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Incidence and mortality of healthcare-associated infections in hospitalized patients with moderate to severe burns

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ABSTRACT

Purpose: This study was to examine the incidence of different types, and isolated pathogens, of healthcare–associated infections (HAIs), and also to determine their prognostic factors for mortality.
Methods: Prospective surveillance was conducted in a medical center from 2005 through to 2016. Multiple logistic regression analysis was performed to assess prognostic factors of mortality.
Results: A total of 709 patients with moderate to severe burns were hospitalized. There were 83 patients (11.7%) with HAIs (158 episodes) and 203 isolated pathogens. The most common HAI types were bloodstream infection (BSI) at 39.2% (8.7% of all patients) and central line–associated BSI (mean 4.8 per 1000 central line days). Overall, *S. aureus* (13.8%) were the most common isolated pathogens, while the most commonly found type of multidrug-resistant pathogen was carbapenems–resistant *Enterobacteriaceae* (23%). The crude mortality rate was 15.7%, and the independent factors ($p < .05$) for mortality were BSI (Odds ratio [OR] 2.70), intensive care unit (OR 5.19) and total body surface area with full-thickness injuries ≥50% (OR 5.22).
Conclusions: Burn patients with BSI were the most common HAI sites, and this was an independent factor for mortality. Effective integrated care and appropriate infection control can reduce the incidence of infection and death.

1. Introduction

Burns are a serious global public health problem. According to the 2017 National Burn Repository Annual Report, the most common type of burn injury was fire/flame and scalds, accounting for 76% of cases reported [1]. These burned patients not only suffered damage to skin integrity and lost their physical barrier, but also had their immune function affected, which might enable pathogens to infiltrate the body and result in microbial infections [2]. There were some risk factors which promoted microbial infection or increased resistance to antibiotics. These important factors related to (1) burn patient factors, including age (e.g., patients aged over 50 years or pediatric patients), and presence of comorbidities (e.g., diabetes mellitus); (2) burn severity factors, including the extent and depth of the burn; (3) medical treatment and care factors, including use of invasive measures or catheters (such as ventilator, urinary catheter, or central venous catheter), environmental cleaning and disinfection, and infection control management and measures etc. [3-9].

The most common healthcare–associated infection (HAI) sites of hospitalized burn patients were bloodstream infection (BSI), urinary tract infection (UTI), pneumonia, tracheobronchitis, skin and soft tissue infections, and surgical site infection (SSI) [3,4,10,11]. Moreover, the proportion of device–related HAIs in burn patients was higher than that of non–burn patients [12,13]. There were even some reports of infection outbreak events [14,15]. Generally speaking, these HAI patients – especially those who were severely burned – not only required prolonged hospitalization, extensive numbers of treatment sessions, and often multiple surgical procedures, but also incurred extra healthcare expenditures and an increased risk of mortality [16-18]. Data from developing and developed countries, as well as from different infection sites, showed that, on average, burn patients had one or more infections, and that their cumulative mortality was 0.3%–36% [1,8-10,19,20].

There have been many articles describing infections in burn patients, but few included HAI reports, and those that did generally only had reports for a single HAI site. We hypothesized that the incidence of HAIs and the distribution of pathogenic microbes in different sites would be different. The purpose of this study was therefore to examine the incidence of different types and isolated pathogens of HAI, and also to determine their prognostic factors for mortality.

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2. Materials and methods

2.1. Participants and hospital setting

This retrospective study, using an active and prospective hospital–wide HAI surveillance database established by the Department of Infection Control, was conducted in a large tertiary medical center located in Taiwan. Burn patients are mainly treated in the division of plastic and reconstructive surgery, which was established in 1970. There is a burn center consisting of a 6–bed intensive care unit (ICU) and a 14–bed ward. Inpatients are mainly treated for moderate to severe burns. All of the burn patients (International Classification of Diseases, ICD–9 code from 940.0 to 949.99) admitted from 2005 to 2016 were eligible for inclusion in the study. HAI was defined as an infection in a burn patient that developed >48 h after admission. Therefore, burn patients who were hospitalized for <2 days were excluded. The protocol for this study was approved by the Institutional Review Board of the medical center.

