Burn Wound Healing Outcomes

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Development of metrics for burn care, including healing of skin wounds during the acute phase of treatment, is essential in an environment of decreasing resources and increasing interest in quality and accuracy of medical information. Advantages of consensus metrics include: tracking of trends in care; consistency of care; and correlation of treatment with medical outcomes. For cutaneous burn wounds, these advantages are confounded by factors that contribute to the heterogeneity of burn wounds, including but not limited to: TBSA of injury, depth of injury (partial or full thickness), cause, patient-dependent factors such as age, sex, and comorbidities, anatomic site, and time between injury and treatment. Similar factors contribute to complex injuries from trauma, and allow for risk adjustment of individuals in the population, who otherwise may be outliers to the statistical mean of the entire population.[1–3]Despite these confounding factors, certain common definitive events are necessary to accomplish healing of a burn wound, including: accurate diagnosis of burn depth, debridement or excision of devitalized tissue, dressing or grafting of the prepared wound bed, and assessment to determine wound closure. In the absence of confounding factors or comorbidities, wound closure is one of the key criteria for discharge from acute care whether in hospital, or ambulatory care. Not surprisingly, these metrics for wound healing have been used repeatedly in the assessment of developing therapies for wound care. In response, review by the FDA of novel therapies has led to Guidance for Industry: chronic cutaneous ulcer and burn wounds—developing products for treatment.[1] With reference to cutaneous burns, this Guidance considers hemodynamic resuscitation, management of comorbidities, timely burn debridement and excision, wound closure, management of wound infection, pain control, nutritional support, measures to inhibit excessive scar formation, and rehabilitation, including passive range of motion when burns overlie joints. Other burn societies, most recently the Australia–New Zealand Burn Association, have also recognized the need for metrics of quality in burn care,[4–7] the need to accumulate data from the practicing community, definition of clinical criteria for data collection, risk adjustment to compensate for variability in clinical populations, and data validation for use. In this context, the participants in the Wound Healing Breakout Session of the Burn Quality Consensus Conference discussed metrics for evaluation of quality in healing of burn wounds. Particular focus was given to diagnosis of burn depth, debridement or excision of devitalized tissue, wound infection, and wound closure. Each of these aspects of burn wound healing will be reviewed as a potential metric for prospective capture and trending in the American Burn Association TRACS/National Burn Registry to allow tracking of quality of burn care. Whereas burn wound healing involves a prolonged process that starts immediately after injury and may continue for many months or years, this consensus statement will focus on the early phase of burn wound healing

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during the first few weeks up to a month. Because of the obvious importance of wound closure in the healing process, wound closure should be considered definitive to any burn care program. Burn wound infection is also of utmost importance because it can lead to burn injury progression or conversion of a superficial burn to a deeper wound. Microbial contamination in burn wounds may also result in systemic infection or sepsis, leading to increased morbidity and mortality. Another important element that measures the quality of care related to the early phase of burn wound healing is the success of autografting after excision of deep burns. Thus, the need for additional grafting or regrafting after a failed first attempt should be measured. The following summary outlines the metrics developed by the Wound Healing Breakout Session Group:

1. Time to burn eschar removal,
2. microbial bioburden or presence of infection in burn wounds,
3. time to wound closure, and
4. failure of, and need for additional autografting of prepared wounds.

DEBRIDEMENT OR EXCISION OF THE BURN ESCHAR

How It Meets Clinical Care Quality Outcomes

Among the most direct and effective interventions for reduction of risks from cutaneous burns is removal of the burn eschar.[8–11] Devitalized skin is a rich medium for microbial growth, and also is known to promote inflammation by release of cytokines and growth factors from injured or lysed skin cells.[12–14] Consequently, practices for care of burn wounds have favored early and complete removal of the burn eschar, but variability in the burn community is recognized, and data are not available.

Proposed Metric for the TRACS Database

Because of the impact of timely removal of the burn eschar on wound closure and scarring, the proposed outcome measure regarding excision of the burn eschar is: Time (in days) from occurrence of the burn injury to complete (>95%) removal of the burn eschar.

BURN WOUND INFECTION

How It Meets Clinical Care Quality Outcomes

The ability of the burn wound to heal is inextricably linked to the presence or absence of infection in the wound bed. All burn wounds have microorganism colonization, which may include bacteria, fungi, or viruses. However, the presence of these microorganisms does not indicate a wound infection. Wounds require constant surveillance to determine whether there are any changes that indicate the evolving development of infection.[15,16] In the preexcisional era of burn care, wound infection was diagnosed as *invasive* when bacteria or fungi caused early separation of the eschar layer and subsequent systemic sepsis. This type of wound infection is not often seen in the excisional era of burn wound care as most burn surgeons excise the deep burn followed by skin grafting before bacterial invasion occurs.

