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Review

Infection control in the burn unit☆

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ABSTRACT

The survival rates for burn patients have improved substantially in the past few decades due to advances in modern medical care in specialized burn centers. Burn wound infections are one of the most important and potentially serious complications that occur in the acute period following injury. In addition to the nature and extent of the thermal injury influencing infections, the type and quantity of microorganisms that colonize the burn wound appear to influence the future risk of invasive wound infection. The focus of medical care needs to be to prevent infection. The value of infection prevention has been acknowledged in organized burn care since its establishment and is of crucial importance. This review focuses on modern aspects of the epidemiology, diagnosis, management, and prevention of burn wound infections and sepsis.

Contents

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1. Introduction

Burns are one of the most common and devastating forms of trauma. Patients with serious thermal injury require immediate specialized care to minimize morbidity and mortality. Data from the National Center for Injury Prevention and Control in the United States shows that approximately 2 million fires are reported each year resulting in 1.2 million burn injuries [1–3]. Moderate to severe burns requiring hospitalization account for approximately 100,000 of these cases and about 5000 patients die annually from burn-related complications [1–6]. In Canada, the estimated number of burn injuries and deaths in serious cases are proportionally smaller on a per capita basis [7–9].

The survival rate for burn patients has improved substantially in the last decade due in part to advances in intensive care management in specialized burn centers. Improved outcome for severely burned patients has been attributed to advances in fluid resuscitation, nutritional support, pulmonary care, burn wound care and infection control practices. As a result, burn-related deaths, depending on the extent of injury, have decreased in the past 40 years [3,6,10–12]. In patients with burns over more than 40% of the total body surface area (TBSA), 75% of all deaths are currently related to sepsis from burn wound infection or other infectious complications and/or inhalation injury [13–17].

The experience accumulated over the past three decades in the early interventional treatment of burn patients has dramatically changed the cause of death; it is now estimated that about 75% of the mortality following burns is related to infections, rather than burn shock and hypovolemia [17]. Knowledge of the responsible bacterial flora of burn wounds, its prevalence, and bacterial resistance becomes of crucial importance for fast and reliable therapeutic decisions [17].

This review focuses on the current epidemiology, diagnosis, management and prevention of burn wound infections and sepsis. Recent factors contributing to the development of burn wound infection including the nature and extent of the burn injury, secondary immunosuppression, prevention of burn wound infection and therapeutic strategies employed by specialized burn care facilities will be reviewed.

2. Epidemiology

Burn wound infections are one of the most important and potentially serious complications that occur in the acute period following injury [18–20]. The most important patient characteristics that influence morbidity and mortality from burn wound infection and sepsis include large TBSA wounds (>30%), significant amounts of full-thickness burns, prolonged open wounds or delayed initial burn wound care. Factors that have favorably impacted the incidence of burn wound infection include early wound closure, topical and prophylactic antimicrobial therapy and advances in infection control measures in modern burn units.

Burns in the elderly constitute more severe injuries than in the general population and result in a higher number of fatalities. A recent review of adult patients admitted to a burn center over a 7 year period showed that 221 of 1557 (11%) were >59 years of age and a higher proportion were women [21]. Most elderly burn patients had one or more preexisting medical conditions and impaired judgment and/or mobility. Approximately one-third of the elderly patients in this study also sustained smoke inhalation injury. Substance abuse as indicated by toxicology screening was a factor in some patients with 10% using alcohol and one-third testing positive for other drugs. Mortality was highest in elderly patients who had more severe burns and/or smoke inhalation injury and existing underlying disease.

A recent study also assessed the factors affecting burn mortality in the elderly and analyzed changes that occurred over the past three decades [10]. The study included 201 patients 75 years of age or older that had been admitted to a university-based burn center between 1972 and 2000. Almost half of these patients died (95 or 47.3%) and the severity of the burn injury as measured by TBSA and the abbreviated burn severity index were both strongly correlated with mortality. Due to improved burn care, however, the elderly are much less likely to die from burns now than in the 1970s unless they have an inhalation injury. Mortality increased significantly with inhalation injury despite advances in intensive respiratory support.

