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Introductory Chapter: An Introduction to Burn Injuries

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1. Introduction

Burn injury of the skin is characterized by the damage to skin tissue from hot (scald, flash, flame, contact), cold, electrical, chemical, radiation, sunlight, or other sources. Burns constitute one of the most common causes of morbidity and mortality worldwide. They can result in significant disfigurement, physical impairment, work loss, psychological problems, and considerable economic burden. Prevention of burn is considered the best strategy to reduce the overall burden of burns. The impact and the management of burn injury depend on the severity of burn. Although minor burns can be treated at outpatient clinics, the management of patients with severe burns requires multidisciplinary approach in specialized burn care centers. Burn trauma differs from the other causes of injuries in many aspects. Increased knowledge about the pathophysiology of burn provided better treatment plans and led to the improvement of overall outcome for these patients. Formation of scar is an undesired consequence of burn with many long-term complications. The local treatment of burn wound should address the major concerns of wound care including anti-inflammatory treatment, wound coverage, and prevention of infection and scar formation. Although superficial burns may be managed with topical treatment, deep burns require excision and grafting. As traditional treatments have many limitations, alternative options with better outcomes have been searched in the restoration of damaged tissues. Tissue-engineered products, stem cells, and gene therapy constitute new concepts that offer promise in the treatment of burn wounds. Although the results with these innovations are encouraging, they require sophisticated techniques, and evidence for their long-term efficacy in burn wounds is lacking. Future search will introduce novel therapeutic options and assist in the establishment of standard burn wound care in clinical settings [1–3].

2. Epidemiology of burn injuries and risk factors for burns

Burns constitute a major health problem worldwide. Considerable amount of patients suffer or die from burn injuries globally. The burns mostly occur in low- and middle-income regions of the world [1, 4, 5]. Burn injuries occur more commonly in men at young adult age [5–8]; however, in elderly, female predominance is seen [5, 6, 8]. Alcohol usage, smoking, presence of open fire source or ground level stoves, wearing high-risk cloths (long, loose-fitting, synthetic), improper temperature setting of water heaters, use of unsafe electrical equipment, use of kerosene lamps, low socioeconomic status, overpopulation, illiteracy, unemployment, belonging to a large and single-parent family, and housing without adequate health and safety requirements are all reported to be risk factors for burn injury [4, 7, 9, 10].

3. Severity of burn injuries

Fortunately, most of the burn injuries fall into mild cases that can be treated in community or in outpatient clinics. However, depending on the severity of the condition, hospitalization or treatment in intensive care unit may be needed [5, 6, 8]. Severity of a burn injury depends on the extent of burned area (expressed as the percentage of total body surface area (TBSA)), depth of tissue damage, presence or absence of inhalation injury, mechanism of injury, age of the patient, and accompanying comorbidities [8]. Median TBSA of all burn cases was reported as 15%, and severe burn injuries constitute less than 10% of total burns [5, 6, 8]. Mostly children, women, and elderly people are affected by severe burns. Low socioeconomic status and being from ethnic minorities are considered as risk factors for experiencing severe burns [5]. Inhalation injury is seen in less than 4% of cases and more likely to be observed in extensive burns [8].

4. Etiology of burn injuries

Burn injuries can result from diverse etiologies including flames, scalds, contact, electricity, chemicals, or even sunlight. The mechanism may differ according to the sex, age, residence, ethnicity, and admittance status (admitted or non-admitted) of the patient. In general, scald, flame, and contact are the major mechanisms for burns [5–7, 10]. Electrical and chemical burns occur less frequently. Other than the abovementioned mechanisms, many other causes including sunburn and flash lasers can also result in burn injury [5].

5. Mortality from burn injuries

Mortality rate from burn injuries differs among different studies and is reported between 1.4 and 18% [5, 6]. Older age, high extent of burned surface, concomitant illnesses, the presence of inhalation injury, African-American race, urban practice setting, and facial location

of burn are all considered as risk factors for mortality [5–8, 10]. Flame burns are in general more fatal than contact burns. Mortality from burn injury is most commonly related to multiorgan failure and sepsis. Pneumonia and acute respiratory distress syndrome (ARDS) are also associated with mortality [5, 8, 11].