The monitoring and practices of prevention and control for burn infection by infection control practitioners (ICPs) have been developed according to recommendations from published guidelines, including education, burn infection surveillance, barrier precautions, hydrotherapy treatments, appropriate use of antimicrobial treatment, equipment and environmental decontamination, and feedback of information to clinicians [7,21–24]. Burn patients are placed in a single room or in cohort care (a two–bed room). There is a requirement that standard precautions, contact precautions, and, if indicated, droplet precautions should be followed when caring for all burn patients, including consistent implementation of appropriate hand hygiene and use of personal protective equipment (such as gloves, gowns, aprons, masks and caps). Infection control procedures are strictly enforced with respect to both healthcare personnel and visitors. Environmental cleaning and disinfection procedures have also been developed. Since 2015, the adenosine triphosphate luminometer has been used to monitor the cleanliness of the environment and instruments.

2.2. Surveillance of HAIs and data collection

All burn patients were monitored and had data prospectively collected by a trained ICP for HAIs that affect particular body sites. The surveillance procedures and HAI site definitions were based on those recommended by the National Healthcare Safety Network (NHSN) of the US Centers for Disease Control and Prevention (CDC) [25], as described in a previous publication [26]. Infections at more than one site in the same patient were counted as separate infections. Reports of cases of HAI were also verified by an infectious disease specialist. The collection of variables for potential covariate factors included demographic and clinical characteristics, therapeutic devices used, and severity of burns, etc. (as list in Table 2). The severity of the burn included the percentage of total body surface area (TBSA) according to Wallace's nine rules and the overall injuries classified according to the depth of damage (superficial with only epidermal involvement, partial-thickness with blistering affecting epidermal and dermal layers, and full-thickness extending to subcutaneous tissues). The revised Baux score was also included; this was calculated as the sum of the age and TBSA. When the Baux score of patients was 17 or more, then these patients were classed as suffering inhalation injury; a score of 0 was assigned to those without inhalation injury [27].

Culturing of pathogens was performed when the patient had a temperature over 38 °C or a fever of unknown etiology, exudates or pus from an insertion site or surgical site, or signs and symptoms of suspected infections. Microbe calculation was performed only once for the same species isolated from same site of a patient. The medical center's microbiology laboratory is certified internationally through the College of American Pathologists. Identification of all microbial isolates was confirmed at the laboratory using an automated method employing VITEK–MS system (BioMerieux Inc., Mercy L'etoil, France) identification cards. Antimicrobial susceptibility tests were performed using the disc diffusion method, as described by the National Committee for Clinical Laboratory Standards. Cultures reported as intermediate sensitivity were considered resistant.

2.3. Statistical analysis

Device–associated infection (DAI) rates were calculated as the number of device–associated infections for a specified body site per 1000 device days. Descriptive analyses of all collected variables were implemented. Percentage, median and range, mean and standard deviation (SD) of demographic and clinical characteristics of burn patients were presented. The overall and stratified analyses of site–specific HAI were also used. Univariate analyses were used to compare patients' mortality and survival. A chi-square or Fisher's exact test was used to evaluate differences in categorical variables, and the Mann-Whitney *U* test was used for continuous data that had non-normal distribution.

Logistic regression with a forward approach was used to assess prognostic factors of mortality, while controlling for potentially confounding variables; colinearity between covariates was also checked for. For example, the HAI site and the use of invasive catheters were highly associated. Coupled with the limited number of deaths, we chose HAI factors which had more direct impact on death in the final mode. A variable was dropped from the model if it did not reach the 5% threshold for statistical significance. Two–tailed estimates of effect (Odds ratios, ORs) and 95% confidence intervals (CI) were reported for all regression coefficients.

