

INFECTION CONTROL IN BURN PATIENTS

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Introduction

Infection in the burn patient is a leading cause of morbidity and mortality and remains one of the most challenging concerns for the burn team. The importance of preventing infection has been recognized in organized burn care since its inception and has followed recurring themes through the years. These included strict aseptic technique, use of sterile gloves and dressing materials, wearing masks for dressing changes, and spatial separation of patients, either using private rooms or cubicles.¹⁻⁴ Certain practices have been discarded, such as routine use of prophylactic antibiotics; use of sterile sheets, introduced following the exposure method of burn treatment; and the practice of infrequent dressing changes in the early post-burn period.

This article will provide a comprehensive review of the epidemiology of infection in the burn patient, including factors affecting risk of colonization and infection and outbreaks that have occurred on burn units. Strategies for infection prevention and control, including unique characteristics, guidelines for culturing and surveillance, isolation of patients, environmental concerns, use of antibiotics, and recommendations for infection prevention at specific sites will be discussed.

Epidemiology of Infection

The development of infection depends on the presence of three conditions, a source of organisms; a mode of transmission; and the susceptibility of the patient. Infection risk for burn patients is different from other patients in several important respects and these differences are included in the discussion below.

Sources of Organisms

Sources of organisms are found in the patient's own endogenous (normal) flora, from exogenous sources in the environment, and from healthcare personnel. Exogenous organisms from the hospital environment are generally more resistant to antimicrobial agents than endogenous organisms. Organisms associated with infection in burn patients include gram-positive, gram-negative, and yeast/fungal organisms. The distribution of organisms changes over time in the individual patient and such changes can be ameliorated with appropriate management of the burn wound and patient. The typical burn wound is initially colonized predominantly with gram-positive organisms, which are fairly quickly replaced by antibiotic-susceptible gram-negative organisms, usually within a week of the burn injury. If wound closure is delayed and the patient becomes infected, requiring treatment with broad-spectrum antibiotics, these flora may be replaced by yeasts, fungi, and antibiotic-resistant bacteria.

Gram-positive organisms of particular concern include methicillin-resistant *S.aureus* (MRSA), enterococci, group A beta-hemolytic *Streptococcus* and coagulase negative *Staphylococcus*. MRSA was first seen in the United States in the late 1960s and has become an endemic organism in many burn units. It has been argued that no extraordinary efforts be made to control its spread, however this view has been increasingly challenged in the era of vancomycin-resistant enterococcus (VRE). With the increasing incidence of VRE in hospitals, the risks associated with infection with this organism are increasing. Risk factors identified in patients colonized with VRE include prior vancomycin use, prior use of third generation cephalosporins and antibiotics active against anaerobes, a critically ill patient with severe underlying disease or immunosuppression, and a prolonged hospital stay. These factors are all present in patients with a large burn injury, including prior vancomycin use in units with a high endemic rate of MRSA.

Gram-negative organisms have long been known to cause serious infection in burn patients. Gram-negative bacteremia has been associated with a 50% increase in predicted mortality for patients with bacteremia compared to those without bacteremia.⁵ This is in contrast to gram-positive bacteremia, which

was associated with no increase in predicted mortality. In a subsequent study, it was found that this increased risk of mortality could be reversed if the occurrence of the bacteremia was delayed which was related to a longer exposure to the effects of treatment and wound closure.

Fungal organisms, especially *Candida* (yeast) species and true fungi (mold) like *Aspergillus*, *Mucor* and *Rhizopus*, have been associated with serious infections in burn patients. *Candida* colonization appear to be primarily from endogenous sources while true fungi are ubiquitous in the environment and can be found in air handling and ventilation systems, plants, and soil.⁶

Mode of Transmission

Modes of transmission include contact, droplet and airborne spread. In burn patients the primary mode is direct or indirect contact, either via 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 as well as in their propensity to disperse organisms into the surrounding environment. In general, the larger the burn injury, the greater the volume of organisms that will be dispersed into the environment from the patient.

Patient Susceptibility

The patient has three principal defenses against infection: physical defenses, nonspecific immune responses, and specific immune responses. Changes in these defenses determine the patient's susceptibility to infection. Physical defenses against infection are listed in Table 1 along with changes induced by burn injury.

