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Contemporary Approaches to Wound Burn Healing

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ABSTRACT

The World Health Organization (WHO) reports that over 11 million individuals get burns annually, resulting in 180,000 fatalities. A burn is a condition resulting by heat, chemical agents, electrical currents, or other forces that inflict tissue damage. Burns primarily impact the skin, however they may also include deeper structures, including bones and muscles. Upon combustion, the skin forfeits its primary functions, including protection against the external environment, infections, moisture evaporation, and thermal regulation. Based on the burn's stage, the patient's health, and the burn's etiology, it is essential to choose the most suitable therapy. Personalization and interdisciplinary teamwork are essential for the effective therapy of burn victims. This thorough study compiles and examines the existing treatment modalities, emphasizing current advancements in topical therapies, wound debridement, dressings, skin grafting, nutritional support, pain management, and scar tissue therapy.

KEYWORDS: thermal injuries; burn treatment; regenerative therapies; dermal grafts; tissue engineering; wound dressing

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INTRODUCTION

Burns represent some of the most severe and agonizing injuries, often impacting infants, those with disabilities, and the elderly, whose population is rising in aging countries. Burns rank as the fourth most prevalent kind of injury, behind road traffic accidents, falls, and physical violence. Due to climate change and elevated temperatures, the incidence of sunburns, linked to several skin malignancies including melanoma, is also growing.

In recent decades, several burn treatment facilities have been developed, offering specialized care and contributing to a reduction in death rates. Despite considerable advancements, burn treatment is regarded as onerous owing to many complications and an extended hospital stay. Furthermore, the rising incidence of patients with severe burns introduces additional challenges, including post-traumatic care, scar management, and the treatment of psychological disorders, since patients often exhibit post-traumatic stress disorder (PTSD).

Burns affecting over 30% of the total body surface area (TBSA) result in burn shock. The ramifications of burns are profoundly severe, given that the skin is the biggest organ in the human body, constituting around 8% of total body weight. The human skin has an area of 1.2 to 2.2 m^2 and has a thickness ranging from 0.5 to 4.0 mm. The structure has many layers: the outer epidermis, the dermis (including papillary and reticular layers), and the subcutaneous tissue, each fulfilling distinct physiological roles.

A burn is a condition characterized by the disruption of the skin barrier due to external thermal, chemical, or electrical agents. When the integrity of the skin is damaged, its functions are impaired, increasing susceptibility to dehydration, infection, metabolic problems, or even mortality. Histologically, the injured region is categorized into three zones, as delineated by Jackson in 1947. The skin has significant regenerating ability; however, when wounded beyond the reticular dermis, its capacity for regeneration diminishes. The wound healing process comprises three distinct phases: inflammation, characterized by coagulation, cytokine release, chemotaxis, and cell recruitment; proliferation, involving dermal resurfacing with angiogenesis and fibroplasia; and maturation, which entails the extracellular matrix. The closure of the incision leads to the development of scar tissue. In this concluding phase of recovery, there exists a potential for hypertrophic scarring, resulting in contractions.

The duration of healing for burn wounds is contingent upon their severity, categorized as superficial, shallow partial, deep partial, or full thickness. Superficial burns affecting the epidermis, though painful (second-degree), heal within weeks

without scarring. In contrast, deep wounds require extended healing time due to the destruction of the extracellular matrix (ECM), degradation of growth factors (GFs), prolonged inflammatory phase, elevated pro-inflammatory cytokines, proteases, reactive oxygen species (ROS), and potential infection. Burns may be categorized into four primary phases according to the depth of penetration, influenced by exposure temperature, duration of contact, source of exposure, and skin thickness.

Wound Repair

As of yet, no burn dressing is commonly used that ensures full healing without necessitating frequent dressing changes, further surgery, or skin grafts. The treatment approach comprises many steps, beginning with conservative therapies for burn shock and wound protection, succeeded by surgical interventions comprising tissue removal and closure using skin grafts. This method induces stress in patients and does not ensure successful recovery or survival. Researchers are diligently pursuing the optimal standard in burn treatment to enhance and expedite the healing process while reducing the likelihood of infection. Expeditious wound decontamination is crucial for efficacious therapy. This may be accomplished using surgical procedures to excise necrotic tissue from the wound or through conservative ways utilizing specific dressings such as hydrogels, hydrocolloids, or enzymatic debridement techniques. Furthermore, when serious burns surpass 30% of the body surface area, suitable graft sources must be identified. The optimal method for burn covering is autologous split-thickness skin grafts (STSGs) harvested from an unharmed donor site, which may be augmented by meshing or the Meek technique for comprehensive wound coverage. Numerous skin harvesting sites for autografting are unpleasant and need wound healing and supplementary therapy. Nevertheless, when intact skin is insufficient, allografts and xenografts provide just provisional wound covering due to the potential for transplant rejection. Current endeavors prioritize the creation of specialized artificial skin substitutes utilizing biological, synthetic, and biosynthetic materials to facilitate the primary and permanent closure of burn wounds, minimize scarring, and decrease treatment duration and expenses, despite the numerous benefits of diverse skin grafts.