3. Results

3.1. Patient demographic data

A total of 709 hospitalized burn patients were admitted during the study period. Of these, there were 83 patients (11.7%) with HAIs (158 episodes). In these HAIs, 50 (60.2%) patients occurred once, and repeated infections of the same patient twice or more accounted for 39.8%. The most common HAI types were BSIs, with 62 (39.2%, 8.7% of all patients) episodes, followed by UTIs with 57(36.1%, symptomatic UTIs 22.8% and asymptomatic UTIs 13.3%) episodes, and respiratory tract infections (RTIs) with 14 (8.9%, 2% of all patients) episodes. The most common DAI types were central line–associated BSI (CLABSI) (mean 4.8 per 1000 central line days), followed by catheter–associated UTI (CAUTI) (mean 3.3 per 1000 urinary catheter days), and ventilator–associated pneumonia (VAP) (mean 0.6 per 1000 ventilator days) (Table 1).

As Table 2 shows, the mean age of these HAI patients was 51.5 ± 24.6 (range 13–90) years old and 58 (69.9%) patients were male. The largest share of ($n = 31$, 37.3%) HAI patients were admitted or transferred from the emergency department, more than half ($n = 45$, 54.2%) of patients spent time in the ICU, and 66 (79.5%) patients had received surgery. The most common invasive devices used in these patients were Foley catheter 62 (74.7%) and central line catheter 53 (63.9%). Mean LOS before onset HAI was 26.9 ± 24.3 (media 20) days. The mean Baux score was 14.2 ± 8.7 points and the crude mortality rate was 15.7% ($n = 13$). Regarding the distribution of severity of burns, there were 45 patients (77.6%) with >20% TBSA and 67 (80.7%) patients had full-thickness injuries. With respect to univariate analysis of demographics and clinical characteristics, there was no statistically significant difference between patients' mortality and survival, except for the ICU stay, inhalation injury, the use of a mechanical ventilator and APACHE II scores in ICU.

After controlling for the main potentially prognostic factors of mortality by multiple analysis, the independent factors ($p < .05$) for mortality were BSI (OR 2.70, 95%CI 1.11–6.55), ICU (OR 5.19, 95%CI

Table 1
Site and episodes of burn patients with healthcare–associated infection.

Variables	Number ($n = 158$)	Percentage (%)
Episodes of HAI		
1 episode	50	60.2
2 episodes	20	24.1
3 episodes	5	6.0
4 episodes	2	2.4
5 episodes	2	2.4
≥6 episodes	4	4.8
Sites of HAI		
Bloodstream infection	62	39.2
CLABSI (per 1000 central line days)[a]		4.8
Urinary tract infection	57	36.1
CAUTI (per 1000 urinary catheter days)[a]		3.3
Respiratory tract infection	14	8.9
VAP (per 1000 ventilator days)[a]		0.6
Burn wound infection	12	7.6
Surgical site infection	8	5.1
Other sites	5	3.2

HAI, healthcare–associated infection; CLABSI, central line–associated bloodstream infection; CAUTI, catheter–associated urinary tract infection; VAP, ventilator–associated pneumonia.
[a] The device used days before onset of HAI were 1300 central line–days, 1727 urinary catheter–days, and 2191 ventilator–days.

1.75–15.37) and TBSA with full-thickness injuries ≥50% (OR 5.22, 95%CI 1.82–14.91) (Table 3).

3.2. Microbiological investigations

Pathogen calculation was performed only once for the same species isolated from the same site of a patient. Table 4 lists the distribution of pathogens isolated from clinical specimens by HAI sites. In total, 203 pathogens were isolated. The top three most commonly isolated pathogens were gram negative bacilli (GNB) 103 (50.7%) including glucose nonfermenting gram negative bacilli (GNFGNB) 52 (25.6%), followed by gram–positive 56 (27.6%) including gram–positive cocci (GPC) 51 (27.6%), and fungus 43(21.2%). Among these, the two most common isolated species were *Staphylococcus aureus* 28(13.8%), *Acinetobacter baumannii* 21(10.3%), while in third place (9.4%) were *Klebsiella pneumoniae, Pseudomonas aeruginosa* and Yeast–like, respectively. In a variety of different HAIs, *S. aureus* (16.7%) and *A. baumannii* (16.7%) were the most common pathogens associated with BSIs, while *Enterobacteriaceae* (40.3%; of these, *K. pneumoniae* 14.9% and *Escherichia coli* 14.9%) accounted for the majority of UTIs. *P. aeruginosa* (27.8%) were the most common RTIs pathogens. The isolated rate of *S. aureus* in the BWI (36.8%) and SSIs (33.3%) was the highest.

