

Review Article

State of the art in burn care: principles and advances in surgical management

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ABSTRACT

Burn injuries remain a major global health challenge, associated with high morbidity, mortality, and long-term disability, particularly in low- and middle-income countries. Over the past decades, burn care has evolved into a multidisciplinary field that integrates early resuscitation, surgical intervention, intensive care, rehabilitation, and long-term reconstruction. Accurate assessment of burn depth and total body surface area, prompt fluid resuscitation, infection prevention, and timely surgical decision-making are fundamental to improving outcomes. Early excision and wound closure, most commonly achieved through split-thickness skin grafting, remain the cornerstone of surgical management for deep burns, while alternative strategies such as dermal substitutes, temporary biological dressings, and bioengineered skin have expanded options for patients with extensive injuries or limited donor sites. Long-term care focuses on the prevention and treatment of scarring and contractures through staged reconstruction and structured rehabilitation. This state-of-the-art review summarizes current principles and advances in burn surgical management, emphasizing individualized, multidisciplinary, and resource-sensitive approaches.

Keywords: Burns, Burns/Surgery, Skin grafting, Wound healing, Tissue engineering

INTRODUCTION

Burn injuries remain a major global public health problem, accounting for substantial morbidity, mortality, and long-term disability worldwide. They represent one of the leading causes of trauma-related death and disability, particularly among vulnerable populations such as children, the elderly, and individuals living in socioeconomically disadvantaged settings. In addition to the immediate life-threatening consequences, burns frequently result in prolonged hospitalization, multiple surgical procedures, psychological distress, social reintegration challenges, and significant economic burden for patients, families, and healthcare systems.^{1,2} Despite advances in prevention strategies, critical care, and surgical management, burns continue to disproportionately affect low- and middle-income

countries, where infrastructure limitations, delayed referral systems, scarcity of specialized burn units, and reduced access to reconstructive surgery contribute to higher complication rates and poorer functional outcomes.

In many of these regions, preventable factors such as unsafe cooking practices, occupational hazards, and limited public health education further exacerbate incidence and severity. Moreover, disparities in access to early fluid resuscitation, operative management, antimicrobial stewardship, and rehabilitation services widen the outcome gap between high-resource and resource-constrained environments.^{1,2} Over the past decades, contemporary burn care has evolved from isolated surgical management to a comprehensive, multidisciplinary model.

Optimal treatment now integrates early and protocol-driven fluid resuscitation, accurate assessment of burn depth and total body surface area involvement, timely surgical intervention—including early excision and coverage—advanced wound care technologies, intensive care support, infection surveillance, metabolic and nutritional optimization, and structured rehabilitation programs. Long-term management extends beyond wound closure and focuses on scar modulation, prevention of contractures, staged reconstructive procedures, and psychosocial support aimed at restoring function and quality of life.^{1,2}

This review summarizes the current state of the art in burn care, emphasizing evidence-based surgical principles, perioperative decision-making, and recent advances in wound coverage techniques, dermal substitutes, and reconstructive strategies. Special attention is given to individualized, context-sensitive approaches that consider resource availability, patient-specific factors, and long-term functional outcomes, reflecting the modern paradigm of comprehensive burn management.^{1,2}

EPIDEMIOLOGY AND PATHOPHYSIOLOGY OF BURN INJURY

The global burden of burns remains high, with considerable mortality and long-term disability among survivors, particularly in regions where healthcare resources are constrained. Burn injuries rank among the most devastating forms of trauma due to their capacity to affect multiple organ systems simultaneously while also producing profound functional and psychosocial sequelae.