6. Ethical issues

In all, but especially pediatric and elderly burns, legal and ethical issues should be considered. As abuse and maltreatment may go unnoticed, identification of suspicious injuries by the physician is important. Delayed referral, suspicious and unreliable history, inconsistent explanations of parents or caregivers, tap water injury, and the presence of immersion lines are some of the clues that should raise the suspicion of abuse [3, 12, 13].

7. Precautions for burn patients

As most of the burns occur accidentally, prevention strategies remain the best approach in order to reduce the morbidity and mortality associated with burns. Increasing knowledge about the epidemiology of burn injuries will aid in defining preventable risk factors that should be targeted. While safety interventions for work-related burns decrease the risk, certain cultural practices and social habits may be related with increased burn accidents in certain geographic regions. Although education and increased awareness of public play important roles in prevention strategies, the introduction of legislation and better regulations are more effective in reducing the burn injury. Additionally, enforcement of legislation is critical to increase the success of prevention programs [5, 9, 10].

8. Pathophysiology of burn wounds

Systemic nature of the burn injury is unique that should be taken into consideration while approaching the patient. Understanding the pathophysiology of burn will provide useful information for early and effective management of burn patients, improve the quality of care for burn wounds, allow the identification of novel targets for the treatment of scar formation, and contribute to efforts to reduce the mortality. The local burn wound induces a generalized inflammatory response characterized by the activation of cytokines and release of various growth factors that can result in detrimental effects on many organs. The magnitude of this response depends on the severity of burn [1, 3, 5, 14, 15]. One of the distinct features of burn injury is that the cytokine-mediated signaling triggered by the tissue damage results in a generalized increase in capillary permeability and extravasation of plasma causing exaggerated edema response even at distant sites [3, 15]. Loss of intravascular fluid is accompanied by a decrease in cardiac output and increase in peripheral vascular resistance that may lead to hypoperfusion of organs and burn shock [1, 3, 15]. Hypercoagulability may occur due

to systemic activation of platelet aggregation and fibrinolysis [1]. After the edema phase, a hypermetabolic state ensues which is characterized by an increase in oxygen consumption, marked protein and lipid catabolism, increase in energy requirements, high cardiac output, tachycardia, severe muscle weakness, cachexia, and decrease in immune functions [3, 15, 16].

Although the wound healing phases are similar to other types of wounds, the prolonged healing time is especially important in burn wounds [1–3]. The severity of burn, the mechanism of injury, and associated diseases of patients influence the wound healing [1]. Inflammatory phase includes the vasodilation and inflammatory cell migration through the cytokine signaling cascade. In proliferative phase, epithelization takes place by the migration of keratinocytes from the epithelium of the wound edges and dermal appendages. Remodeling (maturation) phase is characterized by the deposition of collagen by myofibroblasts, compaction of the connective tissue, and finally the contraction of the wound. Although the wound contraction and scar formation are normal and necessary for the closure of wound, excessive fibrosis and increased tensile stress during remodeling carry the risk of abnormal scar formation. Intense and prolonged inflammatory response with increased release of cytokines, growth factors, and other mediators from the inflammatory cells and platelets are associated with scar formation. The depth of burn, age of the patient, the treatment, and response of wound are important determinants for the development of scar tissue. Wounds that are not healed in 2–3 weeks are generally at risk of developing aberrant scar tissue [1–3].

Superficial burn wounds heal completely in 5–7 days during the proliferative phase. As the required dermal components are lost in deep burns, proliferation cannot be provided, and the epithelialization is delayed. The lack of supportive and vascular tissue is associated with abnormal contraction, and these wounds heal with hypertrophic scarring and contractures if left to heal spontaneously [1–3].

9. Management of the burn patient at first step

Early and appropriate treatment of burn injury is associated with better prognosis. Prehospital management and the treatment of burn patients in the emergency department fall out of the scope of this chapter and include the general rules for trauma patients. As the airway edema may start soon after burn and unexpectedly, early intubation may be indicated. Since massive edema may develop in extended burns, all jewelry and accessories should be taken off. Specific interventions may be indicated according to the mechanism of burn (electrical, chemical burns). Until the patient is referred to the medical center, wounds should just be covered with clean cloth. Cooling with compress may be done; however, unburned regions should be kept warm in order to avoid hypothermia [12, 15].