A total of 48 (23.6%) antimicrobial resistant pathogens were identified in HAIs. The proportion of drug–resistant pathogens isolated by UTI was the highest (24, 30.8%). The most common antimicrobial resistant pathogens were carbapenems–resistant *Enterobacteriaceae* (23%), followed by methicillin–resistant *S. aureus* (23.6%) (Fig. 1).

Table 3
Prognostic factors for mortality of burn patients with healthcare-associated infection by multiple regression analysis.

Variables	Coefficients	Std. error	Odds ratio	95% CI	P–value*
Blood stream infection (yes/no)	0.99	0.45	2.70	1.11–6.55	0.028
Intensive care unit (yes/no)	1.65	0.55	5.19	1.75–15.37	0.003
TBSA with full-thickness injuries (>50%/≤49%)	1.65	0.54	5.22	1.82–14.91	0.002

CI, Confidence interval; TBSA, total body surface area.
* Used a forward approach: other variables ($p > .05$) included age over 65 years and more, gender, inhalation injury, respiratory tract infection, surgical site infection, urinary tract infection, and multidrug resistant microbes.

4. Discussion

Burn patients are one of the higher–risk groups for the occurrence of HAIs in all hospitalized patients. Our results found that 11.7% of burns patients with moderate to severe burns developed HAIs, and that DAI rates ranged from 0.6 to 4.8 per 1000 device–days depending on the types of HAI.

Table 2
Distribution of demographic and clinical characteristics of burn patients with healthcare–associated infection by mortality.

Variables	Total number $n = 83$ (%)	Mortality $n = 13$ (%)	Survive $n = 70$ (%)	Odds ratio (95% CI)
Gender (male)	58(69.9)	9(69.2)	49(70.0)	1.04(0.29–3.74)
Transferred from ER	31(37.3)	5(38.5)	26(37.1)	1.06(0.31–3.58)
Ward (ICU)	45(54.2)	11(84.6)	34(48.6)	5.82(1.20–28.21)*
Service (plastic surgery)	69(83.1)	12(92.3)	57(81.4)	2.74(0.33–22.96)
Surgery (yes)	66(79.5)	13(100)	53(75.7)	–
Multiple surgeries (yes)	63(75.9)	11(84.6)	52(74.3)	1.90(0.38–9.42)
Inhalation injury (yes)	25(30.1)	7(53.8)	18(25.7)	3.37(1.01–11.36)*
Invasive devices (yes)				
Foley catheter	62(74.7)	10(76.9)	52(74.3)	1.15(0.28–4.67)
Central line catheter	53(62.7)	11(84.6)	42(60.0)	3.67(0.75–17.81)
Mechanical ventilator	34(41.0)	11(84.6)	23(32.9)	11.24(2.29–54.95)*
Multidrug resistant microbial infection	21(25.3)	3(23.1)	18(25.7)	0.87(0.21–3.50)
Burns classified according to extent of body surface involved (TBSA,%)				
<20	38(45.8)	6(46.2)	32(45.7)	1.02(0.31–3.34)
20–49	24(28.9)	3(23.1)	21(30.0)	0.70(0.17–2.80)
≥50	21(25.3)	4(30.8)	17(24.3)	1.39(0.38–5.08)
Burn injuries classified				
Full-thickness	67(80.7)	12(92.3)	55(78.6)	3.27(0.39–27.22)
Partial-thickness	8(9.6)	0(0.0)	8(11.4)	–
Burn of esophagus	8(9.6)	1(7.7)	7(10.0)	0.75(0.84–6.67)
Continuity variables	Mean ± SD	Median (min–max)	Median (min–max)	P–value
Age, yrs	51.5 ± 24.6	61(20–87)	51(13–90)	0.310
APACHE II scores (n = 45 in ICU)	16.2 ± 7.3	22(17–26)	12(4–32)	0.004
Baux score	14.2 ± 8.7	17(5–32)	12(3–43)	0.075
LOS before onset HAI	26.9 ± 24.3	16(6–61)	20(4–153)	0.367

CI, confidence interval; ER, emergency department; ICU, intensive care unit; TBSA, total body surface area; SD, standard deviation; APACHE, Acute Physiology and Chronic Health Evaluation; LOS, length of stay; HAI, healthcare–associated infection.
* $p < .05$.

