower process.

From superficial to deep, the first category of burn injuries are first degree or superficial burns. These are confined in the depth of the epidermis, and all dermal appendages and nerve endings are intact. Superficial burns generally heal in 3-5 days with minimal intervention and do not leave significant scarring. Second degree burns are broken up into superficial partial thickness burns, which involve the papillary dermis with intact dermal appendages and partially damaged nerves, and deep partial thickness burns, which involve the deeper reticular dermis and have significant damage to nerves and dermal appendages. Superficial partial burns are very painful but generally heal in 10-15 days with minimal scarring, although pigmentary changes can occur. Deep partial burns can only epithelialize from the periphery of the wound, and therefore heal at the much slower average of 3-5 weeks with significant scarring and scar contracture. Third degree or full thickness burns involve the entire epidermis and dermis and will form significant scarring and contractures with prolonged healing times without surgical intervention. Fourth degree burns involve skin, underlying subcutaneous fat, and even muscle or bone. These will require more extensive debridements, use of dermal autografts, and possibly amputations during treatment.

History and Physical

In addition to standard history of present illness, past medical history, social history, surgical history, family history, review of systems and current medication lists/allergies, there are several key points to the patient history specific to thermal burn care. Mechanism of injury will give insight into burn depth and concomitant trauma or inhalation injury. Certain patterns such as scald burns with discrete lines of demarcation and discrepancies between physical exam and history should raise suspicion for abuse, especially in the pediatric and elderly population. One should ask about the volume and type of resuscitation fluid the patient received in route for proper calculation of resuscitation fluid rates. The history should specifically focus on factors that will negatively affect wound healing (smoking, diabetes, chronic steroids) or increase risk of surgery (COPD, CAD, personal/family history of problems with anesthesia, blood clotting, or bleeding disorders) as these can change treatment strategies.

A full head to toe physical examination is vital to identify all burn injuries and signs of any concomitant trauma or inhalation injury (singed facial hairs, mucosal irritation, increased work of breathing, poor oxygenation on pulse oximetry). Identification of the depth and extent of the burn injuries will give significant insight into the required treatment. Superficial burns with have erythema and mild-moderate pain, but there will be no blistering. Superficial partial burns will have blisters and vesicles or sheared epidermis with wet, pink dermis that readily blanches with pressure. These burns will be very painful due to intact, irritated nerve endings. Deep partial burns will be less painful as many of the nerve endings are damaged and will have white, waxy, non-blanching dermis with no blisters or vesicles. Full thickness burns will be painless with leathery, dry skin, thrombosed blood vessels, and possibly black eschar. Total body surface area (TBSA) of second degree burns or deeper should be estimated using the Wallace rule of 9's for adults or a credible pediatric burn assessment chart such as the Lund Browder Assessment Scale to assist in burn resuscitation. Finally, any part of the body with circumferential partial to full thickness burns must be monitored for compartment syndrome as they may need escharotomies or even formal fasciotomies. Signs of compartment syndrome in an extremity include early pain out of proportion to exam, paresthesias, and poikilothermia and late paralysis and lack of pulse

Evaluation

On evaluation, imaging for any suspected trauma according to ATLS protocol as well as labs to assess end organ health, electrolyte status, and nutritional status including CBC, CMP, PT/INR, and prealbumin should be obtained. Urine drug screen in this patient population is important as well as pregnancy test for women of childbearing age. Elevated Carboxyhemoglobin levels can indicated carbon monoxide poisoning and give insight into possible inhalation injury and impending respiratory failure. However, be aware that the half life of carboxyhemoglobin has been shown to be 4 hours or shorter in a patient on 100% oxygen, and therefore low levels taken several hours after injury do not necessarily rule out inhalation injury.