As the hypovolemic shock is associated with high morbidity and mortality, fluid resuscitation should be done early and adequately. Several criteria have been described for fluid resuscitation of burn patients [11, 17].

10. Evaluation of the severity of burn and referral of the patient

Assessing the severity of burn injury is important in deciding the need for hospitalization. To assess the severity of damage, special indexes have been described including “Burn Index (BI)” and “prognostic burn index (PBI)” [11].

To assess the extent of burned area, several methods can be used including rule of nines, rule of fives, and Lund-Browder Chart. Lund-Browder Chart is especially used for children which more accurately estimates the age-specific percentage of TBSA [11, 12, 15]. Additionally, for local assessments of small burns, the palm method (palm with fingers accounts for 1% of total body surface area) can be used practically in adults. First-degree burns are not considered in the calculation of TBSA [11, 12].

Although more precise methods including laser Doppler flowmetry and video microscopy have been defined, the depth of burn is mostly estimated clinically (the presence of pain or blister, appearance and color of the skin) in practice [11, 15]. Burns can be classified into three types according to the depth of injury:

- (a) **First degree (superficial):** Only the epidermis is involved. The skin is red and painful. There is usually no blistering and skin will blanch when touched. It heals without scarring.
- (b) **Second degree (partial thickness):** In superficial dermal burns (SDB), only the papillary dermis is involved. In this case the skin is painful. Blisters are seen. When the bullae are deroofed, the skin is wet and blanches when touched. It heals with minimal pigmentary changes without hypertrophic scarring. If the reticular dermis is involved, it is considered as deep dermal burn (DDB). In this case, there is less pain and no bullae or blistering. There is eschar and the skin is white or yellow. It does not blanch on pressure. It heals with scarring.
- (c) **Third degree (full thickness):** There is little or no pain. It involves the epidermis and dermis and extends to the subcutaneous layer. The skin is leathery, dark, and inelastic. There is eschar. It does not blanch. It does not heal spontaneously, results in hypertrophic scar and contractures, and requires grafting [3, 11, 12].

Fourth-degree burns involve deeper structures including the subcutaneous tissue, muscle, tendons, ligaments, and bone. There is gangrene of tissue and carbonized appearance [12].

After the prehospital stabilization of the patient, depending on the severity of injury, treatment in a more equipped hospital may be required [11, 12]. The referral criteria may vary across different studies. To explain roughly, while major burns must be managed in hospitals with multidisciplinary burn teams, moderate burns can be managed in minor hospitals. No matter the extent, chemical burns, burns due to lightning strike, burns during pregnancy, and burns with suspicion of child abuse must be hospitalized. On the other hand, minor burns can be treated at outpatient clinics [3, 11, 12].

Pain management is important in burn patients since the discomfort from pain results in anxiety, increases the risk of prolonged hospitalization, leads to loss of patient confidence, and

complicates the interventional procedures [12, 18]. Burn patients may suffer from different types of pain including background and procedural pain. In severe burns, moderate to potent opioids (fentanyl, morphine, ketamine, and others) are preferred, and non-steroidal anti-inflammatory drugs (NSAIDs) may be added to reduce the overall dose of opioids. NSAIDs may be sufficient to relieve pain in patients with mild to moderate burns. As they reduce the perception of pain, anxiolytics such as benzodiazepines may also be used. Although mild anesthetics are adequate for simple procedures, deeper anesthesia (with tramadol, ketamine, etc.) is required for the patients with severe burns during excision and grafting. Antidepressants and anticonvulsants are used as first-line therapies for neuropathic pain that may be seen in burn patients. Psychological therapies have also been reported with various successes for management of pain [12, 18].

11. Local treatment of burn wounds

Knowing the mechanisms involved in wound healing is very important for effective treatment of burn wounds. The treatment strategy for the burn wound varies according to the extent and depth of injury [1–3].