Children have a much higher risk of being burned than adults. In the United States in 2001–2002, an estimated 92,500 children aged 14 years and under required emergency care for burn-related injuries and approximately 500 of these children died [11]. Approximately two-thirds of these children sustained thermal injuries, while children <4 years of age are particularly prone to scald injury [11]. Male children have a higher risk of burn injury and burn-related death than females and obese boys represented a disproportionate number of the patients admitted to a pediatric burn center from 1991 to 1997 [22]. Children who show failure to thrive (e.g., height and/or weight <5% of that expected by age) also have a higher risk of burn injury, perhaps due to the combined effects of malnutrition and neglect or abuse [23]. On the other hand, it has been shown that intravenous drug use and increase alcohol consumption increases the morbidity and mortality associated with burn injury through unclear mechanisms. Warner et al. found that burn patients known to use methamphetamine require very aggressive fluid resuscitation and early cardiac monitoring because of the increased risk of cardiac complications [24].

3. Source of organisms

Sources of organisms may be endogenous (patient's own normal flora) or exogenous (environmental or from health care personnel). Organisms associated with infection in burn patients include gram-positive, gram-negative and yeast or fungal organisms. The distribution of organisms changes over time in individual patients, however, these changes can be ameliorated with appropriate management of the burn wound and the patient [25].

The typical burn wound is initially colonized predominantly with gram-positive organisms, which are rapidly replaced by *antibiotic-susceptible gram-negative* organisms, usually within a week of the burn injury. If wound closure is delayed and the patient becomes colonized and requires treatment with

Fig. 1 – Scanning electron photomicrograph of *Pseudomonas aeruginosa* illustrating microcolonies, polar pillae, and flagellum features that are typical of the organism (from Tredget et al. [29]).

broad-spectrum antibiotics, these organisms may be replaced by yeast, fungi and antibiotic-resistant bacteria. Organisms of particular concern include methicillin-resistant *Staphylococcus aureus* (MRSA), *enterococci*, group A β*-hemolytic streptococcus*, gram-negative rods such as *Pseudomonas aeruginosa* (Fig. 1) and *Escherichia coli* [26,27]. Risk factors identified in patients colonized with drug-resistant organisms include prior use of third-generation cephalosporins and antibiotics active against anaerobes, critically ill patients with severe underlying disease or immunosuppression and prolonged hospital stay. Gram-negative organisms have long been known to cause serious infection in burn patients and have been reported to be associated with a 50% increase in predicted mortality for patients with bacteremia compared with those without bacteremia [28,29].

It is of considerable importance to also be vigilant with certain patient groups especially burn patients who are transferred from other burn units or primary care centers. This patient population is often implicated in hosting a wide array of resistant organisms. As well, patients who are recovering and are in less critical condition who have small colonized or infected wounds and have the ability to ambulate are more likely not to abide by the infection control instructions can also threaten the integrity of infection prevention inside the burn unit. Therefore, isolation of these patient populations in private rooms with contact precaution is recommended [57].

Fungal organisms, especially Candida (yeast) species and molds such as *aspergillus*, *mucor* and *rhizopus*, have been associated with serious infections in burn patients [30]. Candida colonization seems to be primarily from endogenous sources, whereas molds are ubiquitous in the environment and can be found in air handling and ventilation systems, plants and soil [31].

Infections with viruses such as *herpes simplex virus* and *varicella-zoster virus* rarely complicate burn wounds [32].

4. Mode of nosocomial pathogen transmission

Modes of transmission include contact, droplet and airborne. In burn patients the primary mode is direct or indirect contact, either by the hands of the personnel caring for the patient or from contact with inappropriately decontaminated equipment. Burn patients are unique in their susceptibility to colonization from organisms in the environment and in their propensity to disperse organisms into the surrounding environment. In general, the larger the burn injury, the greater the volume of organisms dispersed from the patient into the environment. In almost all cases the colonized patient is thought to be a major reservoir for the epidemic strain [33].