Invasive devices, such as endotracheal tubes, intravascular catheters and urinary catheters, bypass the body's normal defense mechanisms. In general, pediatric patients have fewer problems with pneumonia than do adults because they are less likely to have pre-existing lung damage. Infection from intravascular catheters is of particular concern in burn patients, as often these lines must be placed directly through or near burn injured tissue. Catheter associated bloodstream infection (BSI) is caused by organisms which migrate along the catheter from the insertion site and colonize the catheter tip.⁷ Catheter tips are also susceptible to colonization from hematogenous seeding of organisms from the colonized burn wound.

Incidence of Infection

Catheter-associated 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 SBH, 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, and non-invasive and invasive wound infection (see Figure 1). 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, related to increased exposure to intravascular catheters and to burn wound manipulation-induced bacteremia. At Shriners Burn Hospital (SBH), Boston from 1996-2000 there were 3 cases of BSI in 585 patients with <30% TBSA burn injury compared to 55 cases of BSI in 60 patients with $\geq 30\%$ TBSA. In this series, pneumonia occurred only in ventilated patient, accounting for all 15 cases seen. Similarly, urinary tract infection (UTI) occurred principally in patients with indwelling urinary catheters, accounting for 33 of the 36 cases seen. The rates of device associated infection for SBH-Boston and the NNIS System infection rates for burn ICUs from January 1995 to June 2002 are shown in Figure 2.

Outbreaks On Burn Units

Outbreaks of cross colonization and infection are a major challenge on 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 24 years are listed in Table 2. 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. Other important sources include contaminated hydrotherapy equipment, common treatment areas, and contaminated equipment such as mattresses, which appear to pose unique risks of cross contamination in the burn 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.⁹ 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, plinths, shower tables, straps) is difficult to achieve between patients using this equipment on a daily basis and monitoring techniques are 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 assuring that the room is appropriately cleaned between successive patients. This is difficult to assure given the number of procedures which are performed each day and the necessity of stocking the room with dressing supplies for multiple patients. For patients at increased risk of infection (those with greater than 25% burn or with invasive devices) hydrotherapy and common treatment rooms should be used cautiously, if at all. If dressings can be changed at the patient bedside, this is preferable to exposing these patients to the risks of common treatment rooms or hydrotherapy. At SBH, Boston all 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.

The other principal modes of transmission in burn units are via 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 apron area of the person, as the surfaces (e.g., beds, side rails, tables, equipment) are often heavily contaminated with organisms from the patient. Likewise all equipment used on the patient (e.g., blood pressure cuffs, thermometers, wheelchairs, IV pumps) are also heavily contaminated and may be transmitted to other patients if strict barriers are not maintained and appropriate decontamination carried out. In fact, a single cause is uncommon in a burn unit outbreak; in almost all instances, multiple factors contribute to its occurrence and perpetuation.

Culturing and Surveillance

Culturing and surveillance guidelines are more stringent for the burn patient, particularly the patient with larger injuries, because of the increased propensity for transmission and infection in this population. Burn wound flora and antibiotic susceptibility patterns change during the course of the patient's hospitalization so that the purposes of obtaining routine surveillance cultures are:

- to provide early identification of organisms colonizing the wound
- to monitor the effectiveness of current wound treatment
- to guide perioperative or empiric antibiotic therapy
- to detect any cross-colonizations which occur quickly so that further transmission can be prevented.

Routine surveillance wound cultures should be obtained when the patient is admitted and at least weekly until the wound is closed. Many burn centers recommend obtaining wound cultures two or three times a week for patients with large burn injuries. Admission cultures are particularly important for patients transferred from other facilities, as they may be colonized with multiply resistant organisms and serve as an unsuspected reservoir for cross-transmission to other patients on the unit. For pediatric patients, admission throat cultures are also recommended as about 5% of the population will be colonized with Group A beta-hemolytic *Streptococcus* (*S.pyogenes*) which can have serious consequences if it is transmitted to the burn wound.