11.1. Burn wound care at first step and emergency department

Interventions that should be done at first step may differ according to the severity and mechanism of the burn. For minor burns, burned area should be put under running tap water for 20 min. Clothing that are soaked in hot liquid or contaminated with chemicals should be removed. For chemical burns, neutralizing agents should not be applied (neutralization reaction may cause further heat). Dry chemicals should be brushed away first and then irrigated with tap water. Before transfer to the designated facility, wounds should be wrapped with clean cloth but not covered with topical drugs. Topical silver sulfadiazine can be applied initially at the emergency department except for facial burns. Topical anesthetics are not recommended. Adherent dressings should not be used. Irrigation should be done with caution in order to avoid hypothermia due to cold water exposure [12]. As mentioned above, depending on the severity of burn, wound care in a multidisciplinary burn center may be required [11, 12, 15].

11.2. Topics to be covered in burn wound treatment

As previously mentioned, prolonged and exaggerated inflammatory response in deep burns results in intensified edema which further delays wound repair and is associated with scarring. Although the anti-inflammatory treatments such as prostaglandin inhibitors and glucocorticoids carry the risk of impaired wound healing, it seems reasonable to diminish excess inflammation and edema in burn injury [2, 19]. Indeed, treatment with topical or low dose systemic glucocorticoids in the early phase of burns has been suggested to prevent aberrant inflammation [11, 20]. For deep burns, early excision and grafting are crucial to remove the foci of inflammation and infection. Anti-inflammatory drugs including cytokine inhibitors, corticosteroids, interferons α and β , and methotrexate have also been used to prevent scar formation [1].

As the infection risk is increased in burn patients due to immunosuppression and the wounds can be rapidly contaminated by the organisms, prevention of infection should be the primary strategy in burn wound care [3, 11, 12]. Disinfectants can be used without inhibiting wound healing, and wounds should be cleaned with tap water, saline, and non-irritant soaps [11, 12]. Early covering of burn wound with topical antimicrobial agents may prevent the invasion or contamination of wound [3]. In deep burns, microorganisms may colonize the tissue below the eschar producing a source for infection. As the standard topical antimicrobials cannot penetrate the eschar tissue, early excision of the eschar is important in prevention of infection. Furthermore, early detection of infection is crucial especially in patients with deep and extensive burns [1–3]. Prophylactic antibiotics are not recommended for burn wounds unless there is high probability of infection. In case of wound contamination and in immunocompromised patients (pediatric, perioperative, and diabetic patients), prophylactic antibiotics can be considered [11, 12].

As the burn injury results in a profound hypermetabolic state, nutritional support is recommended in order to enhance wound healing [2, 3, 21]. Although the periodical clinical examination of the wound by the specialist stays the primary way of tracking wound healing, simple measurement tools, sophisticated techniques, and various serum parameters can be used to predict the likelihood of healing and for the follow-up of improvement in healing [2, 22, 23].

11.3. Burn wound coverage and grafting

11.3.1. For the first-degree burn wounds

For the first-degree wounds, topical antibiotics are not necessary. Moisturizing agents are sufficient, and topical anesthetics may be given depending on the patient's condition [12].

11.3.2. For superficial second-degree burn wounds

Although the burn wounds are sterile at the beginning of injury, the wound begins to be invaded by the organisms from the patient's flora or from the environment. Therefore, topical antimicrobials are recommended for superficial second-degree burn wounds. As silver sulfadiazine delays epithelialization, it can be used only for the first days to prevent infection. Wounds should be covered with non-adherent dressings including paraffin-impregnated gauze or ointments containing 0.2% nitrofurazone, zinc oxide, or dimethyl isopropylazulene. Several alternative topical agents have also been suggested to be effective [12]. Various types of dressing materials are available for the local care of burn wounds. Wound dressing selection should be tailored according to the amount of wound exudate, the presence of fibrin or necrotic tissue, and the depth of the wound. Hydrocolloids, hydrogels, chitin, polyurethane foams, alginates, and hydrofibers all have been recommended as treatment options for the local care of second-degree burn wounds [11]. Blisters that may be seen in superficial second-degree burns may serve as an excellent environment for the growth of microorganisms and increase the risk of infection. Small blisters may be left intact; however, large blisters should be removed, and the wound should be dressed [3, 12].