Other important sources include contaminated hydrotherapy equipment; common treatment areas; and contaminated

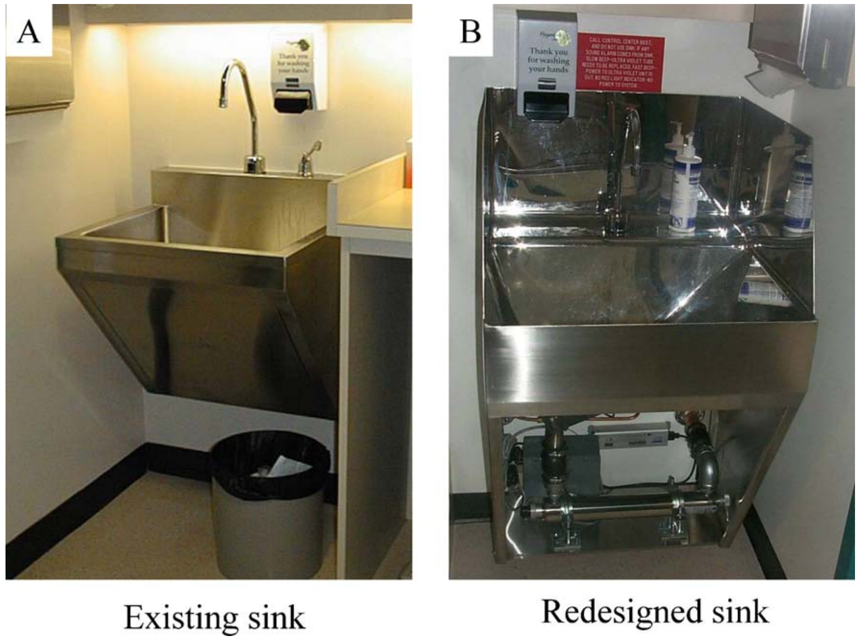

Fig. 2 – (A) Photographs of a defective sink in a burn care facility which led to nosocomial transmission of Pseudomonas that was corrected by a newly designed sink as illustrated (B) (from Tredget et al. [29]).

equipment, such as mattresses, which seem to pose unique risks for cross-contamination in the burn care environment. Risks associated with care of the burn wound, such as hydrotherapy and common treatment rooms, are related to the use of water sources that are frequently contaminated by gram-negative organisms intrinsically and may also be contaminated by organisms from other patients [34]. This aquatic environment is difficult to decontaminate because of continuous reinoculation of organisms from the patients' wound flora and because of the organisms' ability to form a protective glycocalyx in water pipes, drains and other areas, making them resistant to the actions of disinfectants. Adequate decontamination of this equipment (e.g., tanks, stretchers, shower tables, straps) is difficult to achieve between patients using this equipment on a daily basis and monitoring techniques are often insufficient to provide timely detection of contamination. In addition, the patient's own flora may be spread through the water and by caregivers to colonize other sites on the patient that are at increased risk of infection. For example organisms from the wound may migrate to a central venous catheter site or bowel flora may be transferred to the burn wound. The risks associated with a ''common treatment room'' involve the contamination of the surrounding environment and the difficulty in ensuring the room is appropriately cleaned between successive patients. This is difficult to ensure given the number of procedures performed each day and the necessity of stocking the room with dressing supplies for multiple patients [35,36].

The other principal modes of transmission in burn units are by the hands of the personnel and contact with inadequately decontaminated equipment or surfaces. The two areas most likely to become contaminated when caring for the burn patient are the hands and gowns of the personnel, because the surfaces (i.e., beds, side rails, tables, equipment) are often heavily contaminated with organisms from the patient [37]. Likewise, all equipment used on the patient (i.e., blood pressure cuffs, thermometers, wheelchairs, IV pumps) is also heavily contaminated and the same may be transmitted to other patients if strict barriers are not maintained and appropriate decontamination performed. A single cause is uncommon in a burn unit outbreak; in almost all instances, multiple factors contribute to occurrence and perpetuation of infecting organisms [33]. Recently, the propensity of improperly designed hand washing sinks has been recognized as a mechanism of spread of nosocomially acquired *P. aeruginosa* in burn units and intensive care facilities, which has led to the design of novel sink design (Fig. 2) and increased use of alcohol hand wash for the prevention of hand to hand transmission of pathogens [29,38].

