Infection control in severely burned patients

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Abstract

In the last two decades, much progress has been made in the control of burn wound infection and nosocomial infections (NI) in severely burned patients. The continually changing epidemiology is partially related to greater understanding of and improved techniques for burn patient management as well as effective hospital infection control measures. With the advent of antimicrobial chemotherapeutic agents, infection of the wound site is now not as common as, for example, urinary and blood stream infections. Universal application of early excision of burned tissues has made a substantial improvement in the control of wound-related infections in burns. Additionally, the development of new technologies in wound care have helped to decrease morbidity and mortality in severe burn victims. Many examples can be given of the successful control of wound infection, such as the application of an appropriate antibiotic solution to invasive wound infection sites with simultaneous vacuum-assisted closure, optimal preservation of viable tissues with waterjet debridement systems, edema and exudate controlling dressings impregnated with Ag (Silvercel, Aquacell-Ag). The burned patient is at high risk for NI. Invasive interventions including intravenous and urinary catheterization, and entubation pose a further risk of NIs. The use of newly designed antimicrobial impregnated catheters or silicone devices may help the control of infection in these immunocomprised patients. Strict infection control practices (physical isolation in a private room, use of gloves and gowns during patient contact) and appropriate empirical antimicrobial therapy guided by laboratory surveillance culture as well as routine microbial burn wound culture are essential to help reduce the incidence of infections due to antibiotic resistant microorganisms.

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INTRODUCTION

Infection and sepsis are among the most prominent causative factors in burn related mortality and morbidity. The prevention and control of infectious diseases among burned patients present a specialized problem, as the environment in burn units can become contaminated with resistant organisms. Lack of proper wound care, edema formation and lack of resuscitation may actually increase the size and/or depth of the wound. Early burn wound excision is now performed within the first few days after burn injury and has resulted in improved survival and infection control in severely burned patients. In modern burn care and management, there are many additional tools for controlling wound-related sepsis.
EPIDEMIOLOGY OF BURN WOUND INFECTIONS

Burn wound infections are one of the most important and potentially serious complications that occur in the acute period following injury. Approximately 73% of all deaths within the first 5 days post-burn have been shown to be directly or indirectly caused by septic processes.

Until the development of effective topical antimicrobial chemotherapeutic agents in the mid-1960s, the wound was the most common site of infection, causing devastating morbidity and, when invasive, virtually universal mortality in burn patients. Since then, infection in sites other than the burn wound, principally the lungs, has remained the most common cause of death in burn patients. The continually changing epidemiology of infection in critically ill, severely burned patients is a result of greater understanding and improved techniques for burn patient management and burn wound care. Currently, blood-borne and urinary tract infections are more commonly seen than invasive wound infections in severely burned patients.

CLASSIFICATION OF BURN WOUND INFECTIONS

The main signs of wound infection are dark brown, black, or violaceous discoloration of wound which can be focal, multifocal, or generalized, as well as conversion of partial-thickness injury to full-thickness necrosis and hemorrhagic discoloration of subeschar tissue. Edema and/or violaceous discoloration of unburned skin at wound margins (most commonly seen with Pseudomonas infections) and unexpectedly rapid slough of eschar, most commonly due to fungal infection, are other well-known signs. There are three accepted forms of burn wound infections: (1) Cellulitis; (2) Invasive wound infections within unexcised eschar (necrotising infection-fasciitis); and (3) Burn wound impetigo.

Burn wound cellulitis results from an extension of infection into the healthy, uninjured skin and soft tissues surrounding the burn wound or donor site. It is characterised by erythema of surrounding unburnt skin (1-2 cm beyond the wound), pain and oedema, extending the usual rim of inflammation commonly seen in burns. In the past, Group A β-hemolytic streptococci are the most common offenders in case of cellulitis. However, recent studies have shown that this is not currently the case. Staphylococcus aureus has now become the principal etiological agent of burn wound cellulitis and, along with Pseudomonas aeruginosa, remains a common cause of early burn wound infection in many centers.

Patients with areas of unexcised deep partial-thickness or full-thickness burn wound have an increased risk of developing an invasive infection. The histological examination of a burn wound biopsy is the most reliable and expeditious means of confirming a diagnosis of invasive burn wound infection. It is well known that conversion of a partial burn into a full-thickness burn is possible, if infection occurs. In the case of viral burn wound infections, the diagnosis may also be confirmed by histological examination of scrapings from the cutaneous lesions. Histological stages of microbial status of burn wound biopsy are described as a parameter of invasive wound infection: Stage I, Microorganisms present in viable tissue immediately adjacent to subeschar tissue; Stage II, Microorganisms present in viable tissue immediately adjacent to subeschar tissue.

