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Acute Care for Burn Patients: Fluids, Surgery, and What Else?

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Structured Abstract

Purpose: Recently published initiatives spanning the burn care spectrum have substantially changed the standard of care in burn care. The purpose of this article is to describe new impactful concepts in burn first aid, triage, resuscitation, and treatment as well as their impact on future research.

Recent Findings: First aid after burn injury traditionally consists of extinguishing the burn and applying dressings. Recent evidence suggests that applying 20 minutes of cool tap water to the burn wound in the first 3 hours post-burn mitigates burn injury extent. National burn center transfer criteria have been updated, impacting patient initial transfer and management. The adverse effects of hydroxocobalamin, a commonly used antidote for cyanide toxicity, have been delineated. Initial burn resuscitation recommendations for both volume and potentially fluid type are being reexamined. The emergence of innovative skin substitutes may improve burn survival by providing a physiologically stabilizing intermediate dressing. Finally, formal clinical practice guidelines for early mobility in the ICU after burn injury have been defined.

Summary: These changes in burn care, triage, resuscitation, and treatment have challenged traditional burn care standards, created new standards, and are the basis for future prospective randomized trials.

Key Words: burn resuscitation, first aid, hydroxocobalamin, early mobilization

Introduction

Globally there are >8 million new burn cases per year, accounting for >111,000 deaths and >7 million disability-adjusted life years (DALYs) lost.[1] In the U.S. nearly 486,000 people seek medical attention, 45,000 adults and children are hospitalized, and 30,000 people are admitted to burn centers yearly.[2] Mortality after burn injury has improved substantially due to burn injury prevention, the advent of early excision and grafting, advances in respiratory management, and the creation of burn centers. However, mortality remains a significant issue for major burns (>40% total body surface area), inhalation injury, and extremes of age (<2 years and >70 years). Efforts to improve burn care have ranged from initial first aid to defining standards for triage, transfer, resuscitation, and physical therapy. Recently initiatives spanning the burn care spectrum have substantially changed the burn injury care. The purpose of this article is to describe new impactful concepts in burn first aid, triage, resuscitation, and treatment in current care and future research.

First Aid After Burn Injury

Efforts to improve survival after burn injury have traditionally focused on hospital-based interventions. Although remarkably successful, there are intrinsic limitations, as the burn wound is dynamic and may rapidly change in extent based on initial first aid. The burn wound initially consists of three zones of injury: coagulation (irreversible tissue damage), erythema (injured, but will heal), and stasis (injured, but will either heal or progress to irreversible damage based on wound treatment).

The past 3-5 years have seen a resurgence in interest in immediate burn first aid to mitigate stasis conversion to full tissue loss.[3] The concept of cool running water (CRW) as burn first aid, introduced by Galen 2000 years ago, was revived recently in Australia.[4] Initial studies focused on identification of the optimal temperature and time for cool water treatment of burn injury in animal models.[5,6] Subsequent human studies have supported the efficacy of 20 minutes of cool running tap water (20 CRW) in mitigating burn injury in humans.[7-10] Parameters improved by 20 CRW within 3 hours of injury include decreased likelihood of hospital admission[7], reduction in hospital length of stay[8], burn depth[9], time to re-epithelialization[7,10-12] decreased requirement for skin grafting, and reduced ICU length of stay[10]. 20 CRW has been reported to be safe in major burn injuries.[13] These data have prompted Australia, New Zealand, and the British Burn Association to recommend 20 CRW as initial first aid for burn injury. The use of 20 CRW has implications for ER providers as well as the ICU, as it is efficacious for three-hours post injury, and providers may need to use this therapy and be prepared to receive patients post irrigation.

Burn Transfer Criteria

The criteria for burn center transfer have remained constant for approximately 20 years.[14] Because outpatient burn management has become more prevalent, medical knowledge and capabilities progressed, and challenges in burn center bed capacity developed, particularly during COVID, the criteria for burn center referral needed to be updated to meet changing resource capabilities. The American Burn Association (ABA), via the Committee on the Organization and Delivery of Burn Care, reviewed the previously published transfer criteria and established new criteria which provide increased flexibility for consultation and transfer.[15] The recommended changes divide transfer into three categories: patient transfer indicated, telemedicine consultation recommended, and outpatient burn center referral recommended. The ABA simplified the recommendations and incorporated them into the 2023 Advanced Burn Life Support Course[16]. (Table 1) These recommendations are a practical revision of the initial guidelines, which served burn care well, and are designed to simplify the transfer decision as well as address variable care capability in referring centers. Transfer guidelines do NOT detract from the importance of physician-to-physician discussion of each patient transfer, as patients often have comorbidities or other issues that need further consideration.