Methods of burn wound culturing include obtaining a semi-quantitative swab culture or a quantitative biopsy specimen. Semi-quantitative swab cultures provide information on the type of organisms present on the burn wound, as well as the approximate amount and antimicrobial susceptibility. A general rule is to obtain a swab culture for each 10% of open burn to identify organisms of significance on the wound. Quantitative cultures are used to define invasive infection based on bacterial count of 100,000 colonies or more per gram of tissue. However, further study has revealed that this technique is not precise, as 50% of patients with quantitative counts of greater than 100,000 organisms do not have histologic evidence of invasive infection.¹⁰ Furthermore, quantitative culturing is more costly and labor-intensive than swab cultures, and their routine use to identify colonizing organisms on *appropriately* debrided wounds is rarely indicated. Accurate diagnosis of invasive burn wound infection is best determined by clinical criteria, supported when possible by histopathologic examination if the patient's condition is suspicious for this infection.⁹

Surveillance of infection has been shown to diminish the rate of nosocomial infection^{11,12} as well as reduce cost.^{13,14} Surveillance of infection in burn patients should be done to monitor incidence and rates which have been appropriately risk adjusted by size of burn injury and invasive device use. At a minimum, surveillance should include collection of data on burn wound infection, urinary tract infection, pneumonia, and bloodstream infection. Systematic collection of data allows the burn unit to monitor changes in infection rates over time, identify trends, and evaluate current treatment methods.

Isolation Guidelines

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.¹⁵ in a pediatric ICU. Most burn units also supported the concept of barrier techniques and isolation; although there was variation in which types were felt to be appropriate.¹⁶ The open burn wound increases the environmental contamination present around the patient, which is the major difference in burn versus non-burn patients. The degree or amount of contamination is roughly proportional to the size of the open wound and amount of colonization present and is inversely proportional to the distance from the patient. For this reason, appropriate barrier garb is recommended for *any* patient contact unless wounds are minimal and can be occlusively wrapped. The decision to use clean gowns versus plastic aprons should be evaluated for adequacy of protection, ease of use, comfort, and cost. At SBH, Boston plastic aprons are used as they provide all the needed requirements and are felt to be easier to use than gowns. If arms are at risk of becoming contaminated, shoulder-length gauntlets are added. Other requirements of standard precautions include appropriate handwashing, removal of garb immediately upon leaving the room, changing gloves that become contaminated with patient secretions or excretions before contact with another site, and addition of sterile gloves, hats and masks when caring for an open burn wound or other sterile procedures. Equipment and surfaces are considered contaminated following use and should be appropriately decontaminated before storage or use on other patients. Appropriate garb should also be worn when decontaminating this equipment.

Category Specific Precautions

Two groups of burn patients are unique and require additional precautions, patients with larger burn injuries (greater than 25% to 30% TBSA burn) and those colonized with multiply resistant organisms.⁹

Patients with greater than 30% TBSA burn injuries are more immunocompromised, due to 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.^{17,18} Laminar airflow units, in place of private rooms, are used at SBH, Boston.¹⁹ For infection control purposes, either method can provide effective isolation if their use is strictly adhered to. The advantage of laminar air flow units is their unfamiliar appearance to visitors and

personnel from outside the burn unit resulting in increased compliance with infection control practices as these individuals typically ask burn unit personnel what must be worn before seeing the patient.

Special attention is also required for patients with smaller burn injuries who are colonized or infected with multiply resistant organisms (e.g. MRSA, VRE, multiply resistant gram negative organisms). This is especially true for patients with wound drainage that cannot be adequately contained in dry, occlusively wrapped outer 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 on contact precautions, with the addition of droplet precautions in some circumstances.

Patients colonized with multiply resistant organisms must frequently have their need for isolation balanced against their need for rehabilitation. In general, if the patient's wound cannot be occlusively wrapped in a dry outer dressing, the patient should not be taken to the rehabilitation department for therapy when other patients will be 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 afterwards before the area is used by other patients. The rehabilitation therapy staff should wear appropriate attire during therapy.

Environmental Issues

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. Following Spaulding's scheme for categorizing patient care items and equipment,²⁰ the changes for the burn patient population involve what are considered "semicritical" and "noncritical" items. Many items such as blood pressure cuffs, stethoscopes, bedpans, if used on areas without dry, occlusive dressings, may need high-level disinfection as a semicritical item or may need to be restricted to an individual patient.