Definitions and Measurement of Wound Infection

Definitions of wound infection have received extensive consideration as standards in care have advanced. Definitions for surveillance of burn wound infections were proposed in an American Burn Association Consensus Panel Publication on infections and sepsis after burn injuries[15]; the authors emphasized the importance of microbial surveillance. The recommendations of that conference included definitions of wound colonization, wound infection, invasive infection, cellulitis, and necrotizing infection including fasciitis. General definitions for burn wounds were also described in a report of the Centers for Disease Control and National Healthcare Safety Network.[16] Each of these reports provided definitions that have been harmonized in this article to characterize and differentiate invasive and noninvasive infections of burn wounds.

Presence of *invasive* burn wound infection may be defined as:

Infection occurring in a deep partial-thickness or full-thickness burn wound, associated with a change in burn wound appearance or character, such as rapid eschar separation or dark brown, black, or violaceous discoloration of the eschar; requires surgical excision of the burn and treatment with systemic antimicrobials; and may be associated with any of the following:

a. Inflammation (such as edema, erythema, warmth, or tenderness) of surrounding uninjured skin;
b. Histopathologic examination of the burn biopsy specimen showing an invasion of the infectious organism in adjacent viable tissue;
c. Isolation of the organism from a blood culture in the absence of other identifiable infection;
d. Systemic signs of infection such as hyperthermia, hypothermia, leukocytosis, tachypnea, hypotension, oliguria, hyperglycemia

at a previously tolerated level of dietary carbohydrate, or mental confusion.

What is more commonly seen is a *local or noninvasive* wound infection in a healing partial-thickness or grafted full-thickness injury, which can cause delayed healing or failure of the skin graft. Presence of noninvasive (local) burn wound infection may be defined as:

Burn wounds that have a purulent exudate that is culture positive (if performed), requires a change in treatment (which may include a change or addition to antimicrobial therapy, the removal of wound covering, or an increase in the frequency of dressing changes); and at least one of the following:

a. Loss of synthetic or biologic covering of the wound;
b. Changes in wound appearance, such as hyperemia;
c. Erythema in the uninjured skin surrounding the wound;
d. Systemic signs, such as hyperthermia or leukocytosis.

Microorganisms responsible for these infections include bacteria, fungi, or viruses. Bacteria include gram-positive organisms such as *Staphylococcus aureus*, β-hemolytic *Streptococcus group A*, or *Enterococcus* species (including vancomycin-resistant enterococci). Gram-negative organisms include nonenteric organisms such as *Pseudomonas aeruginosa* and *Acinetobacter baumannii* or enteric organisms such as *Klebsiella* species, *Escherichia coli*, or *Enterobacter* species. Yeasts include the *Candida* species and are generally part of the body's normal flora. Environmental fungi, of which the most common are the *Aspergillus* species, can cause life-threatening, invasive infection and extensive tissue loss. Viral infection, most commonly *Herpes simplex* virus, is less frequent.

Of increasing importance are the antimicrobial resistance patterns identified in many of the bacterial organisms, which may affect the effectiveness of prevention and treatment efforts. Specific organisms of concern include methicillin-resistant *S. aureus*, vancomycin-resistant *Enterococcus*, and multiple–drug–resistant *A. baumannii* and *P. aeruginosa*. In recent years, the frequency of identifying these organisms has increased and several strains of *Acinetobacter* and *Pseudomonas* have been found to be resistant to all tested antimicrobials except colistin.

Proposed Metric for the TRACS Database

Because of the impact of burn wound infection on wound closure and scarring, the proposed outcome measure are:

1. Occurrence of invasive burn wound infection.
2. Occurrence of noninvasive burn wound infection.

WOUND CLOSURE

How It Meets Clinical Care Quality Outcomes

Wound healing is a complex yet highly regulated process that comprises several overlapping phases including inflammation, new tissue formation, and remodeling.[17] One of the earliest and most important phases of wound healing is wound closure, which is generally defined as complete wound reepithelialization or reestablishment of the outermost epidermal layer, the stratum corneum. Wound closure reestablishes a microbial barrier, reducing the risk of infection and limiting evaporative fluid losses. Early wound closure may also affect the ultimate healing of burns, their function, and appearance. Multiple studies have shown that burns that reepithelialize earlier are less likely to scar, possibly because of a reduction in inflammation and granulation tissue formation.[18] A wide body of evidence has demonstrated that superficial burns that heal or close within 2 to 3 weeks usually resolve without hypertrophic scarring or functional impairment.[19] In contrast, deep burns that fail to heal within 3 weeks frequently lead to hypertrophic scarring and functional impairment.[20]

