WJCCM World Journal of Critical Care Medicine

Online Submissions: http://www.wjgnet.com/esps/
wjccm@wjgnet.com
doi:10.5492/wjccm.v1.i4.94

World J Crit Care Med 2012 August 4; 1(4): 94-101
ISSN 2220-3141 (online)

EDITORIAL

Infection control in severely burned patients

Yusuf Kenan Coban

Yusuf Kenan Coban, Burn Unit, Department of Plastic Reconstructive and Aesthetic Surgery, Turgut Ozal Medical Centre, Inonu Üniversity Medical Faculty, Malatya 44910, Turkey
Author contributions: Coban YK solely contributed to this paper.
Correspondence to: Yusuf Kenan Coban, MD, Associated Professor, Burn Unit, Department of Plastic Reconstructive and Aesthetic Surgery, Turgut Ozal Medical Centre, Inonu Üniversity Medical Faculty, Malatya 44910, Turkey. ykenanc@yahoo.com
Telephone: +90-422-2384780 Fax: +90-422-3773000
Received: August 16, 2011 Revised: June 19, 2012
Accepted: July 12, 2012
Published online: August 4, 2012

Abstract

In the last two decades, much progress has been made in the control of burn wound infection and nasocomial infections (NI) in severely burned patients. The continiually 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 chateterization, and entubation pose a further risk of NIs. The use of newly designed antimicrobial impregnated chateters or silicone devices may help the control of infection in these immunocomprimised 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 incidance of infections due to antibiotic resistant microorganisms.

Key words: Severe burn injury; Infection control; Wound care; Infection control programs; Surveillance

Peer reviewers: Jean-Marc Cavaillon, Professor, Institut of Pasteur, Unit Cytokines and Inflammation, 28 Rue Dr. Roux, 75015 Paris, France; Bruno Mégarbane, Professor, Department of Toxicological, Medical Critical Care, Lariboisière Hospital, 2 Rue AMbroise Paré, 75010 Paris, France

Coban YK. Infection control in severely burned patients. *World J Crit Care Med* 2012; 1(4): 94-101 Available from: URL: http://www.wjgnet.com/2220-3141/full/v1/i4/94.htm DOI: http://dx.doi.org/10.5492/wjccm.v1.i4.94

INTRODUCTION

Infection and sepsis are among the most prominent causative factors in burn related mortality and morbidity[1,2]. 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 resusciation may actually increase the size and/or depth of the wound[3] (Figure 1). 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[4-6]. 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[7,8]. Approximately 73 % of all deaths within the first 5 d post-burn have been shown to be directly or indirectly caused by septic processes[9].

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[10]. Since then infection in sites other than the burn wound, principally the lungs, has remained the most common cause of death in burn patients[11]. 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[8].

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[12]. However, recent studies have shown that this is not currently the case[13]. Staphylococcus aureus has now become the principal etiological agent of burn wound cellulitis and, along with pseudomonas aurginosa, remains a common cause of early burn wound infection in many centers[14].

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 on wound surface or penetrating to variable depth of burn eshcar; 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[15]. 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 (Figure 2). Anaerobic organisms such as *Clostridium* sp. and facultative anaerobes such as *Aeromonas* sp. can

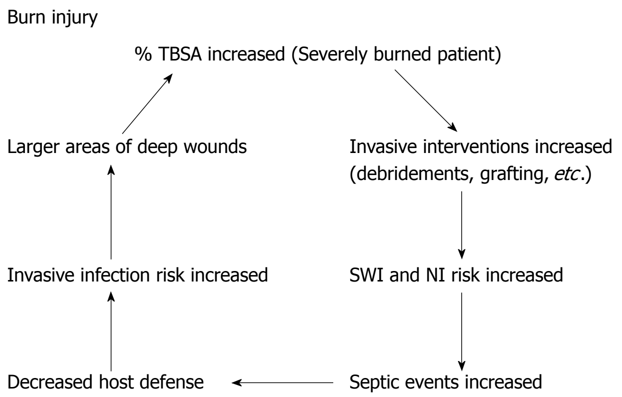

Figure 1 Vicious circle for increased infection risk in severely burned patient. SWI: Surgical wound infections; NI: Nasocomial infections; TBSA: Total burned surface area.