In a group of 19 patients with histologically documented invasive burn wound sepsis, only the 5 patients in whom no positive blood cultures were obtained survived, with their infected tissue excised before dissemination to remote tissues and organs had occurred. Although Pseudomonas aeruginosa is the gram-negative organism that most often causes invasive burn wound infection, virtually any bacterium can be present in severely burned patients. Anaerobic organisms such as Clostridium sp. and facultative anaerobes such as Aeromonas sp. can
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cause invasive burn wound sepsis. Clostridial infections have characteristically occurred in patients in whom associated mechanical trauma or vascular occlusion have resulted in ischemic damage of muscle and subcutaneous tissue [21]. Effective treatment of deep tissue delayed infections requires surgical excision of all affected tissues and use of broad spectrum antibiotics against aerobic and anaerobic microorganisms. Application of an effective topical antimicrobial agent substantially reduces the microbial load on the wound surface [17,18]. Silver sulfadiazine is mostly used for both ambulatory and hospitalized patients. Silver nitrate is not routinely used now as it discolors the wound bed. Mafenide acetate cream is used after debridement of burn eschar [19].

In a molecular study, a total of 228 different Candida species were obtained from various body locations of burn patients. Species identification revealed that C. albicans was the most common followed by Candida tropicalis. The risk factors for fungal infection in burns are age of patient, total burn size, full-thickness burns, inhalational injury, prolonged hospital stay, late surgical excision, open dressing, artificial dermis, central venous catheters, antibiotics (imipenem, vancomycin, aminoglycosides), steroid treatment, long-term artificial ventilation, fungal wound colonisation, hyperglycaemic episodes and other immunosuppressive disorders [20,21].

Impetigo involves the loss of epithelium from a previously reepithelialized surface, such as grafted burns, partial-thickness burns allowed to close by secondary intention, or healed donor sites. Treatment consists of unroofing all abscesses, meticulous cleansing of the infected areas twice daily with a surgical detergent disinfectant, and twice-daily application of a topical antibacterial ointment, such as mupirocin which has potent inhibitory activity against gr (+) skin flora such as coagulase (-) staphylococci and staphylococcus aureus including methicillin-resistant staphylococcus aureus [22].

NASOCOMIAL AND SURGICAL WOUND INFECTIONS IN BURNED PATIENTS

The mode of infection transmission may be by contact, droplet or airborne spread. Modern burn centers have a contained perimeter that is designed to minimize the unnecessary traffic of health care workers and visitors. Modern infection control practice requires strict compliance with a number of environment control measures that include hand washing and the use of personal protective equipment. All personnel must be gowned (either disposable or reusable gowns) during the contact with the patient. All equipment in the isolation room must be regularly cleaned.

With universal employment of early excision and grafting, a burn wound transforms to an open burn-related surgical wound. This means that open burn-related surgical wound infection (SWIs) get more clinical attention than bacterial colonisation of an unexcised wound. New refinements of the standardized definitions for infection and sepsis in burn patients have been proposed by many authors. They assert that suspicious systemic infection (sepsis) should be considered as a clinical syndrome defined by the presence of signs and symptoms of systemic infection even with negative blood microbial cultures. It was recommended that systemic infection should be identified according to positive blood microbial culture or clinical response to antimicrobials [23].

It has been believed that the surgeons are likely to have overestimated the infection rate because they did not use standardized, written definitions [24]. To prevent unnecessary use of antimicrobial agents, burn surgeons were advised to apply standardized, written criteria, like those developed by the Centers for Disease Control (CDC).

The burned patient is at a high risk for nosocomial infection (NI) as a result of the nature of the burn injury itself, the immunocompromising effects of burns, prolonged hospital stays and intensive diagnostic and therapeutic procedures [25]. There are conflicting results from different burn centers regarding the most commonly seen infections in acute burn care. Some reports suggest that burn wound infection is the most common type of infection, whereas other reports show predominance of pneumonia and primary bloodstream infection [26,27]. The same authors concluded that these differences might be related to the variation in the rates of usage of invasive devices such as ventilators, catheters etc.