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.²¹

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. Toys should be nonporous and washable, designated for individual patient use, and thoroughly disinfected after use and before being given to another child to use. Paper items, such as storybooks and coloring books, should always be designated for single patient use and should be disposed of if they become grossly contaminated or when the child is discharged.

The importance of well trained, dedicated, environmental services support for units caring for burn patients cannot be overemphasized. Routine cleaning, disposal of waste, and gathering of soiled linen is essential to reduce the bioburden of organisms which are present and ensure that the unit is as clean as possible.

Routine environmental surveillance culturing is not generally recommended on units with burn patients. The exception may be the hydrotherapy room and common treatment room used in burn wound care. Environmental culturing is important as part of any outbreak investigation which is done on the burn unit. If environmental culturing is considered; either for routine use in hydrotherapy/treatment rooms, in outbreaks, or for educational purposes; the hospital's infection control department should be consulted for guidance on the location, types, and frequency of culturing and interpretation of results.

Antimicrobials and Burns

Systemic antimicrobial treatment must be thoughtfully considered in the care of the burn patient to prevent the emergence of resistant organisms. The burn wound will always be colonized with organisms until wound closure is achieved and administration of systemic antimicrobials will not eliminate this colonization but rather promote emergence of resistant organisms. If antimicrobial therapy is indicated to treat a specific infection, it should be tailored to the specific susceptibility patterns of the organisms, as soon as this information is available. Also, if antibacterial treatment is necessary, awareness should be heightened for the possibility of superinfection with resistant organisms, yeasts, or fungi. Systemic antimicrobials are indicated to treat documented infections, such as pneumonia, bacteremia, wound infection, and urinary tract infection (UTI). Empiric 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 surrounding excision or grafting of the burn wound when it is used to cover the documented increase in risk of transient bacteremia. Treatment should be started immediately prior to the procedure and generally discontinued within 24 hours, assuming restoration of normal cardiovascular hemodynamics. Prophylactic penicillin therapy in the early post-burn period may be recommended if there is a delay in quick identification and treatment of pediatric patients colonized with group A beta-hemolytic streptococci.

Sites of Infection and Prevention Techniques

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 patients with burn injuries, particularly large injuries. In burn injuries, the skin and core temperatures increase, and there is an increase in heat production, which is associated with the onset of a hypermetabolic response. The core temperature is commonly "reset" to a higher level (38° to 39°C [100.4° to 102.2°F])²². Because of this response, fever alone, without other signs and symptoms, is not indicative of infection.

Burn Wound Infection

Overall, the incidence of burn wound infection has declined in recent years with the change to early excision and wound closure. As the size of the wound increases, so does the risk of infection. Causes of burn wound infection relate to the loss of the protective barrier of the skin and thrombosis of the subcutaneous blood vessels. The resulting avascular wound bed makes an excellent medium, which can support the growth of microorganisms as well as prevent the penetration of systemically administered antimicrobial drugs. Burn wound infection can be subdivided into local or non-invasive infection and invasive infection. Local wound infection is characterized by erythema or cellulitis, purulent drainage, graft loss, fever >38.5°C and leukocytosis. Invasive wound infection is characterized by conversion of partial-thickness to full-thickness injury, rapid eschar separation, necrosis of small blood vessels, edema, erythema, and tenderness at the wound edges. Systemically, the patient may be hypothermic or hyperthermic, hypotensive, have a decreased urine output and ileus. Laboratory results will reveal leukocytosis or leukopenia, thrombocytopenia, positive blood cultures, hyperglycemia and invasion of organisms into viable tissue on histopathologic examination of the wound.

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, with immediate notification of the physician if any deterioration occurs. Strict aseptic technique should be used when handling the open wound and dressing materials as well as frequency of dressing should be based on the assessment of the wound condition. If the wound has necrotic material present, a debriding dressing should be chosen while a protective dressing is best for clean, healing wounds.

Treatment of an existing wound infection includes consideration of a change of the topical agent being used along with increasing the frequency of the dressing changes. If an invasive infection is present, surgical excision of the infected wound is usually required, as well as appropriate systemic antimicrobial therapy.