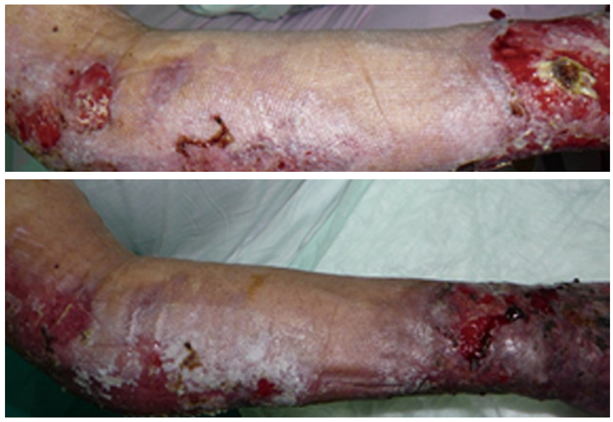

Figure 2 An example for burn wound infection. Top: Nine days following admission a severe edema and inflammation at the periphery of the wound is seen with a positive wound culture for pseudomanas auerginosa; Bottom: Following treatment with topical octenidine dihydrochlorure (octenidex, senamed medical, Turkey) and sterile petroleum gauze (jelonet, Smith and nephew, United Kingdom), and peroral ofloxacine 500 mg × 2 for day, rapid epitheliazation and decreased edema was achieved at the 10th day of the treatment.

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[16]. 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 sulfodiazine 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 (-) staphyloccoci and staphylococcus aureus including methicilline-resistant staphyloccus 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 unneccessary 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 euipment. All personel must be gowned (either disposable or reuseable gowns) during the contact with the patient. All equipment in the isolation room must be regularly cleaned.

With universal employement 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 nasocomial 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 ifnfection, whereas other reports show predominance of pneumonia and primary blood stream 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 Surveliance System[30]. Surveillance for SWIs is a very important part of any nosocomial infection surveillance strategy. Posluszny *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 with the need for regrafting increased overall length of stay and was closely associated with number of NIs. As a result of the increased need for operative events, presence of a SWI may be a risk factor for the development of NIs.

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

Is there any delayed deep tissue infection in the patient with severe burn?

Yes

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

No

Search for systemic findings and/or other sources of infection

Microbial culture positive?

Yes

No

Use effective antimicrobials based on antibiograms

Still, any infection problem persist?

No

Yes*

*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 dreesing containing ag

Use spesific laboratory information obtained from bacterial culture and susceptibility results and give apropriate systemic antiobitics based on these informations

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

should use these updated definitions so that the results of fortcoming reports sould more accurately reflect reality. Communication of timely, accurate, risk-stratified data on SWI rates is essential if surveillance is to become an indispensable tool for surgeons[33]. Figure 3 show an algorythm for management of burn wound infection problems.

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[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[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 algoritms spesific to each burn unit should be developed secondary to the outcome analysis of laboratory surveliance 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.

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) Optimising 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 treament 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[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 etyhlenemethyl acrylate wound

Table 1 Therapeutic tools used for controlling different aspects in the wound treatment

Epithelialization	Infection control	Macerattion	Tissue necrois
Collagen	Detergents	Alginates	Osmotic autolysis
Hyalurinic acid	Disinfectants	Hydrocolloid fibers	Larval autolysis
Growth factors	Advanced medications: Ag	Polyurethans	Enzymatic autolysis
VAC	Systemic antibiotherapy	VAC	Ultrasonic debridement
Artificial derma	VAC instill		Waterjet (Versajet) debridement
Skin grafting			Surgical debridement

VAC: Vacuum-assisted closure.