Table 4
Distribution of pathogens isolated from clinical specimens by healthcare–associated infection sites.a

Isolated pathogens (%)	All sites (n = 203)	BSI (n = 78)	UTI (n = 67)	RTI (n = 18)	BWI (n = 19)	SSI (n = 12)	Others (n = 9)
Gram–positive	27.6	25.6	16.4	27.8	47.4	58.3	44.4
Staphylococcus aureus	13.8[a]	16.7[a]	0.0	22.2[a]	36.8[a]	33.3[a]	0.0
Enterococcus spp.	3.9	1.3	9.0	0.0	0.0	0.0	11.1
coagulase–negative *staphylococcus*	3.0	0.0	1.5	5.6	10.5	8.3	11.1
Enterococcus faecium	2.5	2.6	3.0	0.0	0.0	0.0	11.1
others	4.4	5.1	3.0	0.0	0.0	16.7	11.1
Gram–negative	50.7	50.0	56.7	61.1	36.8	33.3	44.4
Glucose–fermentative Gram–negative bacilli	25.1	19.2	40.3	5.6	15.8	33.3	11.1
Enterobacteriaceae	21.7	14.1	40.3	5.6	15.8	8.3	11.1
Klebsiella pneumoniae	9.4[a]	6.4	14.9[a]	5.6	10.5[a]	8.3	0.0
Klebsiella oxytoca	1.0	0.0	3.0	0.0	0.0	0.0	0.0
Escherichia coli	6.9	3.8	14.9[a]	0.0	5.3	0.0	0.0
Enterobacter cloacae	2.5	2.6	3.0	0.0	0.0	0.0	11.1
Proteus mirabilis	2.0	1.3	4.5	0.0	0.0	0.0	0.0
others	3.4	5.1	0.0	0.0	0.0	8.3	0.0
Glucose–non–fermentative Gram–negative bacilli	25.6	30.8	16.4	55.6	21.1	0.0	33.3
Acinetobacter baumannii	10.3[a]	16.7[a]	6.0	16.7[a]	5.3	0.0	0.0
Pseudomonas aeruginosa	9.4[a]	5.1	9.0	27.8[a]	10.5[a]	0.0	22.2
Burkholderia cepacia	2.0	5.1	0.0	0.0	0.0	0.0	0.0
others	3.9	3.8	1.5	11.1	5.3	0.0	11.1
Anaerobes	0.5	0.0	0.0	0.0	0.0	0.0	11.1
Fungus	21.2	24.4	26.9	11.1	10.5	8.3	11.1
Yeast–like	9.4[a]	0.0	20.9[a]	11.1	10.5[a]	8.3	0.0
Candida albicans	5.4	11.5[a]	3.0	0.0	0.0	0.0	0.0
Candida parasilosis	2.5	6.4	0.0	0.0	0.0	0.0	0.0
others	3.9	6.4	3.0	0.0	0.0	0.0	11.1

BSI, bloodstream infection; UTI, urinary tract infection; RTI, respiratory tract infections; BWI, burn wound infection; SSI, surgical site infection.
[a] The three most common pathogens isolated in specific site associated infection.

4.1. HAI sites

The common HAI sites were BSI, RTI, and UTI, and most of those infections were related to catheter use [11]. Data from developing and developed countries were highly heterogeneous. The difference in the frequency and ranking of HAI sites might be due to the different study populations, the severity of burns, the medical care environment, and the study methods used, etc. Overall, the HAI rate of this present study was much lower than in previous retrospective reports (27.8–71.3%) [3,10]. In our data, the most common of all HAI sites was BSIs (39.2%, cumulative incidence rate 8.7% of all burn patients) and the highest incidence density of all DAI types was CLABSI (mean 4.8 per 1000 central line days). This result differs from several other reports in the literature, which were mainly VAP or wound-associated infections [3,4,10,11]. As regards CLABSI, compared with the NHSN report (which noted a pooled rate of CLABSI of 2.4–3.4 per 1000 catheter–days) [12,13], our data were relatively higher. The main reason may be that with the patients included in the present study mainly had moderate to severe burns; more than half of them had TBSA of >20%, and more than four–fifths had third–degree burns, so there was also a high proportion of burn patients with central line catheter (62.7%). However, our CLABSI data were also lower than some studies reported (10.7–49.4 per1000 catheter–days) [10,11,28]. Generally, CLABSI is caused by organisms which migrate along the catheter from the insertion site and colonize the catheter tip, and it often occurs in relation to a colonized or infected burn wound [6]. Removing the device as early as possible when the burn patient no longer needs an indwelling catheter, although challenging, is the only way to avoid biofilm formation and infection.