5. Patient susceptibility

Very young children and the elderly have an increased risk of poor clinical outcome than patients in other age groups [11,23,39]. Individuals with self-inflicted burn injuries and the disabled have been shown to have more severe injuries with longer hospital stays than those with accidental injuries [40]. Obese adults and those who have underlying medical conditions, such as diabetes, have also been shown to have higher morbidity and mortality [41,42]. AIDS patients seem to have more complications because of infection, delayed wound healing and increased mortality, although reported outcome data for HIV-infected and AIDS patients is limited [9,43,44]. It is expected that burn patients with other types of severe immunosuppression have similar problems, particularly

Table 1 – Summary of common features of outbreaks in burn unit.

Year	Organism	Modes of transmission and reservoirs: Hand carriage	Hydrotherapy and related equipment	Other patient care equipment/surfaces	Staff carriage	Breaks in precaution techniques	Staffing patterns
1971 [68]	*P. aeruginosa*	X	X	sink faucets towel racks			
1975 [69]	*Salmonella typhimurium*	X				X	
1976 [70]	*Providencia stuartii*	X		X			
1979 [71]	*P. aeruginosa*						
1979 [72]	*E. cloacae*	X	X				X
1979 [73][†]	MRSA[*]	X	X		X		
1981 [74]	*P. aeruginosa*[*]			Mattress			
1982 [75]	MRSA[*]	X			X		
1982 [76]	MRSA[*]	X	X		X		X
1983 [77]	MRSA[*]	X	X	X			
1983 [78][‡]	MRSA[*]	X					
1985 [79]	*A. calcoaceticus*	X	X	Mattress[§] and other			
1992 [26]	*P. aeruginosa*[*]		X[‖]				
1993 [80]	*A. anitratus*[*]			Mattress			
1993 [81]	*P. aeruginosa*		X				
1994 [82]	*P. aeruginosa*[*]		X			X	
1994 [83]	MRSA[*]	X		OR Surfaces		X	
1994 [84]	*P. aeruginosa*[*]		X				
1995 [85]	*A. baumanii*[*]	X		X			
1996 [86]	Group A streptococci				X		
1998 [87]	*P. aeruginosa*[*]						
1998 [88]	*A. xylosoxidans*		X				
2001 [89][†]	MRSA[*]		X[‖]				
2001 [90]	*A. baumanii*[*]			Door handles and other	X		
2001 [91]	*P. aeruginosa*[*]						
2002 [92][†]	*A. baumanii*[*]	X	X	X		X	
2002 [93]	*A. baumanii*[*]						
2003 [94]	*A. baumanii*	X		X		X	
2007 [95]	*A. baumannii*[*]		X	Room surfaces			
2008 [96]	MRSA[*]			Aerosolization during dressing changes			

MRSA, Methicillin-resistant Staphylococcus aureus.
[*] Strains resistant to multiple antibiotics.
[†] Unit closed for decontamination and cleaning.
[‡] Unit permanently closed.
[§] Major reservoir identified.
[‖] Hydrotherapy discontinued. With permission from Weber et al. [48].

increased problems with wound infection, sepsis and higher mortality.

Normally, the patient has three principal defenses against infection: physical defenses, nonspecific immune response and a specific immune response. Changes in these defenses determine the patient's susceptibility to infection. Invasive devices, such as endotracheal tubes, intravascular catheters and urinary catheters, all contribute. Infection from intravascular catheters is of particular concern in burn patients, because often these lines must be placed directly through or near burn-injured tissue. Catheter-associated bloodstream infection is caused by organisms that migrate along the catheter from the insertion site and colonize the catheter tip [45]. Catheter tips are also susceptible to colonization from hematogenous seeding of organisms from the colonized burn wound. Risk factors for the development of a burn wound infection [46] are listed in Table 1.