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 sphylococus aureus and vancomycine resistant enterococus. 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 irrgation, 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 surveliance 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 bacteriuria 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-

Figure 4 V-link luer activated device with Vitalshield protective coating, non-DEHP catheter extension set (Baxter ref vmc 8374).

ing total parenteral nutrition and those who are neutrogenic 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 SURVELLIANCE 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 prevoius 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[45].

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 assesment and infection control assesment, 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 become unneccessary with the advent of early excision wound therapy[48]. The other main point of discussion is hydrotherapy usage in burns. Despite the recognised risk of immersion hydrotherapy treament in burn units, this was a standard practice in many burn centers until 1990s[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 surveliance 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*[26]. 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.

REFERENCES

1 **Demling RH**. Burns. *N Engl J Med* 1985; **313**: 1389-1398
2 **Robson MC**. Burn sepsis. *Crit Care Clin* 1988; **4**: 281-298
3 **Palmieri TL**, Greenhalgh DG. Topical treatment of pediatric patients with burns: a practical guide. *Am J Clin Dermatol* 2002; **3**: 529-534

4 **Barret JP**, Herndon DN. Modulation of inflammatory and catabolic responses in severely burned children by early burn wound excision in the first 24 hours. *Arch Surg* 2003; **138**: 127-132
5 **Hart DW**, Wolf SE, Chinkes DL, Beauford RB, Mlcak RP, Heggers JP, Wolfe RR, Herndon DN. Effects of early excision and aggressive enteral feeding on hypermetabolism, catabolism, and sepsis after severe burn. *J Trauma* 2003; **54**: 755-761; discussion 761-764
6 **Sheridan RL**, Tompkins RG, Burke JF. Management of burn wounds with prompt excision and immediate closure. *J Intensive Care Med* 1994; **9**: 6-17
7 **Appelgren P**, Björnhagen V, Bragderyd K, Jonsson CE, Ransjö U. A prospective study of infections in burn patients. *Burns* 2002; **28**: 39-46
8 **Dodd D**, Stutman HR. Current issues in burn wound infections. *Adv Pediatr Infect Dis* 1991; **6**: 137-162
9 **Tancheva D**, Hadjiiski O. Effect of early nutritional support on clinical course and septic complications in patients with severe burns. *Ann Burns Fire Disasters* 2005; **18**: 74-78
10 **Pruitt BA**, O'Neill JA, Moncrief JA, Lindberg RB. Successful control of burn-wound sepsis. *JAMA* 1968; **203**: 1054-1056
11 **Pruitt BA**, McManus AT. The changing epidemiology of infection in burn patients. *World J Surg* 1992; **16**: 57-67
12 **Pruitt BA**. Burns and soft tissues. In: Polk Jr HC, editor. Infection and the Surgical Patient: clinical surgery international. London: Churchill-Livingstone, 1982: 113-131
13 **Bang RL**, Gang RK, Sanyal SC, Mokaddas EM, Lari AR. Beta-haemolytic Streptococcus infection in burns. *Burns* 1999; **25**: 242-246
14 **Altoparlak U**, Erol S, Akcay MN, Celebi F, Kadanali A. The time-related changes of antimicrobial resistance patterns and predominant bacterial profiles of burn wounds and body flora of burned patients. *Burns* 2004; **30**: 660-664
15 **McManus WF**, Goodwin CW, Pruitt BA. Subeschar treatment of burn-wound infection. *Arch Surg* 1983; **118**: 291-294
16 **Pruitt BA**, McManus AT, Kim SH, Goodwin CW. Burn wound infections: current status. *World J Surg* 1998; **22**: 135-145
17 **Murray PM**, Finegold SM. Anaerobes in burn-wound infections. *Rev Infect Dis* 1984; **6** Suppl 1: S184-S186
18 **Heggers JP**, Hawkins H, Edgar P, Villarreal C, Herndon DN. Treatment of infections in burns. In: Herndon DN, editor. Total burn care. London: WB saunders, 2002: 120-169
19 **Gupta N**, Haque A, Lattif AA, Narayan RP, Mukhopadhyay G, Prasad R. Epidemiology and molecular typing of Candida isolates from burn patients. *Mycopathologia* 2004; **158**: 397-405
20 **Struck MF**. Infection control in burn patients: are fungal infections underestimated? *Scand J Trauma Resusc Emerg Med* 2009; **17**: 51; author reply 56
21 **Meier PA**, Carter CD, Wallace SE, Hollis RJ, Pfaller MA, Herwaldt LA. A prolonged outbreak of methicillin-resistant Staphylococcus aureus in the burn unit of a tertiary medical center. *Infect Control Hosp Epidemiol* 1996; **17**: 798-802