Burn Resuscitation: Treatment of Cyanide Toxicity

Inhalation injury, burn size, and patient age are the key determinants of survival in burn injury.[17] Inhalation injury has several different forms: type 1-inhalation of toxic gases, type 2-upper airway obstruction, and type 3-lower airway injury due to smoke particulates. Improvement in inhalation injury outcomes for types 2 (early intubation) and 3 (lung protective ventilation strategy) have reduced mortality. Type 1 inhalation injury survival has improved with the recognition and treatment of carbon monoxide toxicity. In recent years the treatment of cyanide toxicity with hydroxocobalamin has been introduced into the EMS system. Cyanide is generated when plastics burn. Unfortunately, obtaining the results of laboratory serum cyanide testing takes 3-5 days, precluding pretreatment testing verification. Hence, clinical presentation, usually in the form of persistent acidosis despite adequate resuscitation, dictates treatment. Hydroxocobalamin, a precursor of vitamin B12, has recently been introduced as a therapeutic agent to treat cyanide toxicity. The cobalt ion in hydroxocobalamin combines with the cyanide to form cyanocobalamin, a nontoxic molecule, which is excreted.[18] Despite the paucity of randomized trials supporting its use, the administration of hydroxocobalamin for burn patients with acidosis has increased nationwide. Hydroxocobalamin, however, has several side effects which have implications for critical care management[19]. First, hydroxocobalamin causes a purplish/reddening of the skin and purple/red urine, making burn depth determination difficult. The red/purple urine may be mistaken for rhabdomyolysis. More importantly, hydroxocobalamin may cause hypertension, rash, methemoglobinemia (children), or anaphylaxis.[20] The colorimetric changes in serum also interfere with the function of hemodialysis machines, as the pigment causes diffraction of light in the effluent path of the blood leak detector, which precludes further dialysis.[21] A recent study by Dang also highlighted the impact of hydroxocobalamin on laboratory chemistry, coagulation, and liver function testing which could adversely impact the patient.[19] These alterations are present for 72 hours after administration of hydroxocobalamin. Hence, intensivists need to be prepared to change treatment strategies, and the clinical laboratory should be consulted after hydroxocobalamin has been administered. Hemodialysis can only be performed using the machines that do not have a colorimetric leak detector. Hence, while there is now a simple treatment for presumed cyanide toxicity, awareness of its unintended effects is essential.

Burn Resuscitation: Fluid Administration

One of the hallmarks of burn resuscitation is intravenous fluid administration to compensate for the “leaky capillaries” generated by the burn injury. Perhaps the most utilized burn resuscitation formula is the Parkland formula, which consists of administration of 4 ml/kg/% burn, half administered in the first 8 hours post-injury.[22] This formula has saved countless burn-injured patients. However, it also has led to “fluid creep”, in which excessive fluid is administered.[23] The resulting complications, such as abdominal compartment syndrome, pleural effusions, pericardial effusions, blindness, (elevated intraocular pressure), have led to a reevaluation of the formula. A recent burn resuscitation state of the science meeting concluded that measures need to be taken, such advanced monitoring and early colloid administration, to reduce fluid creep.[24] The American Burn Association applied these recommendations to the most recent Advanced Burn Life Support Course in the form of revised burn resuscitation formulas. [16] All formulas still rely on weight and burn size. However, the new recommendations vary based on patient age and mechanism of injury. (Table 2) Adults should start with lactated ringers solution at 2 ml/kg/% burn, children 3 ml/kg/% burn, and electrical injury 4 ml/kg/% burn with all categories then being divided by 16 to obtain the starting rate. The new recommendations emphasize that the calculated rates are only STARTING rates. Intravenous fluid resuscitation should be titrated hourly based on patient response (primarily in the form of urine output, but other parameters should also be used based on patient condition. Practically, this will lower initial fluid volume administered, so intensivists need to be prepared to adjust fluids, particularly if patients become hypotensive.