6. Incidence of infection

Specific sites of infection that are particularly important for burn patients include bloodstream infection, pneumonia, burn wound infection and urinary tract infection. Fever, a highly specific indicator of infection for many patient populations, often does not correlate well with the presence of infection in burn patients, because of core temperature increases and an increase in heat production, associated with the onset of a hypermetabolic response [47]. As a result, fever alone, in the absence of other signs and symptoms, is not often indicative of infection. Furthermore, gauging burn wound sepsis by clinical signs and symptoms is difficult and diagnosis is best made by careful serial evaluations of the wound. Patients with extensive burn wounds generally manifest physiologic changes associated with hypermetabolism, including tachycardia, hypothermia or hyperthermia, tachypnea, ileus, glucose intolerance and mental status changes. Clinical signs suggestive of burn wound infection that need attention in particular include the progression of partial-thickness to full-thickness injury and change in wound color, green discoloration of subcutaneous fat, violaceous discoloration and edema of wound margins, subeschar hemorrhage or rapid eschar separation [48].

Catheter-associated blood stream infection (BSI) rates for burn intensive care units (ICUs) enrolled in the National Nosocomial Infections Surveillance (NNIS) System, Centers for Disease Control and Prevention (CDC) in the United States from January 1995 to June 2002 were 8.8 per 1000 central venous catheter days (CVC), compared with pooled mean rates of 7.4 for pediatric ICUs, 7.9 for trauma ICUs, and 5.2 for surgical ICUs. These rates include both adult and pediatric burn patients [8].

Incidence of infection is also affected by the size of the patient's burn injury. At Shiners' Burn Hospital for Children in Boston the incidence of infection was determined for patients with $<$30% TBSA burn injury compared to patients with $\geq$30% TBSA burn injury from January 1996 to December 2000 for BSI, pneumonia, urinary tract infection (UTI), and non-invasive and invasive wound infection. The overall incidence of infection was low for patients with $<$30% TBSA burn injuries and generally associated with the need for invasive devices. Invasive burn wound infection was seen in only 4 of 645 patients during this period, all in patients with $\geq$30% TBSA. Bloodstream infection (BSI) increases dramatically as burn wound size increases, which is related to increased exposure to intravascular catheters and to burn wound manipulation-induced bacteremia [48].

7. Burn unit outbreaks

Outbreaks of cross-colonization and infection are a major challenge in burn units, requiring a clear understanding of how and why they occur if they are to be prevented and controlled. Common features associated with burn unit outbreaks over the past 25 years include, strains that are resistant to multiple antibiotics, the closure of units for decontamination and cleaning, permanent closure of centers or the reservoir identified e.g.: hydrotherapy discontinued. The exact cause for many of these outbreaks could not be determined, however certain patterns are clear. In almost all cases the colonized patient is thought to be a major reservoir for the epidemic strain. For patients at increased risk of infection (those with $>$25% TBSA or with invasive devices) hydrotherapy and common treatment rooms should be used cautiously, if at all. When possible, dressings should be changed at the patient's bedside, this may be preferable to exposing these patients to the risks of common treatment rooms or hydrotherapy. In many burn units currently, patient dressings are performed at the bedside to decrease the risks of cross-contamination and consequently the incidence of cross-infection has remained very low (less than 5% of infections) for the past 25 years [33].

8. Culturing and surveillance

Surveillance of infection has been reported to diminish the rate of nosocomial infection [49–51]. Systematic collection of data allows the burn unit to monitor changes in infection rates over time, identify trends and evaluate current treatment methods. Culturing and surveillance guidelines have to be more stringent for the burn patient, particularly those with large TBSA involvement, because of the increased propensity for infection and its transmission [29]. Burn wound flora and antibiotic-susceptibility patterns have been reported to change during the course of a patient's hospitalization and further transmission can be prevented by early identification of organisms colonizing the wound, monitoring the effectiveness of current wound treatment and controlled perioperative or empiric antibiotic therapy and detecting cross-colonization, quickly when it occurs.

