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Review Article

Surgical management of burn injuries: current concepts and advancements in reconstructive strategies

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ABSTRACT

Severe burn injuries pose complex clinical challenges requiring multidisciplinary management. Surgical intervention remains a cornerstone in the treatment of deep partial-thickness and full-thickness burns, aiming to achieve early wound closure, minimize infection risk, and restore function and aesthetics. This manuscript reviews the principles, timing, and techniques of surgical management of burn injuries, including early excision and grafting, reconstructive options, and recent advancements in surgical care aimed at improving patient outcomes. A comprehensive literature review was conducted using PubMed, Embase, and Scopus, analyzing clinical trials, meta-analyses, and consensus guidelines related to burn surgery. Key aspects such as timing of surgery, excision methods, grafting techniques, and reconstructive innovations were explored. Early excision and grafting within the first 72 hours post-injury significantly reduce mortality, infection rates, and hospital length of stay. Autologous split-thickness skin grafts remain the gold standard, but alternatives such as dermal substitutes, allografts, and bioengineered skin have shown promising results in large surface area burns. Recent developments in spray-on skin cells and meshed grafts have further improved functional and aesthetic outcomes. The surgical approach to burn management has evolved significantly, emphasizing early excision, optimized grafting strategies, and advanced reconstructive techniques. A patient-centered, staged surgical plan tailored to burn severity and anatomical location ensures optimal recovery and rehabilitation.

Keywords: Burn surgery, Early excision, Skin grafting, Burn reconstruction, Dermal substitutes, Functional recovery

INTRODUCTION

Burn injuries constitute a major public health concern worldwide, with significant morbidity, mortality, and long-term disability. According to the World Health Organization, an estimated 180,000 deaths annually result from burns, predominantly in low-and middle-income countries.

Survivors often face devastating physical and psychological sequelae, including disfigurement, functional impairment, and chronic pain.[1-5] Surgical intervention is a critical component of burn management, particularly for deep partial-thickness and full-thickness burns. Timely surgical treatment reduces the systemic inflammatory response, prevents infectious complications, and accelerates wound closure.

The ultimate goal is not only survival but also restoration of function and appearance, minimizing contractures and enhancing quality of life.[1,3]

This manuscript discusses the modern surgical approach to burn management, including the principles of early excision, grafting options, reconstructive strategies, and the latest advancements in surgical care.

SURGICAL MANAGEMENT FRAMEWORK

Principles of surgical management

Early excision and wound closure

Early excision, ideally within 24–72 hours post-injury, is now considered the standard of care for extensive burns. Early removal of necrotic tissue limits the inflammatory cascade, reduces bacterial colonization, and improves patient outcomes.[6-8]

Functional and aesthetic restoration

Surgical management aims to preserve function, particularly in joints and facial areas, while minimizing scarring and aesthetic deformities.[9-11]

Reduction of hospital stay and morbidity

Timely surgical interventions correlate with decreased hospital stays and improved survival, particularly in patients with burns covering more than 20% of total body surface area (TBSA).[6,10]

Timing of surgical intervention

Early excision (within 24–72 hours)

Associated with reduced systemic inflammatory response syndrome (SIRS), lower infection rates, and improved graft take.[9,11]

Delayed excision (>72 hours)

Reserved for patients with hemodynamic instability or significant comorbidities preventing early intervention.[9,11]

Figure 1: Superficial second-degree burn, epifast placement.

Figure 2: Pediatric patient after allograft removal (epifast).

Figure 3: Harvesting and application of split-thickness skin graft on upper extremity (forearm).

Figure 4: Graft integration in a geriatric patient, direct fire burn.

Figure 5: The intact fish-skin graft in the shape of the hand to easily allow application on its complex 3D structure.