Definition and Measurement of Wound Closure

Despite the importance of wound closure, there is no standard, validated method used to measure wound closure. Anatomically, wound closure is defined by reestablishment of a neoepidermis that completely covers the wound. From a physiologic standpoint, wound closure is characterized by reestablishment of the barrier function as defined by a reduction in water vapor transmission, and/or a decrease in the surface hydration of the skin.[21,22] Although the anatomy and physiology of the skin are interrelated, anatomic restoration of the epidermis generally precedes physiologic restoration of the barrier by days to weeks.[23]

The prevailing standard for complete wound reepithelialization is histologic analysis of tissue specimens.[24,25] A major limitation of this method is that it is invasive, exposing the patient to pain and the risk of infection and scarring from the biopsy itself. Histologic analysis may also be subject to sampling bias, because it only represents the wound site biopsied, and it may not be representative of the entire wound. Additionally, sample preparation can sometimes inadvertently remove the fragile neoepidermis.

Thus wound closure is generally determined by noninvasive assessments of the skin surface, which examine the entire wound area.[26]

There is no standard clinical definition of wound reepithelialization, and it is often presumed that experienced clinicians have good interobserver agreement. The Wound Healing Consensus Work Group suggests that a wound is closed when it no longer readily transmits water, no longer needs dressings or bandages, is dry to the touch, and more pink or opalescent than red or transparent. One simple way to determine whether the wound surface is dry is to blot it with a tissue paper and see if the paper absorbs moisture. A recent study in a porcine burn model found high interobserver agreement of clinicians in determining clinical wound reepithelialization based on photos, but there was poor agreement between the clinical assessment and the histologic assessment questioning the validity of clinical assessment in the porcine model.[27] No similar study in humans was found, and it is unclear whether results in swine correlate with those in humans.

Several noninvasive methods have been used to assess the anatomical and functional integrity of the wound. Anatomical integrity can be assessed using either high-frequency ultrasound or optical coherence tomography.[28–30] However, both these methods are still experimental and have not been validated on a large scale. Furthermore, they are unlikely to be widely available to clinicians, limiting their broad applicability. Barrier properties of the skin can be measured noninvasively by one of two methods: electrical resistance and water vapor transmission. These properties are assessed in dermatologic practice with instruments that are validated and calibrated for human skin.[31] These instruments may be considered for measurements of healing in burn wounds, but impose a cost and requirements for training.

Proposed Metric for the TRACS Database

Wound closure can be summarized more simply by one of two methods. With daily wound assessment, the approximate time to complete closure can be determined. If wounds cannot be assessed frequently, the percentage of the burns that are reepithelialized or closed at specific time points (3 or 4 weeks) may be determined. In order to limit the number of burn metrics, the panel proposed using the *time to complete wound closure in days* as the ideal quality metric for wound closure. Because some patients will be discharged before complete wound closure, we propose measuring the size (TBSA) of open wounds at hospital discharge as an alternative metric of wound closure. Although no recommendations for benchmarking are proposed here, data collection might allow eventual optimal quality standards. The proposed outcome measures for wound closure are:

1. Time (in days) to complete (>95%) wound closure
2. Size (TBSA) of open wounds at the time of hospital discharge.

AUTOGRAFTING OF DEEP BURNS

How It Meets Clinical Care Quality Outcomes

With regard to large deep burns (ie, >20% TBSA), the Consensus Work Group recognized that comorbidities and limited availability of donor skin might complicate and protract wound closure. Therefore, metrics for large superficial and small deep burns may not be reliable for larger deep burns. Rather, as a metric for whether or not the treatment of large, excised burns is effective, the panel believed that failure of autograft procedures that require regrafting provides a valid measure of quality. This metric would be applied to grafting of burn wounds, regardless of whether the graft was with donor skin, engineered skin, or cell therapies. The metric would not be applied to healing of donor sites for skin autograft because they are surgical wounds, not burns. The committee also recognizes that the ability of a graft to take is dependent on multiple patient, environmental, and practitioner factors that need to be taken into account when considering why a particular graft failed to take.

Proposed Metric for the TRACS Database

Because of the fact that failure of autografting delays healing and negatively affects patient outcome the proposed outcome measure regarding closure of deep excised burn wounds is: occurrence of regrafting of any autografted site.

GAPS IN KNOWLEDGE AND OPPORTUNITIES FOR RESEARCH

After specification of the metrics for wound healing, gaps in knowledge that provide opportunities for prospective research were addressed. The Consensus Work Group identified four topics:

A. To develop and test metrics for burn wound healing.
B. To include wound treatment of outpatients as part of the data collection, because data in the National Burn Repository includes only inpatients.

C. To evaluate whether best practices and outcome metrics correlate with less scar, or less grafting.
D. To determine whether or not risk adjustments for mortality[3] are applicable to wound closure.

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