Infection control protocols include surveillance cultures on an as needed basis, cohort patient care teams, strict enforcement of patient and staff hygiene, alcohol-based hand washing product dispensers throughout the burn unit, patient isolation, monitoring of antibiotic use and monitoring antibiotic-susceptibility results. A reliable and highly discriminatory typing method is also important to determine the path of transmission for nosocomial outbreaks. Genotyping methods represent more stable markers for tracking Pseudomonas strains; they are based on differences in chromosomal DNA rather than on phenotypical differences. Older typing methods such as serotyping, isoelectric focusing of pyoveridin or phage typing are susceptible to the rapid phenotyping changes resulting from gene regulation. Restriction fragment length polymorphism, pulsed field gel electrophoresis (Fig. 3), random amplification of polymorphic DNA and more recently multilocus sequence typing are commonly used to study the evolution and spread of antibiotic-resistant Pseudomonas. We believe the results presented in this retrospective study support the cost effectiveness of a preventative approach toward nosocomial pseudomonas transmission in burns [52].

9. Isolation and unit design

Standard precautions should be followed when caring for all patients with burn injury. The effectiveness of simple protective barrier precautions in reducing nosocomial colonization and infection was shown in a study by Klein et al. [53] in a pediatric ICU. Most burn units also support the concept of barrier techniques and isolation; although there was no consensus about which type was preferable [54]. The presence of large, open burn wounds appears to increase the environ-

Fig. 3 – Pulsed gel electrophoresis of four *Pseudomonas aeruginosa* clinical isolates and sink trap organisms within a burn care facility confirming the identical nature of the organism within the patients and the sinks (from Tredget et al. [29].

mental contamination present around the patient, which is one unique difference in burn patients compared to other types of critical illness. The larger the burn size the more vulnerable it is to contamination. Although the use of personal protective garments for all healthcare professionals involved with caring for the wounds of patients in the burn unit is primarily for personal protection, some studies advocate the use of gowns and aprons as a means to decrease possible cross-contamination and wound colonization. It is also recommended all surfaces be decontaminated following a dressing change. The use of sterile gloves and masks while dealing with an open wound is also of crucial importance [34] and finally, it is also advisable to minimize wound exposure time and keep the contact with different healthcare professionals as restricted as possible. Appropriate personal protective equipment should also be worn when decontaminating this equipment.

10. Impact of nosocomial infections on outcome

Although the recognition of infection in the burn population should include the cardinal signs of infection, pyrexia or fever alone can not be a reliable indicator of infection in burns. Moreover, burn wound infection in these patients should be diagnosed by regular, frequent evaluation of the wounds in addition to the other clinical signs of systemic infection. Patients with burn wounds greater than 15–20% TBSA usually develop signs and symptoms of a hypermetabolic state that can include low grade fever that mimics the clinical manifestations of infection. Therefore, the progression of wounds to full thickness from partial thickness, the presence of offensive discharge and easy separation of the eschar are more specific indices of infection. Infections from other areas independent of the burn wound are common and should be considered in this patient population. Sites such as the blood stream, respiratory tract, urinary tract, peripheral and central venous or arterial cannulas should also be investigated when signs of infection exist [47]. Recently, the importance of very early timely, aggressive management of sepsis in intensive care environments such as burn units has been recognized as an important factor in improved outcomes.