In addition, our results showed that the incidence density of CAUTI (mean 3.3 per 1000 urinary catheter–days) and VAP (mean 0.6 per 1000 ventilator–days) were lower than in the NHSN report. In particular, the VAPs were also far lower than in other previous reports [4,11,14]. There were several retrospective reports on RTIs in burn patients. In one study performed at a large regional BICU over a 5–year period, there was a 50% incidence of VAP and a mean VAP rate of 4.22 per 1000 ventilator days (yearly rates ranged from 2.8 to 5.6) [14]. In another study conducted at a tertiary care facility over 5 years, the authors pointed out that the most common site of HAIs was the respiratory tract (44.4%, VAP 4.16 per 1000 ventilator days) [11]. An article similar to the present study using 'active, prospective and patient–based surveillance from Infection Control Committee' retrospective 10 years' data showed that the VAP was 4.16 per 1000 ventilator days [4]. According to the HAI definition of the US CDC, RTI and VAP must be consistent with the infection that occurred 48 h after admission. Of patients with moderate to severe burns in this study, more than one–fourth had inhalation injury >17 points at admission. These burn patients may also have had RTI such as pneumonia on admission, and it would not be judged as RTI of HAI if the condition had not changed during hospitalization.

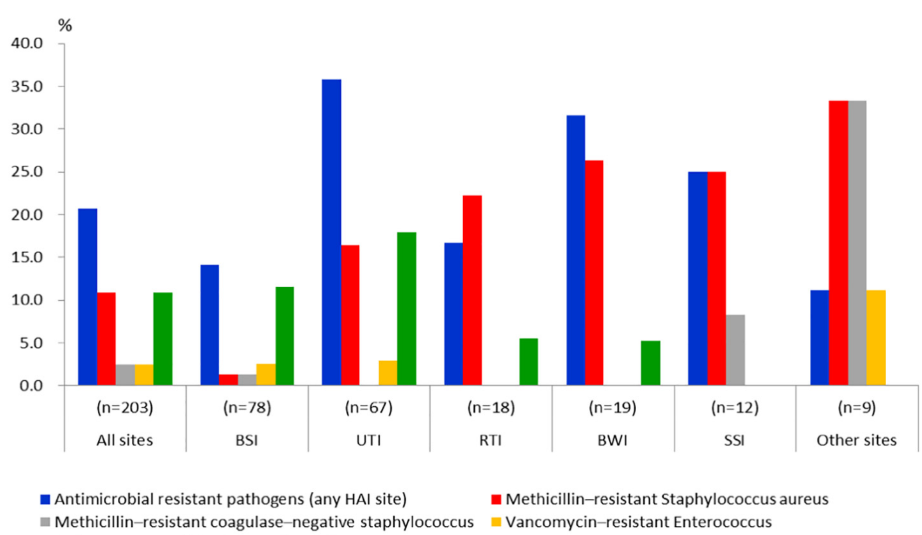

Fig. 1. Distribution of antimicrobial resistant pathogens by healthcare–associated infection sites. * BSI, bloodstream infection; UTI, urinary tract infection; RTI, respiratory tract infections; BWI, burn wound infection; SSI, surgical site infection.

Skin and soft tissue infections in burns are also a non–negligible aspect. In our data, the mean rates of the SSI site (5.1%) and burn wound infections (BWIs, 7.6%) were within the scope of previous research reports (SSI 0.74–4.3%, skin infections (7.0–47.5%) [3,10,11]. In addition to the continuous development and application of dressing materials in recent years, this study also agrees that early excision was an important recommendation for the prevention of BWI [4]. The patients in this study were having early escharotomy or debridement performed to remove damaged tissue in the operating room, but all cases requiring dressing were performed under the appropriate arrangement and protection of their bedside.