Epidemiological data consistently demonstrate higher incidence rates in low- and middle-income countries, where domestic accidents, occupational exposures, unsafe cooking practices, and limited prevention programs increase vulnerability. Furthermore, children and elderly individuals represent especially high-risk groups, both in terms of incidence and severity. Reviews have emphasized that delayed presentation, limited infrastructure, lack of organized prehospital systems, and restricted access to specialized burn centers significantly contribute to worse outcomes, including higher infection rates, prolonged hospitalization, and increased mortality.¹⁻³

Beyond survival, the long-term impact of burn injury is substantial. Survivors frequently face chronic pain, hypertrophic scarring, contractures, and functional limitations that impair quality of life and socioeconomic reintegration. In resource-limited settings, barriers to rehabilitation and reconstructive surgery further exacerbate disability, reinforcing the importance of prevention strategies and early access to definitive care.¹⁻³ Pathophysiologically, burn injury produces a complex local and systemic response that evolves dynamically

over time. At the local level, thermal insult leads to coagulative necrosis and the classical description of burn wound zones: the central zone of coagulation, surrounded by a zone of stasis, and an outer zone of hyperemia.

Microvascular thrombosis, endothelial dysfunction, and inflammatory mediator release within the zone of stasis may result in progressive tissue ischemia and burn wound conversion if resuscitation and wound management are inadequate. This phenomenon underscores the importance of early fluid resuscitation, infection control, and timely surgical intervention to limit secondary tissue loss.^{4,5} Systemically, severe burns involving significant total body surface area trigger a profound hypermetabolic and hyperinflammatory state.

The release of cytokines, catecholamines, and stress hormones promotes increased energy expenditure, protein catabolism, insulin resistance, and muscle wasting. Concurrent immune dysregulation compromises host defense mechanisms, increasing susceptibility to sepsis and multiple organ dysfunction.

Cardiovascular instability, capillary leak syndrome, and fluid shifts further complicate the acute phase, necessitating structured resuscitation protocols and close intensive care monitoring. These pathophysiological changes provide a clear rationale for early definitive wound closure, aggressive nutritional support, metabolic modulation, and comprehensive critical care strategies aimed at reducing morbidity and improving long-term outcomes.^{4,5}



Figure 1: Deep second-degree scald burn with high-density liquid covering 7% of the total body surface area (TBSA) on the right upper extremity (author's own figure).

PRINCIPLES OF INITIAL BURN MANAGEMENT

Accurate assessment of burn depth and total body surface area (TBSA) underpins clinical decision-making. Contemporary reviews emphasize structured initial evaluation and early management priorities including airway protection (when indicated), fluid resuscitation, pain control, nutritional support, and prevention of hypothermia.³⁻⁶

Infection prevention begins early with wound cleansing, topical antimicrobials/dressings when appropriate, and removal of devitalized tissue. Modern approaches emphasize individualized care delivered by multidisciplinary teams combining surgery, anesthesia/critical care, nursing, nutrition, rehabilitation, and (when needed) infectious diseases.^{6,7}



Figure 2: Diagnosis: deep second-degree and third-degree burns from direct fire and ignition covering 14% of TBSA in the right hemithorax, abdomen, genital region, and proximal third of the right thigh. (author's own figure).

SURGICAL MANAGEMENT OF ACUTE BURN WOUNDS

Early excision and wound closure

Early excision and wound closure—often within the first 24-72 hours in selected patients—has become a foundational concept in many high-resource burn systems. Multiple reviews report associations with reduced infectious complications and shorter hospital length of stay, and describe early excision as a key component of contemporary operative burn care.⁸⁻¹¹ However, the effect on mortality is nuanced and may be

confounded by factors such as age, TBSA, comorbidities, and inhalation injury; recent reviews highlight the need for individualized timing and patient selection rather than a rigid universal threshold.¹⁰⁻¹²



Figure 3: Procedure: surgical cleansing + debridement + harvesting and application of partial-thickness meshed skin graft (author's own figure).

Excision techniques and autografting

Tangential excision remains a standard operative technique for deep partial-thickness and full-thickness burns, aiming to remove nonviable tissue while preserving as much viable dermis as possible.⁹⁻¹³ Split-thickness skin grafting (STSG) continues to be the mainstay for definitive closure when spontaneous re-epithelialization is unlikely, and is consistently described as the “workhorse” of burn wound closure across reviews and updates.^{8,9,14}