P. aeruginosa remains an important infectious threat to patients with thermal injuries. The ubiquity of this organism, its environmental resilience, its relative resistance to antibiotics and its flexible nutritional and metabolic requirements help account for the frequency and success with which it acts as an opportunistic pathogen. Despite advances in medical and surgical care, it is often not possible to prevent all *P. aeruginosa* and other types of infections in burn patients. We found that by delaying the onset of pseudomonas infections to beyond the first 30 days post-burn injury, there is a substantial reduction in the mortality among the burn patients as compared to burn patients who were otherwise matched for the severity of injury and other major predictors of mortality who were contaminated within the first 30 days post-injury. When nosocomial transmission of aminoglycoside resistant *P. aeruginosa* occurred in burn patients during the acute stage of burn injury (within the first 30 days), there was a seven fold increase in mortality, as well as a significant increase in the number of surgical procedures, blood products required, and antibiotics administered. These early breaks in infection control led to significant potentially avoidable increases in the overall cost of care as compared to non-contaminated burn patients treated in the same burn center that were otherwise not significantly different in severity of injury or age [52]. Furthermore, the substantially greater resource consumption required to treat these nosocomially infected patients did not prevent significantly higher mortality rates when compared to case-matched control patients [52]. Thus, prevention, identification and eradication of nosocomial pseudomonas colonization and likely most other pathogens is critical for cost-effective, successful burn care [52].

11. Prevention

Prevention of burn wound infection involves assessment of the wound at each dressing change for changes in the character, odor or amount of wound drainage. Strict aseptic technique should be used when handling the open wound and dressing materials and frequency of dressing should be based on wound condition. If the wound has necrotic material present, a debriding dressing should be chosen, whereas a protective dressing is preferable for clean healing wounds. Treatment of an existing wound infection includes considering changes to the topical agent being used along with changing the frequency of the dressing changes. In those cases where invasive infection is present, surgical excision of the infected wound and appropriate systemic antimicrobial therapy may be required.

Prevention of bloodstream infection centers on appropriate care of the burn wound, to minimize the extent of hematogenous seeding and appropriate handling of intravascular devices. Whenever possible, catheters should be placed through unburned skin, preferably at a sufficient distance from the wound to prevent contamination of the insertion site. Because this is not always feasible in patients with large burn injuries, who require long-term vascular access, frequent change of the catheter may be required. The optimum frequency for changing central venous catheters has not been definitively determined. Some advocate changing the catheter to a new site every 3 days, others prefer less frequent replacement protocols [55,56]. Care of an intravenous catheter site through or near a burn wound presents a challenge, because occlusive dressings cannot be used. A non-occlusive povidone–iodine dressing changed every 2–4 h depending on the degree of surrounding wound contamination has been recommended in such cases [57]. At our institution, the practice is to use 2% chlorhexidine gluconate and 70% isopropyl alcohol for insertion, then change the dressing every 48 h unless it becomes damp, loose, soiled or non-occlusive as recommended in the CDC guidelines [51].

12. Infection control

Treatment of pneumonia should be started promptly, with systemic antibiotic selection modified when culture and sensitivity results are available. Treatment should also include vigorous chest physiotherapy, turning, deep breathing, coughing and suctioning. Newer ventilatory strategies, such as high-frequency ventilation and permissive hypercapnia, to prevent or treat patients with pneumonia and severe respiratory compromise have also been recommended [58].

Treatment of catheter-associated urinary tract infection includes removal of the catheter, when possible and use of systemic antimicrobial agents. Prevention of urinary tract infection includes removal of the catheter as soon as it is no longer required for clinical monitoring of urine output, maintaining a closed urinary drainage system and urinary catheter care. Improved strict adherence to aseptic technique in placement of central venous catheters has been associated with significant improvements in infection rates in intensive environments [59].

Universal precautions are a standard practice when caring for all patients with burn injury. The open burn wound increases the environmental contamination present around the patient, which is the major difference in burn versus non-burn patients. The larger the burn size the more vulnerable it is to contamination. Although the use of personal protective garments for all healthcare professionals involved with caring for the wounds of patients in the burn unit is primarily for personal protection, some studies advocate the use of gowns and aprons as a mean to decrease possible cross-contamination and wound colonization. It is also recommended all surfaces be decontaminated following a dressing change. The use of sterile gloves and masks while dealing with an open wound is also of crucial importance [34] and finally, it is also advisable to minimize wound exposure time and keep the contact with different healthcare professionals as restricted as possible.