Treatment / Management

Assessment and stabilization of the burn patient's airway, breathing, and circulation according to ATLS guidelines should be the first step to treating any burn patient, as they are first and foremost considered trauma patients. Appropriate supportive care including resuscitation with crystalloids, blood products, and possibly endotracheal intubation may be required. After initial stabilization, appropriate assessment for transfer to an accredited burn center must be considered, and indications for transfer include TBSA of partial thickness or deeper burns of 10% or greater, burns involving the face, hands/feet, genitalia/perineum, or major joints, chemical or electrical burns, large burns with concomitant trauma, inhalation injury, large burns in patients with special social or rehabilitation needs or significant medical problems that affect mortality, and if the evaluating hospital is without qualified personnel/equipment to care for pediatric burns.

Initial TBSA calculation will guide the need for resuscitation and resuscitation fluid rates. Burn resuscitation may be the most important and also one of the most controversial elements of burn care, with many differing opinions among experts. The 2012 American Burn Association Consensus acknowledges 20% TBSA as criteria for requiring formal resuscitation but also recognizes that pediatric burns may need different criteria, and many institutions have their own guidelines for this patient population. They also acknowledge that there is insufficient evidence that more expensive colloid resuscitation is advantageous than crystalloid resuscitation. The most popular burn resuscitation formulas are the Parkland formula (4 x %TBSA x weight in kg) and the newer Modified Brooke formula (2 x %TBSA x weight in kg). They both calculate a number with units in milliliters. The first half of this calculated volume is divided evenly over the first 8 hours and the second half is divided evenly over the second 16 hours. Both original formulas advocated use of colloid but more recently lactated ringers has been the resuscitation fluid of choice. After initial resuscitation rates are calculated, both formulas also advocate titration of rates to markers of physiologic response such as urine output of 0.5-1cc/kg/hr, and one should be aware that over-resuscitation can be as detrimental as under-resuscitation.

There is significant variation in burn wound care regimens, but all follow several basic principles. Adequate wound care serves to prevent infection, allows for slow mechanical removal of devitalized tissue, helps prevent fluid loss, and is cost effective. Common classic topical antibacterial regimens from least to most tissue penetrance includes silver nitrate, silver sulfadiazine, and mafenide acetate. The most commonly used is silver sulfadiazine as it has a good penetrance, good antibiotic spectrum against gram positives and negatives, and is less painful than mafenide acetate. Silver nitrate, with activity against Staph species and Pseudomonas, is generally used for superficial burns in patients with Sulfa allergies. Mafenide acetate, which is highly effective against gram negatives and has deep tissue penetrance, is generally reserved for very deep, heavily contaminated wounds, those with eschar, and for auricular burns due to its superior cartilage penetration.

For deep partial or full thickness burns, surgical excision of damaged tissue and split thickness skin grafting for wound closure is indicated. While it is possible for a deep partial or full thickness burn to heal without surgery, these wound generally take 3 weeks or longer to heal. This prolonged wound healing process predisposes the patient to wound infection, hypertrophic scarring, and formation of scar contractures. With excision and grafting by ten days following the burn injury, a patient can heal the wound within 7-10 days post op and decrease the risk of infection or scarring significantly. For larger % TBSA burns, early removal of the burn injury and closure of the wounds with skin graft or skin substitute allows for significant decrease in systemic inflammation and assists in temperature regulation and fluid management. Of note, deeper wounds may require surgical excision and placement of dermal substitute prior to a skin grafting procedure.

Pearls and Other Issues

A multi-disciplinary approach is necessary for successful thermal burn care. Patients can require several surgeries over their lifetime for improvement of scar contractures and aesthetic outcomes, and Plastic and General surgeons that take interest in burn care will often keep relationships with patients throughout their careers. Post operative physical and occupational therapy is often required to prevent contracture formation. Case managers must assist in socioeconomic needs and Psychiatrist or Psychologists who specialize in burn care can offer great comfort in this time of physical, emotional, and economic hardship. Success in burn care requires not just thorough knowledge of treatment guidelines but the dedication to bring all of these specialties together for a common goal.

Questions

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