The percentage of total burned surface area (TBSA) is a significant risk factor for burn wound infections, although it is not a risk factor for the device-associated infections. Duration of use of urinary catheters and ventilation are identified as risk factors for the corresponding hospital-acquired infection. As an effective infection control policy, decreased usage of invasive devices, better infection control procedures and improved aseptic technique while inserting devices could decrease the rates of NI on burn units [28].

SWI is the third most commonly reported nosocomial infection and accounts for 14%-16% of all NI among hospital inpatients [29]. The most widely used definition of SWI is that employed by the CDC’s National NI Surveillance System [30]. Surveillance for SWIs is a very important part of any nosocomial infection surveillance strategy. Poslusny et al. [31] evaluated the SWI impact on rates of regrafting and the relationship between SWIs and NIs. They found that 24 of 62 burned patients with TBSA of 20% or more had a SWI and that development a SWI resulted in ischemic damage of muscle and subcutaneous tissue.

In 2007, experts in burn care and research met in Tucson Arizona to develop a standardized definition for sepsis and infection-related diagnoses in the burn population [32]. In order not to overestimate or underestimate the infection rate among burned patients surgeons
Patients with large burn wounds are routinely debrided at the management of all burn victims. Prophylactic antibiotics promote the development of secondary infections and after surgical interventions, especially in patients with severe burns (TBSA = 40%, or more). Prophylactic antibiotic administration in burn patients must be carried out for a short period of time, for example immediately before, during and after surgical interventions, especially in patients with severe burns (TBSA = 40%, or more). Prophylactic antibiotics promote the development of secondary infections (otitis, diarrhea) and should not be used routinely in the management of all burn victims.

ADVANCES IN BURN WOUND CARE

Patients with large burn wounds are routinely debrided at the first medical facility able to provide this service. This process may include debriding residual blisters, especially if the blisters are large or cover large surface areas. The choice of which topical burn dressing to apply to the wound is based on several factors: material at hand, provider preference, adjacent wounds, anticipated time and distance between successive medical facilities. Advances in wound care may be classified under the following subheadings: (1) Advances in wound exudate and edema control; (2) Optimizing the wound environment with ideal skin disinfectants; (3) Advances in wound debridement systems; and (4) Enhancements to systemic care and management through new technologies.

There is now a wide range of wound dressings available. Various types of wound dressing offer effective control of different aspects of wound healing. Table 1 shows these among the therapeutic tools which have been in routine use for wound treatment over the last two decades.

Burn wounds often involve contiguous areas of open soft tissues wounds that are the result of direct tissue loss, degloving injuries, or surgical debridement. Wounds of this nature are left open for serial debridement and until definitive coverage or closure can be performed. In many cases, negative pressure wound dressings such as the vacuum-assisted closure (VAC, KCI, San Antonio, TX) dressings that use open-pore foam are ideal. The VAC Instill was introduced in 2003 and differs from traditional VAC therapy because it allows the clinician to add solutions to the wound, as well as apply negative pressure. A wound culture may be obtained prior to starting the VAC Instill to select an optimal solution for a specific patient\(^\text{[36]}\). Other major tools to control burn wound exudate are non-adherent hydro-alginates and polyurethans. These dressings are sterile, non-woven pads composed of a high G (glucuronic acid) alginate, carboxymethyl cellulose and silver (Ag) coated fibers, laminated to a perforated non-adherent ethylmethyl acrylate wound

**SYSTEMIC ANTIBIOTIC USE IN BURNS**

Most antimicrobial therapy prescribed for burn patients is administered topically. Antibiotic resistant microorganisms have been associated with infections of burn wounds\(^\text{[34]}\). Risk factors for acquisition of an antibiotic resistant organisms include receipt of antibiotics prior to development of infection and extended duration of hospitalization. Burn centers should routinely determine and track the specific pattern of burn microbial flora and trends in the nasocomial spread of these pathogens\(^\text{[35]}\). In order to overcome infection by resistant microorganisms, the following two precautions must always be taken: (1) Antibiotic utilization should be based on monitoring of antibiotic resistance trends within individual burn centers. Empirical treatment algorithms specific to each burn unit should be developed secondary to the outcome analysis of laboratory surveillance systems involving periodic sampling of burn wounds; and (2) Systemic antibiotic administration in burn patients must be carried out for a short period of time, for example immediately before, during and after surgical interventions, especially in patients with severe burns (TBSA = 40%, or more). Prophylactic antibiotics promote the development of secondary infections (otitis, diarrhea etc) and should not be used routinely in the management of all burn victims.