Excision techniques

Tangential excision

Layer-by-layer removal of necrotic tissue until viable bleeding tissue is reached. Preserves as much dermis as possible, enhancing graft adherence and functional outcomes.[9,11]

Fascial excision

Involves removal of all tissues down to the fascia. Used in extensive full-thickness burns or where rapid closure is necessary. While effective, it results in more significant contour deformities.[8,10]

Hydrosurgical Debridement (e.g., Versajet®)

A precise technique using pressurized saline to remove necrotic tissue while preserving viable tissue, minimizing blood loss and improving wound bed preparation.[12-15]

GRAFTING TECHNIQUES

Autologous skin grafts

Split-thickness skin grafts

The gold standard for burn coverage, harvested typically from the thigh, back, or scalp. Meshed grafts can cover larger areas but may result in more visible scarring.[16-18]

Full-thickness skin grafts

Used for areas requiring superior aesthetic outcomes, such as the face and hands.[16-18]

Skin substitutes and dermal regeneration templates

Integra® dermal regeneration template

A bilayer matrix facilitating neodermis formation before thin autografting.[16]

Biobrane® and Alloderm®

Used in selected cases to improve wound healing and reduce scar formation.[16]

Kerecis®, a notable biologic skin substitute made from fish skin, increasingly used in burn surgery for its regenerative properties and low immunogenicity.[19]

Table 1: Summary of key aspects.

Aspect	Details
Timing of surgery	Early Excision: Within 24–72 hours (Preferred)- Delayed Excision: After stabilization in unstable patients
Excision techniques	Tangential Excision: Layered removal to viable tissue- Fascial Excision: Deep excision to fascia for full-thickness burns- Hydrosurgical Debridement: Precise debridement using pressurized saline
Grafting techniques	Autologous Grafts: Split-Thickness Skin Grafts (STSG): Standard Full-Thickness Skin Grafts (FTSG): For aesthetic areas- Skin Substitutes: Integra®, Biobrane®, Alloderm®, Kerecis®- Advanced Therapies: ReCell® Spray-On Cells, Cultured Epithelial Autografts (CEA)
Reconstructive options	Local Flaps (Z-Plasty), Regional and Free Flaps for complex defects- Skin Expansion Techniques
Complications	Graft Loss- Infection- Hypertrophic Scarring- Joint Contractures- Donor Site Morbidity
Emerging technologies	Stem Cell-Based Therapies- 3D Bioprinted Skin- Advanced Laser Scar Treatments

Bioengineered skin and cell-spray technologies

ReCell® (spray-on skin cells)

Allows autologous epidermal cell application over large areas with minimal donor site morbidity.[16]

Cultured epithelial autografts

Used in extensive burns when donor sites are limited, though with variable take rates.[17]

Reconstructive strategies for contractures and late complications

Local and regional flaps

Utilized to address scar contractures, particularly in functionally important areas such as the neck, axilla, and hands.[6-8]

Free flap transfers

Indicated for complex defects and exposure of critical structures where local tissues are inadequate.

Z-Plasty and skin expansion techniques

Applied to improve scar pliability, break contractures, and achieve better cosmetic outcomes.[6-8]

Laser therapy for hypertrophic scars

Fractional CO_2 and pulsed dye lasers have shown efficacy in improving scar appearance and pliability.[6-8]

OUTCOMES AND COMPLICATIONS

Positive outcomes

Reduced mortality and infection rates with early excision and grafting. Improved functional recovery, particularly with early mobilization post-surgery. Enhanced aesthetic outcomes with modern skin substitutes and bioengineered solutions.

Common complications

Partial or total graft loss due to infection, poor wound bed preparation, or inadequate perfusion. Hypertrophic scarring and keloid formation. Joint contractures leading to long-term functional deficits. Chronic pain and sensory disturbances at graft and donor sites

CONCLUSION

The surgical management of burns has advanced considerably, emphasizing early, aggressive intervention to improve survival and functional outcomes. Techniques such as tangential excision and split-thickness grafting remain the foundation of burn surgery, while innovative approaches like dermal substitutes, bioengineered skin, and spray-on cell technologies continue to expand the reconstructive options available to surgeons.

Future directions include further development of stem cell therapies, 3D bioprinting of skin constructs, and improved methods for minimizing hypertrophic scarring. A comprehensive, individualized surgical plan, combined with early rehabilitation and psychosocial support, remains essential for optimizing long-term recovery and quality of life for burn survivors.

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