22 **Peng YZ**, Yuan ZQ. [Standardized definitions and diagnostic criteria for infection in burn patients]. *Zhonghua Shao Shang Zazhi* 2007; **23**: 404-405
23 **Pottinger JM**, Herwaldt LA, Peri TM. Basics of surveillance--an overview. *Infect Control Hosp Epidemiol* 1997; **18**: 513-527
24 **Bone RC**, Balk RA, Cerra FB, Dellinger RP, Fein AM, Knaus WA, Schein RM, Sibbald WJ. Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. The ACCP/SCCM Consensus Conference Committee. American College of Chest Physicians/Society of Critical Care Medicine. *Chest* 1992; **101**: 1644-1655
25 **Peck MD**, Weber J, McManus A, Sheridan R, Heimbach D. Surveillance of burn wound infections: a proposal for definitions. *J Burn Care Rehabil* 1998; **19**: 386-389
26 **Garner JS**, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. *Am J Infect Control* 1988; **16**: 128-140
27 **Lari AR**, Alaghehbandan R. Nosocomial infections in an Iranian burn care center. *Burns* 2000; **26**: 737-740
28 **Oncul O**, Ulkur E, Acar A, Turhan V, Yeniz E, Karacaer Z, Yildiz F. Prospective analysis of nosocomial infections in a burn care unit, Turkey. *Indian J Med Res* 2009; **130**: 758-764
29 **Smyth ET**, Emmerson AM. Surgical site infection surveillance. *J Hosp Infect* 2000; **45**: 173-184
30 **Horan TC**, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* 1992; **13**: 606-608
31 **Posluszny JA**, Conrad P, Halerz M, Shankar R, Gamelli RL. Surgical burn wound infections and their clinical implications. *J Burn Care Res* 2011; **32**: 324-333
32 **Greenhalgh DG**, Saffle JR, Holmes JH, Gamelli RL, Palmieri TL, Horton JW, Tompkins RG, Traber DL, Mozingo DW, Deitch EA, Goodwin CW, Herndon DN, Gallagher JJ, Sanford AP, Jeng JC, Ahrenholz DH, Neely AN, O'Mara MS, Wolf SE, Purdue GF, Garner WL, Yowler CJ, Latenser BA. American Burn Association consensus conference to define sepsis and infection in burns. *J Burn Care Res* 2007; **28**: 776-790
33 **Mertens R**, Ronveaux O. The role of communication in surgical wound infection surveillance. *Acta Chir Belg* 1996; **96**: 1-2
34 **Edlich RF**, Rodeheaver GT, Spengler M, Herbert J, Edgerton MT. Practical bacteriologic monitoring of the burn victim. *Clin Plast Surg* 1977; **4**: 561-569
35 **Boyce JM**, White RL, Causey WA, Lockwood WR. Burn units as a source of methicillin-resistant Staphylococcus aureus infections. *JAMA* 1983; **249**: 2803-2807
36 **Wolvos T**. Wound instillation--the next step in negative pressure wound therapy. Lessons learned from initial experiences. *Ostomy Wound Manage* 2004; **50**: 56-66
37 **Tredget EE**, Shankowsky HA, Groeneveld A, Burrell R. A matched-pair, randomized study evaluating the efficacy and safety of Acticoat silver-coated dressing for the treatment of burn wounds. *J Burn Care Rehabil* 1998; **19**: 531-537
38 **Wilson JR**, Mills JG, Prather ID, Dimitrijevich SD. A toxicity index of skin and wound cleansers used on in vitro fibroblasts and keratinocytes. *Adv Skin Wound Care* 2005; **18**: 373-378
39 **Koburger T**, Hübner NO, Braun M, Siebert J, Kramer A. Standardized comparison of antiseptic efficacy of triclosan, PVP-iodine, octenidine dihydrochloride, polyhexanide and chlorhexidine digluconate. *J Antimicrob Chemother* 2010; **65**: 1712-1719
40 **Coban YK**, Erkiliç A, Analay H. Our 18-month experience at a new burn center in Gaziantep, Turkey. *Ulus Travma Acil Cerrahi Derg* 2010; **16**: 353-356
41 National Nosocomial Infections Surveillance (NNIS) System Report, Data Summary from January 1992-June 2001, issued August 2001. *Am J Infect Control* 2001; **29**: 404-421
42 **Crnich CJ**, Maki DG. The promise of novel technology for the prevention of intravascular device-related bloodstream infection. II. Long-term devices. *Clin Infect Dis* 2002; **34**: 1362-1368
43 **Stamm WE**. Urinary tract infection. In: Bennett JV, Brachmand PS, editors. Hospital infections. 4th edition. Philadelphia: Lippincott-Raven, 1998: 477-485
44 **Schumm K**, Lam TB. Types of urethral catheters for management of short-term voiding problems in hospitalized adults: a short version Cochrane review. *Neurourol Urodyn* 2008; **27**: 738-746
45 **Cruse PJ**, Foord R. The epidemiology of wound infection. A 10-year prospective study of 62,939 wounds. *Surg Clin North Am* 1980; **60**: 27-40
46 **Wibbenmeyer L**, Danks R, Faucher L, Amelon M, Latenser B, Kealey GP, Herwaldt LA. Prospective analysis of nosocomial