11.3.3. For deep second-degree, third-degree, and fourth-degree burns

The removal of the necrotic tissue, prevention of infection, and the maintenance of a moist environment are the primary goals to facilitate the wound healing in deep burns [11].

Eschar is the tough, leathery necrotic tissue seen in full-thickness burns. Circumferential eschar tissue may compromise circulation on extremities or restrict breathing over the chest. Escharotomy may be indicated in these patients. In the case of compartment syndrome, fasciotomy should be performed [3, 12]. Eschar tissue does not break down spontaneously, except in the case of infection [12]. Although the necrotic tissue of small deep burns may be treated by topical necrolytic agents, surgical debridement is needed in extensive burns [11]. As spontaneous healing is not expected and the scar formation is the final outcome of deep second-degree and third-degree burns, early excision of the eschar and grafting are the preferred treatments for these wounds. After the excision of eschar, temporary wound covering for the first days by topical antimicrobials (silver sulfadiazine) or wound dressings prevents infection and maintains moisture before surgery [1, 2, 11].

As the formation of scar can be prevented by the early and appropriate management of burn wound, excision should be done as soon as the patient is stabilized [3, 12]. Although the split-thickness autografts are the gold standard method in deep burns, they have many disadvantages. Allografts and xenografts may serve a good option for larger burns until the allografts are incorporated; however, they have also many limitations [1, 2]. Tissue engineering has provided a new era in the wound care field. Skin tissue regeneration by tissue-engineered products showed promising results in wound healing. Tissue scaffolds, healing-promoting factors (growth factors), stem cells, and gene therapy are the current solutions provided by bioengineering. Tissue scaffolds consist of epidermal, dermal, or composite substitutes which can provide a three-dimensional tissue for the optimal proliferation of cells and tissue regrowth. Several growth factors may be used as healing-promoting factors. Although the experimental studies with either embryonic or adult stem cells demonstrate the potential use of stem cells in the treatment of chronic wounds, further research is required to investigate their long-term effects on wound healing process. Gene therapy is a promising approach for the future treatment of burn wounds. It involves the transfer of genes into cells that encode growth factors required for enhancing wound repair. However, its use in burn wounds is limited by technical challenges. In conclusion, further trials are required to explore the long-term effects and safety of tissue engineering methods in burn wound treatment [1, 2, 24].

Fourth-degree burns are associated with significant functional impairments which require complicated and repeated surgeries. They often lead to amputations. Whereas local flaps may be used for the reconstruction of mild to moderate cases, burns with extensive damage need tissue transfers [1].

The common goal of all therapeutic tools abovementioned is to optimize wound healing, prevent scar formation, and minimize the functional disability. There are more other treatments that have been used for these purposes with varying success. Hyperbaric oxygen therapy has been suggested as a safe and effective treatment for burn wounds and can be used in conjunction with other modalities for burn patients [2, 25]. Silicone gels have been suggested to be useful in burns which carry high risk of hypertrophic scarring. They are recommended to be used before

the maturation of scar [26]. Experimental studies showed promising results in the wound healing with platelet-rich plasma (PRP) treatment; however, its routine use in burn wounds and scars requires further evaluation [27]. Various types of lasers including pulse dye laser (PDL) and fractional ablative laser may offer better results when used in combination with surgery [28]. Pressure garments and massage therapy are also used to minimize scar contraction. Burn rehabilitation, splintage, and physiotherapy are very important to prevent contractures and to improve functional outcome. Additionally, as burn survivors may experience significant psychosocial problems, proper specialists should be consulted as soon as possible [3].

12. Malignancy on burn scars

Marjolin's ulcer is a rare cutaneous malignancy which may develop in burn scar. It occurs approximately two to three decades after the burn and is commonly seen on lower extremities as verrucous lesions. The squamous cell carcinoma is the most common form. The prevention of scar carcinoma by the early and effective treatment of scar formation is of primary importance to reduce the associated morbidity and mortality. Additionally, regular follow-up of patients with burn scars and early detection and evaluation of the non-healing ulcers are important considerations [29, 30].

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