The other major change in burn resuscitation in the 21st century is the gradual inclusion of colloid in burn resuscitation in the first 8 hours after injury. The administration of colloids is theorized to decrease the amount of resuscitation fluid administered, decreasing burn edema. In the early years of burn management, capillary permeability was thought to limit albumin or other colloid utility, as it would simply leak into the subcutaneous tissue, abdomen, or pleural space. However, the landmark ABRUPT multicenter prospective trial confirmed that albumin administration is indeed being used in older burn patients with larger and deeper burns and organ dysfunction.[25] This study is the nidus of an ongoing randomized prospective trial of albumin use in major burn injury.

Albumin is not the only colloid that has recently been introduced into burn resuscitation. Fresh frozen plasma (FFP) has been shown to decrease endotheliopathy in burn and trauma patients.[26] Several recent publications have suggested that FFP improves outcomes after burn injury.[27-29] FFP is not without side effects, such as transfusion reaction, infectious disease transmission, and transfusion related fluid overload. A prospective randomized multicenter trial is in progress to determine if FFP will indeed improve burn outcomes. Unfortunately, the albumin and FFP trials are separate studies, so further evaluation of these agents in a single study will be needed to fully define which should be used in burn resuscitation.

Surgical Management of the Burn Wound

Burn injury is singular in that survival of the skin is essential to recovery. The burn patient will succumb if the skin is not restored. As such, burn injury is one of the few disorders treated in the ICU which requires prioritization of the skin throughout all facets of care, particularly during times of physiologic stress. Excision of the burn wound and split thickness skin grafting is the mainstay of burn treatment. However, skin grafts suffer from scarring, lack of skin appendages (dry skin, inability to sweat), paresthesia or loss of sensation in grafted areas, loss or alterations in pigmentation, itching, and hypertrophic scarring. Skin substitutes, which can potentially decrease these issues, are currently being developed, and several new products are being used.[30] In the past 18 months two specific new products have been introduced and rapidly adopted by the burn care team: Novosorb® Biodegradable Temporizing Matrix (BTM) and RECELL® [31].

Synthetic Skin Substitutes: BTM is a synthetic skin substitute composed of a perforated polyurethane sealing membrane, which mimics the epidermis, bonded to polyurethane foam. BTM is placed and stapled to a fully excised burn wound and allowed to engraft for 10 days to 3 weeks. (Figure 1) At engraftment maturation, BTM is vascularized and has a classic “salmon” color. Once engrafted, the sealing membrane is removed, the tissue abraded to punctate bleeding, and a thin meshed split thickness skin graft placed. BTM is synthetic; hence, no risk for disease transmission. The sealing membrane, when BTM is adherent, decreases fluid loss, simplifies dressing changes, and stabilizes the wound bed. BTM is ideal for patients with large burns, limited donor sites, and frail patients. While waiting for BTM engraftment, patients can be optimized for surgery, including nutrition and physical and occupational therapy to increase strength and mobility. Although BTM is resistant to infection, wound infection can occur, and infection beneath the BTM can progress rapidly. Fluid may collect beneath BTM as the polyurethane generates an inflammatory response. The fluid can be expressed through the BTM fenestrations. If, however, copious foul-smelling fluid collects in conjunction with nonadherent BTM, the patient should be treated with IV antibiotics, topical antibiotics, and BTM promptly removed. BTM has been used successfully in the elderly, massive burns (with cultured epithelial autograft), face and hand burns, and burn reconstruction. A randomized prospective trial is currently underway to establish efficacy and safety of BTM in third degree burns and is the standard of care in Australia and other countries.

Autologous Skin Cell Suspension: The other major advance in burn wound management is RECELL®, an autologous skin cell suspension created from a very small donor site contains fibroblasts, melanocytes, and stem cells.[32] RECELL® is currently approved for 2 uses in the U.S.: 1. direct spraying of cells on partial thickness burns in patients 18 years old or older and 2. Application (via spray) in combination with meshed autografting for acute full-thickness thermal burns in both adults and children. RECELL® must either be used in a wound with an underlying scaffold, such as a second degree burn wound, or in conjunction with a skin graft, as RECELL® does NOT work without some form of scaffold. One of the major uses of RECELL® is in massive burns in conjunction with widely meshed skin to maximize wound coverage and wound healing. The other use in massive burns is to spray the RECELL® on donor sites to accelerate donor site healing. RECELL® is often not used with topical antimicrobials, as they may injure the cells. Hence, the intensivist must remain alert to the potential for wound infection and treat rapidly should wounds become malodorous with drainage or high fevers develop. The use of RECELL® is rapidly expanding in the U.S., as it may accelerate wound healing and thus decrease burn hospitalization duration.