Bloodstream and Intravascular Catheter Infection

Bloodstream infection occurs more often in burn patients than in any other patient population. Intravascular catheter-associated bloodstream infection rates are higher in the burn population than in any other. These two facts are related to the hematogenous seeding of catheters that often occurs related to the colonized or infected burn wound and to the often-necessary placement of catheters near or through the wound in patients with extensive injuries.

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. This is not always feasible in patients with large burn injuries, requiring long-term vascular access. The optimum frequency for changing central venous catheters has not been definitively determined in burn patients. Some centers change catheters to a new site every 3 days, whereas others perform less frequent replacement protocols. At SBH, Boston catheters are changed approximately every 7 days, either to a new site or over a guide wire with a low rate of catheter-associated infection.²³⁻²⁵ Arterial catheters generally are associated with a low risk of infection. In pediatric patients, use of the femoral artery is sometimes required and is associated with a low rate of infectious and mechanical complication at SBH Boston²⁶, if proper care is used in its insertion.

Insertion site care of intravascular catheters placed through or near a burn wound presents a challenge, as occlusive dressings cannot be used. Common practice includes treatment of the insertion site with the same antimicrobial as the surrounding burn wound. A non-occlusive povidone-iodine dressing is used at SBH, Boston which is changed every 2 to 4 hours, depending on the degree of surrounding wound contamination.²⁷

Pneumonia

Pneumonia has become a more prominent cause of significant morbidity and mortality following the decline in invasive wound infection. It is a more significant problem for adult patients with pre-existing lung disease than it is for the pediatric population, however it may still be a serious infection in pediatric patients with smoke inhalation injury. The impact of inhalation injury on pneumonia is clinically important, resulting in an incidence rate of 22.2% of ventilated pediatric patients in one study compared to 7.7% of ventilated pediatric patients without inhalation injury.²³ Onset of pneumonia can either be early, generally within 7 days of the burn injury, or later in the burn course when it usually accompanies generalized systemic sepsis.

Diagnosis of pneumonia includes clinical symptoms such as hyperthermia, cough, chest pain, wheezing, rhonchi or, in the intubated patient, progressive respiratory deterioration (e.g., increased respiratory rate, decreased oxygen saturation), and new onset of purulent sputum or a change in the character of the sputum, with changes on the chest radiograph showing a new or progressive infiltrate, consolidation, cavitation, or pleural effusion. Sputum culture and Gram's stain results reveals more than 25 neutrophils (WBCs) with less than 10 squamous (epithelial) cells per low-power field.

Treatment of pneumonia should be started promptly, with antibiotic selection modified when culture and sensitivity results are available. Treatment should also include vigorous chest physiotherapy, turning, coughing, deep breathing, and suctioning. Prevention of pneumonia also includes these strategies, with the exception of antibiotic treatment. Newer ventilatory strategies are also being used (e.g., high-frequency ventilation, permissive hypercapnia) to prevent or treat patients with pneumonia and severe respiratory compromise.²⁸

Urinary Tract Infection

Urinary tract infection (UTI) has received little attention in burn patients. Thought to be a benign infection by many, it is associated with a 2% to 4% risk of bacteremia and a case fatality rate in non-burn patients which is 3 times as high as patients without UTI. Risk factors specific to burn patients includes the presence of perineal burns in certain patients and the increased length of time patients require catheterization in the treatment of extensive injuries. In pediatric burns, nosocomial UTI occurs almost

exclusively in patients with indwelling urinary catheters. Signs and symptoms of UTI may be present or obscured in burn patients relative to other conditions accompanying the injury.

Treatment of catheter-associated UTI includes removal of the catheter, if possible, and may include systemic antimicrobial treatment to eradicate the infection. Prevention of UTI 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 performance of urinary catheter care.

Conclusion

Many questions have yet to be answered for the burn patient related to appropriate management of infection control issues. Investigation of the role of hydrotherapy in the care of the burn patient, including identification of appropriate patients and standards for use, is needed to prevent infectious complications, which often accompany this form of therapy. The use of invasive devices, in particular central venous catheters, should be reevaluated in light of the new catheter technologies and improved wound management techniques.