Two groups of burn patients are unique and require additional precautions: patients with larger burn injuries (>25–30% TBSA) and those colonized with multiply resistant organisms [60]. Patients with >30% TBSA burn injuries are also immunocompromised, because of the larger size of their injury. This, in combination with their loss of physical defenses and need for invasive devices, significantly increases their risk of infection. These patients also represent a significant risk for contamination of their surrounding environment with organisms, which may then be spread to other patients on the unit. These may include multiply resistant organisms, if broad-spectrum antibiotic treatment has been required to treat infectious complications. For these reasons, it is recommended that patients with larger burn injuries be isolated in private rooms or other enclosed bed spaces to ensure physical separation from other patients on the unit. Such isolation has been associated with a decrease in cross-transmission of organisms [61].

Special attention is also required for patients with smaller burn injuries who are colonized or infected with multiple drug-resistant organisms (i.e., *methicillin-resistant S aureus*, *vancomycin-resistant enterococci*, multiple drug-resistant gram-negative organisms). This is especially true for patients with wound drainage that cannot be adequately contained in dry, occlusive dressings or pediatric patients who cannot comply with hand washing or other precautions.

Patients transferred to the burn unit after treatment in another hospital should also be included in this group until the results of their admission cultures are known. These patients are frequently colonized with resistant organisms and may serve as an unsuspected reservoir for transmission to other patients unless they are isolated. Isolation for this group of patients generally includes placement in a private room and contact precautions, with the addition of droplet precautions in some circumstances [62].

Patients colonized with multiple drug resistant organisms must frequently have their need for isolation balanced with their need for rehabilitation and psychosocial needs. In general, if the patient's dressing cannot be occlusive, the patient should not be taken to the rehabilitation department for therapy when other patients are present in the same area. If rehabilitation needs cannot be met in the patient's room, then sufficient time should be scheduled in the rehabilitation department to allow for the patient's treatment followed by thorough cleaning of all equipment and surfaces before the area is used by other patients. The rehabilitation therapy staff should wear appropriate attire during therapy [33].

Disinfection and sterilization guidelines for patient care equipment must take into account the presence of sometimes extensive, open wounds, which is the major difference separating this population from other patient populations. Many items, such as blood pressure cuffs, stethoscopes and bedpans, if used on areas without dry, occlusive dressings, may need high-level disinfection or be restricted to an individual patient [63]. Pediatric burn patients should also have policies restricting the presence of non-washable toys, such as stuffed animals and cloth objects. These can harbor large numbers of bacteria and are difficult to disinfect.

Routine cleaning, disposal of waste and gathering of soiled linen is essential to reduce the load of organisms and ensure that the unit is as clean as possible. Routine environmental surveillance culturing is generally limited to the hydrotherapy room and common treatment room used in burn wound care; however, its scope needs to be extended [63].

Plants and flowers should not be allowed in units with burn patients because they harbor gram-negative organisms, such as *Pseudomonas species*, other enteric gram-negative organisms and fungi. Many of these organisms are intrinsically resistant to multiple antibiotics, which may serve as reservoirs to colonize the burn wound [60].

Modern burn centers have a contained perimeter that is designed to minimize unnecessary traffic of health care workers and visitors through the unit [64–66]. Cross-contamination is further diminished within the burn unit by housing burn patients in individual nursing units composed of individual isolation rooms, each with its own laminar airflow [67]. Nosocomial outbreaks caused by antibiotic-resistant organisms have been described in modern burn units because critically ill burn patients and equipment had to be moved between the burn unit and the trauma intensive care unit [65]. Modern burn unit designs should allow all intensive and burn care procedures, including mechanical ventilation and operative procedures, to be done within the burn center itself or, as a minimum, the facility design should minimize the need to transfer patients out of the burn unit for different aspects of their care.

Conflict of interest

None.

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