Figure 3  Diagram showing the management of infection problems in severe burns.

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
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<tr>
<td>Is there any delayed deep tissue infection in the patient with severe burn?</td>
<td></td>
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<tr>
<td>Do prompt surgical excision of affected deep tissues + use broad spectrum anti-biotics against aerobic and anaerobic microorganisms at perioperative period prophylactically + apply an effective topical antimicrobial agent</td>
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<tr>
<td>Search for systemic findings and/or other sources of infection</td>
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<td>Still, any infection problem persist?</td>
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<td></td>
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<tr>
<td>Use effective antimicrobials based on antibiograms</td>
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</table>
| *Consider a mixt infection and/or infection with a resistant microorganism
  Use nystatin powder with other topical antimicrabials for severe fungal infections
  Use mupirocin (bactroban) cream for staphylococci including MRSA
  Use mafenide acetat cream or wound dressing containing ag
  Use specific laboratory information obtained from bacterial culture and susceptibility results and give appropriate systemic antibiotics based on these informations |     |    |

*Figure 3  Diagram showing the management of infection problems in severe burns.*
contact layer. Their composition allow management of exudates in moderate to heavily exuding wounds, creating a moist wound healing environment favourable to effective wound management and allowing intact removal. Ag kills a broad spectrum of microorganisms associated with the bacterial colonisation and infection of wounds. Ag impregnated hydrofiber dressings (Aquacell Ag Convatec, USA) provide a continious antimicrobial activity for Pseudomonas aurginosa, methicilline resistant styphlococcus aureus and vancomycine resistant enterococcus. A newly developed nanocrystalline silver dressing (Acticoat, Smith and Nephew) overcomes some shortcomings of older dressings, such as the need of daily change of dressings and increased patient comfort by providing sustained release of Ag up to 7 d[37].

Techniques used in wound cleansing include high-pressure irrigation, swabbing, low-pressure irrigation, showering, bathing and washing the affected area under a running liquid or total immersion in a whirlpool bath. A variety cleansing liquid are used including water, saline and antiseptic solutions. Most of these antiseptic solutions are toxic to fibroblasts and keratinocytes are some patients may be sensitive to some wound cleansers[38]. Irritation of intact healthy tissues seriously impacts the rate of tissue repair. For indications such as wound antisepsis and treatment of mucosal infections, where a prolonged antiseptic treatment is required, octenidine along with polyhexanine have been found to be the most effective microbistatic and microbicidal treatment[39]. The role of antiseptics on wounds is now being reconsidered in order to formulate rigid guidelines or to propose an algorithm.

VersaJet have several advantages for burn wound debridement. These include reduced blood loss, optimal preservation of viable tissues and effective elimination of bacterial colonization. The over 50% reduction in the death rate among patients with TBSA, compared to earlier published results, may be a result of use of these technologies[40].

Catheter tips are susceptible to colonization through hematogenous seeding of organisms from the colonized burn wound. Biofilms may grow within the medical devices, so preventive measures should be taken against the obvious problem. All types of intravascular devices (IVDs) are associated with a substantial risk of bloodstream infection (BSI). National surveillance studies for 2001 showed that catheter-associated urinary tract infections were 6.7 per 1000 urinary catheter days, catheter-associated BSIs were 7.0 per 1000 central venous catheter days, and ventilator-associated pneumonia were 12.0 per 1000 ventilator days[41]. Novel securement devices and antibiotic lock solutions have been shown to reduce the risk of IVD-related BSI in prospective randomized trials[42]. Introducing an antimicrobial solution into the catheter lumen limits biofilm formation. In the United States catheter-associated urinary tract infections make up 40% of all hospital-acquired infections with approximately 3% of these assessed as connected or contributing to mortality[43]. A variety of specialized urethral catheters have been designed to reduce the risk of infection. These include antiseptic impregnated catheters and antibiotic impregnated catheters. Antiseptic catheters are impregnated with either silver oxide or silver alloy (Figure 4). Nanosilver particles stably embedded in the polycarbonate matrix release minute quantities of bacterisidal ionic silver from the surface into the fluid pathway. Silver oxide catheters are not associated with a statistically significant reduction in bacteria in short-term catheterized hospitalized adults but silver alloy catheters have been found to significantly reduce the incidence of asymptomatic bacteriuria in hospitalized adults catheterized for < 1 wk[44]. A novel nanosilver impregnated polycarbonate-valved needleless connector has been approved by The Food and Drug Administration and is now in use in many hospitals in USA. Anti-infective impregnated central venous catheters are recommended if institutional rates of infection are above 3.3 BSIs per 1000 IVD-days despite full adherence to maximal barrier precautions, especially for patients at high risk for IVDR (IVDs related) BSI. Patients receiv-
ing total parenteral nutrition and those who are neurogenic or who have a CVC that is likely to remain in place for more than 4 d are good examples for these patient groups.