An important area for future study relates to the clinical problem of appropriate precaution strategies, particularly for patients colonized with multiply resistant organisms, with the goal to be identification of cost-effective measures that prevent outbreaks involving other patients on the unit. Currently, there exists wide variation in precautions for burn patients with no agreed upon standards followed in most burn centers. In addition, in the ongoing era of changing health care priorities, studies are needed to evaluate the efficacy of caring for burn patients outside of the burn center or of caring for non-burn patients in the burn center. Integral to decisions on this issue must be the impact that these patients will have on existing infection rates and infectious complications, and the effect these decisions will have on patient outcomes, costs, and patient satisfaction.

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Figure 1. Incidence of infection by site at Shriners Hospitals for Children, Boston from January, 1996 to December, 2000. Rates are infections per 1000 patient days. BSI = Bloodstream infection, UTI = Urinary tract infection, TBSA = total body surface area burn.

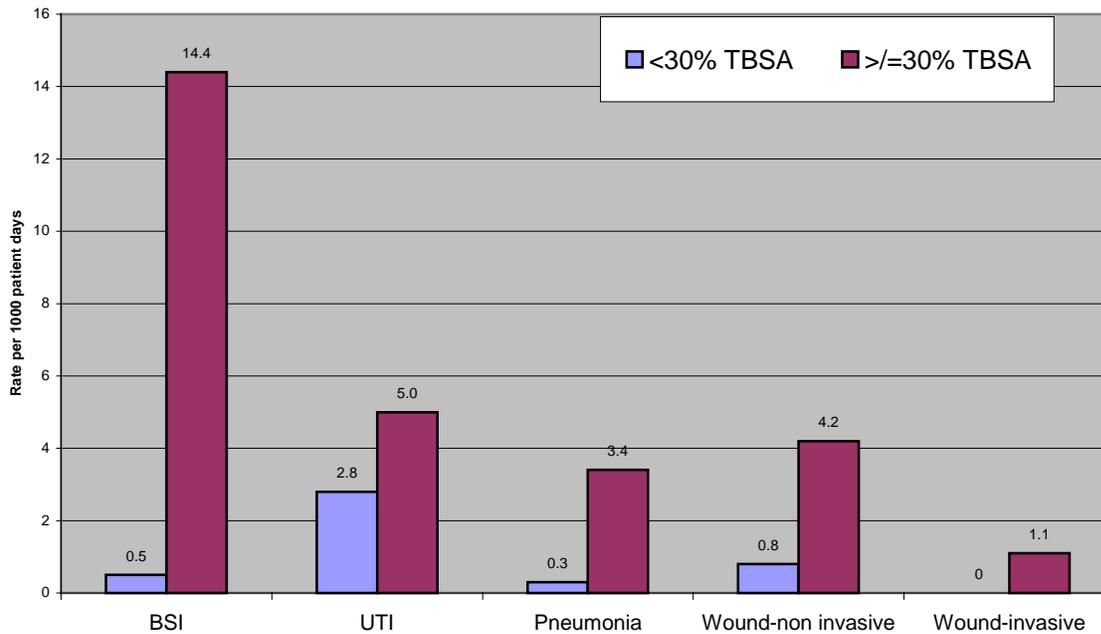


Figure 2. Device associated infection rates for Shriners Hospitals for Children, Boston from January, 1996 to December, 2000 and the National Nosocomial Infection Surveillance (NNIS) System for burn ICUs from January, 1995 to April, 2000. Rates are infections per 1000 device days. BSI = Bloodstream infection, UTI = Urinary tract infection.