Early Mobilization in Burns

Early ICU mobilization has been a tenet of burn care for >20 years, as loss of lean muscle mass after major burn injury is ubiquitous. The American Burn Association assembled a multidisciplinary expert paned to examine the burn literature and formulate Clinical Practice Guidelines (CPG) for early mobilization and rehabilitation of critically ill burn patients using PICO (Patient, Intervention, Comparator, Outcome) methodology.[33] The prolonged bed rest and immobilization common in critically ill burn patients due to sedation requirements, analgesic medications, and monitors leads to deconditioning of the cardiovascular system, atrophy of skeletal muscles, and weakening of the respiratory muscles. This is a must-read paper for any intensivist who takes care of burn patients, as it is a comprehensive and systematic review of the literature on the impacts of early mobilization and rehabilitation in the ICU on: 1. duration of mechanical ventilation and development of ICU acquired weakness; 2. development of pressure injuries, 3. effects on skin grafts (i.e. does early mobility endanger skin grafts). This paper highlights the importance of early mobility while acknowledging the overall gaps in ICU rehabilitation research. The methodology used is sound and is an example of how guidelines should be developed. CPG in other important areas of burn care, including resuscitation and blood transfusion are underway and should provide guidance in these areas.

Conclusion

Burn care continues to progress as new technologies are introduced. Some areas, such as first aid, have employed methodologies introduced in ancient times, while others, such as skin substitutes and autologous skin suspension, leverage latest technologies. Despite a >50-year history of burn resuscitation, debate on the proper fluid and the proper volume of fluid to administer continues. Understanding the risks of the drugs we administer, be it resuscitation fluids or antidotes, is important, as the unintended side effects for drugs such as hydroxocobalamin can adversely affect patients. Finally, the development of standards for triage and early mobility are important to move the bar forward in burn care. The need to reevaluate and improve remain a constant.

Bullet Points

1. The use of twenty minutes of cool running tap water as burn first aid decreases wound extent and need for grafting when used within 3 hours of injury.
2. Hydroxocobalamin, used for cyanide toxicity, should be reserved for patients with metabolic acidosis despite adequate resuscitation due to its colorimetric impact on laboratory values, urine and wound appearance, and hemodialysis machine function.
3. Major burn injury resuscitation guidelines have been changed to decrease initial lactated ringers solution resuscitation in adults (2 ml x kg x percent burn divided by 16) and children (3 ml x kg x percent burn/16).
4. National guidelines have been published for institution of early mobility in the burn intensive care unit for all burn injured patients.
5. Emerging new skin substitutes and autologous skin cell suspension technologies hold great promise for improving burn patient outcomes.

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Conflicts of interest

None

Table 1: American Burn Association Guideline for Consultation and Transfer for Patients with Burn Injuries

	Immediate consultation with consideration for transfer	Consultation recommended
Thermal burn	Full thickness burns • Partial thickness burns <10% TBSA* • Partial thickness 10% TBSA* • All potentially deep burns of any size • Any deep partial or full thickness burns involving the face, hands, genitalia, feet, perineum, or over any joints • Patients with burns and other comorbidities • Patients with concomitant traumatic injuries • Circumferential injuries • Poorly controlled pain	• Partial thickness 10% TBSA* • All potentially deep burns of any size
Inhalation injury	All patients with suspected inhalation injury	Patients with signs of potential inhalation such as facial burns, singed facial hairs, or smoke exposure
Pediatrics (≤14 years of <30 kg)	All pediatric burns may benet from burn center referral due to pain, dressing change needs, rehabilitation, patient/caregiver needs, or non-accidental trauma	
Chemical injuries	All chemical injuries	
Electrical injuries	• All high voltage (1000V) electrical injuries • Low voltage electrical injuries (<1000 V) • Lightning injury	Low voltage electrical injuries (<1000 V): consultation and consideration to follow-up in a burn center to screen for delayed symptom onset and vision problems

Table 2

Category	Age and Weight	Initial Fluid Rate
Flame or scald	Adults and teenagers ≥13 years old)	2 ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate
	Children (≤12 years old)	3 ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate Plus D5LR at maintenance rate
Electrical Injury	All	4 ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate Plus D5LR at maintenance rate for children -12 years old

Figure Legends

Figure 1 Example of BTM Engraftment. Figure A: original burn wound. B: BTM appearance at time of surgical excision and initial placement. C: wound appearance after skin grafting 21 days post BTM placement. D. wound appearance 12 months post grafting.