infection rates, antibiotic use, and patterns of resistance in a burn population. *J Burn Care Res* 2006; **27**: 152-160
47 **Tablan OC**, Anderson LJ, Besser R, Bridges C, Hajjeh R. Guidelines for preventing health-care--associated pneumonia, 2003: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. *MMWR Recomm Rep* 2004; **53**: 1-36
48 **Shankowsky HA**, Callioux LS, Tredget EE. North American survey of hydrotherapy in modern burn care. *J Burn Care Rehabil* 1994; **15**: 143-146
49 **Steve L**, Goodhart P, Alexander J. Hydrotherapy burn treatment: use of chloramine-T against resistant microorganisms. *Arch Phys Med Rehabil* 1979; **60**: 301-303
50 **Embil JM**, McLeod JA, Al-Barrak AM, Thompson GM, Aoki FY, Witwicki EJ, Stranc MF, Kabani AM, Nicoll DR, Nicolle LE. An outbreak of methicillin resistant Staphylococcus aureus on a burn unit: potential role of contaminated hydrotherapy equipment. *Burns* 2001; **27**: 681-688
51 **Tredget EE**, Shankowsky HA, Joffe AM, Inkson TI, Volpel K, Paranchych W, Kibsey PC, Alton JD, Burke JF. Epidemiology of infections with Pseudomonas aeruginosa in burn patients: the role of hydrotherapy. *Clin Infect Dis* 1992; **15**: 941-949

S- Editor Gou SX **L- Editor** Hughes D **E- Editor** Zheng XM