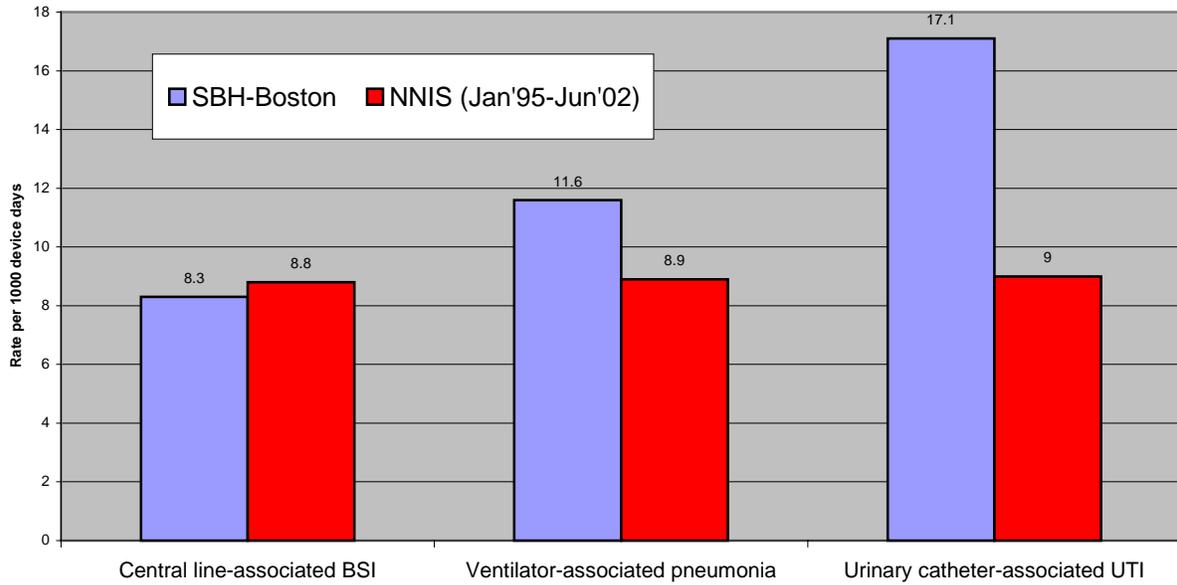


Table 1. Physical Defenses and Their Alteration by Burn Injury

Organ	Defense Mechanism	Effect of Burn Injury
Intact skin	Physical barrier Normal flora Low pH maintained by fatty acids Dryness, desiccation, desquamation	Loss of epidermis and all or part of dermis, depending on depth of injury Colonization of wound by opportunistic and pathogenic organisms Moist wound bed with necrotic tissue, eschar
Respiratory tract	Mucociliary lining of tract Cough and sneeze reflex Lysosomes in nasal secretions Alveolar macrophages	Smoke inhalation injury with direct damage to lining of respiratory tract Endotracheal intubation Immobility
Gastrointestinal tract	Peristalsis Hydrochloric acid Mucous gel on epithelial surfaces Normal flora Secretory IgA Bile acids and enzymes Fatty acids Bacteriocin	Adynamic ileus in burn shock period immediately after injury Altered gut permeability with large injury Elevated pH for stress ulcer prophylaxis Altered flora after administration of antibiotics Nasogastric tubes and feeding tubes
Urogenital tract	Flushing action and bacteriostatic pH of urine Normal flora (lactobacilli)	Burns in genital area Urinary catheter drainage
External ear and conjunctiva	Flushing action of tears Lysosomes Sebum and ciliary action of ear canals	Inability to close burned eyelids Accumulation of wound exudates and debris in ear canal

Table 2. Common Features of Outbreaks in Burn Units

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
1979 ¹	<i>E.cloacae</i>	X	X				X
1979 ^{2†}	MRSA*	X	X		X		
1981 ³	<i>P.aeruginosa</i> *			Mattress			
1982 ⁴	MRSA*	X			X		
1982 ⁵	MRSA*	X	X		X		X
1983 ⁶	MRSA*	X	X	X			
1983 ^{7‡}	MRSA*	X					
1985 ⁸	<i>A.calcoaceticus</i>	X	X	Mattress§ and other			
1992 ⁹	<i>P.aeruginosa</i> *		X				
1993 ¹⁰	<i>A.anitratus</i> *			Mattress			
	<i>P.aeruginosa</i>						
1993 ¹¹	<i>P.aeruginosa</i>		X				
1994 ¹²	<i>P.aeruginosa</i> *		X			X	
1994 ¹³	MRSA*	X		OR Surfaces		X	
1998 ¹⁴	<i>A.xylosoxidans</i>		X				
1999 ¹⁵	<i>A.baumannii</i> *		X				
2002 ^{16†}	<i>A.baumannii</i> *	X	X	X		X	

MRSA, Methicillin-resistant *Staphylococcus aureus*.

*Strains resistant to multiple antibiotics.

†Unit closed for decontamination and cleaning.

‡Unit permanently closed.

§Major reservoir identified.

||Hydrotherapy discontinued.

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