Figure 1. Dermofasciotomies in Mixed Burns Second Degree Deep and Third Degree for Prevention of Compreneurtal Syndrome

Figure 2. Placement of cadaveric skin for third-degree burn in the posterior ocxipital area of the head

Figure 3. Third-degree burn and deep second-degree partial thickness graft and graft with meshing technique

Figure 4. Mesh graft in neck third degree burn

Escharotomy

When circumferential eschar encircles anatomical structures, especially the fingers, extremities, belly, chest, or neck, the underlying tissues experience elevated pressure. This pressure is intensified by the onset of edema during the first 4 to 6 hours post-injury. As interstitial pressure increases, it first obstructs venous blood outflow and then hinders arterial blood influx. The outcome is malfunction, ischemia, or necrosis in or distal to the impacted anatomical structures, often occurring with quick start. In the extremities, it may cause the degeneration of nerves and muscles, resulting in chronic functional impairment or necessitating surgical procedures such as amputation. In the abdominal area, compromised blood flow to the intestines, kidneys, and other internal organs leads to the fast development of liver and kidney failure, bowel ischemia, and diminished diaphragmatic movement. Abdominal compartment syndrome (ACS), resulting from intra-abdominal hypertension (IAH), may also arise as a consequence of burn injuries. ACS may be managed with fluid resuscitation combined with continuous venovenous dialysis and ultrafiltration, or through urgent surgical decompression via laparotomy. Escharotomy is a surgical intervention designed to alleviate constriction from eschar, therefore reinstating sufficient perfusion and normal function to the impacted tissues and organs. In many instances, a single incision fails to provide enough alleviation from the constricting eschar. Consequently, it is customary to perform bilateral escharotomy incisions on the trunk or medially and laterally on each afflicted limb.

The World Health Organization (WHO) advises performing escharotomy during the first 48 hours as part of the initial care of burn wounds. The majority of specialists assert that early surgical intervention, preferably within 6 hours after symptom onset, is advantageous, whereas postponing the treatment results in significant sepsis complications. Only a limited number of papers advise against early surgical intervention due to potential iatrogenic consequences.

Debridement

The debridement procedure starts with the cleansing of the adjacent skin using soap, disinfectant, or povidone iodine, and shaving the hair if required. The wound is then irrigated and sanitized with 0.1% benzalkonium chloride or 0.05% chlorhexidine. Meticulous debridement treatments are used to reduce inflammation. Thoroughly eliminate detached non-viable epithelium from burst blisters and debris. In superficial partial-thickness burns, big blisters may be drained, but tiny blisters should remain intact. In cases of severe cutaneous burns, particularly those resulting from hot liquids, the loosely adhering epithelium must be excised.

Routine debridement has been shown to accelerate healing by diminishing the activity of proteases that destroy growth factors. Wound cleaning during the first 24 hours (or 48 hours) may decrease the risk of invasive burn infection, especially in pediatric patients. Surgical debridement entails the excision of healthy tissue and the alteration of the wound's shape, hence enlarging the wound surface area. Furthermore, it need specialized treatment and intravenous analgesia. Presently, other techniques for the removal of necrotic epidermis are advised, including hydrosurgery, larval therapy, laser treatment, and specialized cauterization systems. A notable technique for non-surgical burn debridement involves the use of minimally invasive enzymatic debridement using proteolytic enzymes.

4.3 Localized Therapy

Research indicates that the predominant source of contamination in first burn wounds is the natural skin flora, namely staphylococci, streptococci, and methicillin-resistant Staphylococcus aureus (MRSA). Pseudomonas aeruginosa and Escherichia coli have been identified in chronic wounds, often inside the deeper dermal layers. Research indicates that chronic wounds may be concurrently colonized by many pathogens, resulting in the formation of bacterial biofilms. Bacterial biofilms, encased in a protective extracellular polymer, perpetuate chronic inflammation, impede epithelial regeneration, and shield bacteria from antibiotic treatment and the host's immunological response.

Topical antimicrobials are available as creams, ointments, and lotions. Burn centers often possess specific preferences for dressings. Silver sulfadiazine (SSD) is the most often used topical antibacterial drug, demonstrating efficacy against Staphylococcus and Streptococcus, and has been extensively employed in the care of burn wounds since 1968.

Polyhexanide is used in several burn centers. A 2017 research validated the efficacy of polyhexanide-betaine gel over silver sulfadiazine in treating partial-thickness burn wounds, demonstrating superior outcomes in healing time, infection rates, bacterial colonization rates, and pain scores ($p < 0.001$). Besides its antibacterial properties, polyhexanide has other advantages, such as alleviating wound pain, minimizing

wound odor, enhancing granulation tissue production, and stimulating keratinocyte and fibroblast activity.

Topical therapies include povidone-iodine, mafenide acetate/silver nitrate/sodium hypochlorite, which have broad-spectrum efficacy against both Gram-negative and Gram-positive bacteria, and nystatin, which has antifungal properties. Bacitracin, neomycin, mupirocin, and polymyxin B ointments are often used for the treatment of superficial wounds.

Aloe vera gel (Asphodelaceae) have a long-standing history of therapeutic use originating from ancient civilizations. A multitude of research has been undertaken over the years to examine its pharmacological characteristics, including antibacterial, antiviral, anticancer, antioxidant, and anti-inflammatory actions.

Research has demonstrated the benefits of Albizia julibrissin, Arnebia euchroma, Betula pendula, Betula pubescens, Centella asiatica, Hippophaë rhamnoides, and Juglans regia compared to silver sulfadiazine cream, including accelerated healing, reduced pain and burning sensations, and an increased rate of wound epithelialization, among other advantages.

CONCLUSIONS

Recent technological advancements have enhanced burn care efficacy, leading to a decrease in burn-related fatalities. Significant advancements have occurred in biomaterials and tissue engineering; yet, an optimal biomaterial that replicates the skin's structure and restores its function, color, appendages, arteries, and nerves remains undeveloped. Randomized studies in extensive populations are necessary to assess the efficacy of experimental treatments using novel dressings and skin replacements. Acellular and cellular tissue-engineered skin constructions seem to be promising. Current research trends involve the development of a skin substitute through the accelerated cultivation of stem cells on specialized polymeric substrates, intended to cover wounds and serve as bioactive dressings that enhance wound functionality and expedite the healing process.

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