Alternatives and adjuncts to autografting

In extensive burns or when donor sites are limited, temporary coverage and adjunctive technologies become critical. Reviews describe the use of allografts and xenografts as temporary biological dressings to protect the wound bed and bridge to definitive closure.^{15,16} Dermal substitutes and bioengineered matrices are commonly discussed as tools to improve pliability and scar quality, particularly in deeper injuries.¹⁵⁻¹⁷ Emerging strategies—cultured epithelium, spray-on cell approaches, and other regenerative technologies—are presented as evolving options with practical limitations related to availability, cost, and variability in outcomes depending on setting and indication.⁴⁻¹⁸

RECONSTRUCTION AND MANAGEMENT OF BURN SEQUELAE

Long-term outcomes in burn survivors are heavily influenced by scar formation and contracture development. Comprehensive reviews of scar management describe a spectrum of operative techniques

(contracture release, Z-plasty, grafting, local/regional flaps, and free flaps in selected cases) integrated with rehabilitation strategies to restore function and aesthetics.¹⁷ Special anatomical regions such as the eyelids require tailored surgical strategies due to high functional demand and risk of exposure-related complications; recent systematic reviews emphasize technique selection and outcomes in pediatric eyelid burns.¹⁷ Free flap reconstruction has also been reviewed as an option for complex defects, particularly when local options are exhausted or when durable vascularized tissue is required.¹⁸

MULTIDISCIPLINARY AND LONG-TERM CARE

Burn outcomes are optimized through coordinated multidisciplinary care across the acute and reconstructive continuum. Critical care reviews highlight the importance

of integrated resuscitation, organ support, infection surveillance, nutrition, and pain management—particularly in severely ill burn patients.^{6,7} Long-term scar modulation and functional recovery require structured rehabilitation and, when indicated, procedural adjuncts discussed in contemporary scar reviews.¹⁷

FUTURE DIRECTIONS

Contemporary “state-of-the-art” reviews consistently frame operative burn care within an evolving landscape of biomaterials, engineered skin, and regenerative approaches, while underscoring that these innovations complement—rather than replace—core surgical principles (timely excision, reliable coverage, and staged reconstruction) and must be adapted to resource context.⁴⁻¹⁸

Table 1: General overview.

Domain	Key concepts	Clinical relevance
Epidemiology	High global incidence and burden of disease; disproportionate impact in low- and middle-income countries	Explains persistent morbidity, mortality, and long-term disability among burn survivors
Pathophysiology	Local tissue necrosis, inflammation, microvascular injury, systemic hypermetabolic and immunosuppressed state	Justifies early intervention and timely definitive wound closure
Initial burn assessment	Accurate evaluation of burn depth and total body surface area (TBSA)	Guides resuscitation, surgical timing, and reconstructive planning
Early multidisciplinary care	Fluid resuscitation, airway protection, nutritional support, pain control, infection prevention	Reduces early complications and supports survival in severe burns
Early excision and closure	Surgical excision within 24-72 hours in selected patients	Associated with reduced infection rates and shorter hospital stay
Excision techniques	Tangential excision preserving viable dermis	Optimizes graft take and functional outcomes
Definitive wound coverage	Split-thickness skin grafting (STSG) as the gold standard	Reliable, widely available, and effective for deep burns
Adjunctive wound coverage	Allografts, xenografts, dermal substitutes	Temporary protection and improved wound bed preparation
Bioengineered skin options	Cultured epithelium, spray-on cells, emerging regenerative approaches	Useful in extensive burns or limited donor sites, with current practical limitations
Reconstruction of sequelae	Contracture release, z-plasty, local/regional flaps, free flaps	Restores function and aesthetics in chronic burn injuries
Specialized anatomical regions	Eyelids, hands, joints require tailored reconstructive strategies	High functional demand and risk of long-term disability
Long-term rehabilitation	Scar modulation, physical therapy, psychosocial support	Essential for functional recovery and quality of life
Future directions	Advanced biomaterials, regenerative medicine, personalized surgical planning	Complement—but do not replace—core surgical principles

CONCLUSION

Modern burn surgery is anchored in accurate assessment, early resuscitation, infection prevention, and timely excision with definitive closure—most commonly via STSG—supported by multidisciplinary critical care and

long-term reconstructive strategies to mitigate scarring and contracture. Current advances expand options for coverage and scar management, but individualized decision-making and resource-sensitive implementation remain essential.

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