HOSPITAL INFECTION CONTROL POLICIES, CULTURING AND SURVEILLANCE STUDIES

Empirical antimicrobial therapy to treat fever should be strongly discouraged because burn patients often have fever secondary to the systemic inflammatory response to burn injury. Prophylactic antimicrobial therapy is recommended only for coverage of the immediate perioperative period around excision or grafting of the burn wound. Infection control programs need to document and report burn wound infections according to recent classification systems. The incidence of infections reported among burn patients has been found closely related to the person who is assessing the patient for infection. On the basis of the infection control assessment, using the CDC’s definitions, individual researcher’s rates can be compared with the pooled means from previous prospective studies, especially those using multivariable analysis to assess independent risk factors for infections. Preparation of burn unit-specific antibiograms will reveal effective topical antimicrobial agents. Surveillance for surgical site infections and reporting of these rates to surgeons has been shown to reduce the rates of infection[41].

The infection control literature indicates that precise, written definitions are essential to accurately identify hospital-acquired infections. It has been suggested that because of discrepancies between the surgeon’s assessment and infection control assessment, burn patients are over-treated with antimicrobial agents and antimicrobial use could possibly be decreased if more precise definitions of infection were used in clinical practice[46]. Burned surface area, the number of comorbidities, and invasive device use were significantly associated with nosocomial infection in the logistic regression model of risk factors for infection, as identified by either set of criteria. Decreased use of invasive devices, and improved aseptic technique when inserting devices could decrease the rates of nosocomial infections in burn units. CDC has developed evidence-based guidelines for preventing central venous catheter-associated BSIs[47]. Thus, wherever possible, use of indwelling devices should be minimized and these devices should be removed when no longer needed.

ISOLATION GUIDELINES AND ENVIRONMENTAL MEASURES

The followings are the key general measures for preventing the spread infection within burned patients; the implementation of contact precautions (single use masks, gowns, and gloves are worn while in contact with the patient and the hands are washed after finishing contact with the patient), cohort nursing (grouping patients of a given colonization status, with designated Health Care Workers, and a targeted minimum ratio of 1:1 of nursing staff to patients), strict adherence to aseptic techniques for changing dressings, hand disinfection and location of hand disinfectant (alcohol 70% isopropanol/ethanol) dispensers near all beds and installation of Laminar airflow techniques in burn units. Timely closure of the burn wound and the use of a dedicated operating theatre for burn surgeries are other positive factors for controlling burn-related infections in burn units.

DEBATABLE ISSUES ON PREVENTIVE MEASURES FOR BURN INFECTION

The first debatable issue is the use of selective oral bowel decontamination therapy. This was never widely adopted as routine therapy because unnecessary with the advent of early excision wound therapy[48]. The other main point of discussion is hydrotherapy usage in burns. Despite the recognized risk of immersion hydrotherapy treatment in burn units, this was a standard practice in many burn centers until 1990[49]. In addition to possible microbial contamination of the tank water, aerators and agitators in hydrotherapy tubs were difficult to clean leading to risks of cross-contamination between the patients. This problem was partially solved with adding disinfectants to the hydrotherapy tank water, thereby decreasing the microbial load on the burn wound surface and on health care workers[50]. Instead of immersion, showering with a hand-held sprayer has gradually replaced hydrotherapy for cleansing and debridement of the burn wound. Outbreaks of pseudomonas and MRSA related to shower hydrotherapy have been reported[51].

CONCLUSION

Although eradication of infection in burn patients is impossible, a well conducted surveillance infection control program, using novel antimicrobial devices in long-stay patients and analytical antimicrobial therapy may help to reduce infection and mortality rates in burn centers. To limit use of antimicrobial agents and, thereby, reduce the incidence of antimicrobial resistance, burn surgeons should minimize use of prophylactic antimicrobial agents and apply standardized written criteria, such as those developed by the CDC and by Garner et al[52]. Infection control programs must now strive to apply essential control measures and preventive technologies with all types of IVDs in order to reduce the risk of IVDR BSIs in the management of severely burned patients.

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