Reducing the death of burn patients is an important goal of clinical care. Two retrospective studies found that important prognostic factors included age >60 years, >40% TBSA burned, burn depth, and inhalation injury [20,29]. Patients with >40% TBSA burns require specific and specialized care, as up to 75% of all burn–related deaths were associated with infectious complications [4]. Our results demonstrated that, compared with <49% of TBSA with full-thickness injuries, in burn patients with TBSA with full-thickness injuries of >50%, the likelihood of death was increased 5.2-fold. Another independent factor for mortality was hospitalization in the ICU, which is understandable because burn patients who require intensive care and monitoring are often also severely burned and need invasive equipment.

In addition, infection is still an important negative predictor of death in burn patients. Oncul and colleagues performed prospective HAIs surveillance in burn patients (TBSA 36.3 $\pm$ 9.6%), and mortality rate was found to be 23.2%, with at least one episode of HAI occurring in relation to up to 94.4% of these deaths; of these, 60.2% had more than one episode of HAIs [3]. In the present study, the mortality rate (15.7%) in HAI patients (one quarter of patients with TBSA >50% and inhalation injury 30%) was relatively low. Our data illustrated that BSI risk of death increased significantly, by 2.7 times. Other reported mortality rates among patients with BSIs ranged from 33% to 36% [19,30]. As bacteremia is closely related to the use of intravascular catheters, catheter indwelling care and manipulation on burn patients are very important to prevent infection. It is also worth noting that the risk of death in burn patients with mechanical respirators was up to 11 times higher in univariable analysis.

4.2. Microbiological investigations

In the isolated microbes of burn patients with HAI, GNB have always played a major role in all pathogens. Overall, half of these HAI burn patients in our data were infected with GNB; of these, *Enterobacteriaceae* and the proportion resistant to carbapenem were highest in UTIs. As regards other pathogens, our findings were also similar to other reports, for example in relation to *P. aeruginosa* and *A. baumannii* in RTI and BSI [3,14,19,31]. One report noted that Gram–negative drug–resistant bacteria such as multidrug–resistant *P. aeruginosa* and *A. baumannii* were important microbes in burn patients with BSI, particularly in long–term care [32]. Some studies even reported an incidence of *A. baumannii* resistant to carbapenem as high as 90% or more in burn patients [11,19,33].

In addition, Gram–positive bacteria in burn patients also warrant attention. For example, the isolation rates of *S. aureus* were in the top three of all microbes, and it was also highly resistant to methicillin or oxacillin by >50% [11,14,19]. There was also a report on the lower drug resistance of *S. aureus*, but the TBSA range of their subjects was smaller (interquartile 4–14%) [10]. Our HAI data displayed lower isolated frequency of *S. aureus* and a higher proportion of MRSA; their main sites were the BWIs and SSIs. Norbury and colleagues reviewed the pertinent English–language literature, and they noted that *S. aureus* remains the chief cause of BWI [31]. There is thus a need for more caution in regard to care and dressing replacement and techniques for burn wounds.

The resistance of all pathogens isolated from HAIs to antimicrobial agents found in this study was lower than that reported in other investigations [14,34]. Nevertheless, MDRO poses a serious threat to high acute, persistent or recurrent infections in clinical treatment and care. Effective implementation of compliance with various infection prevention and control measures and antimicrobial stewardship are important strategies for eliminating MDRO [23,35].

The strength of this study was that the HAI data were derived from internationally used forward-looking surveillance and definitions, so it can provide related information on HAIs of various sites for comparison. There are several points to be noted regarding our study. First, the study was performed at a single medical center and focused on moderately to severely burned patients. The generalisability inferences are limited. However, the clinical epidemiological data of HAIs and microbes in moderately to severely burned patients could be provided for comparison with teaching hospitals or other facilities with a similar level of burn severity. Second, skin burns result in an intense inflammatory response. However, this manuscript was mainly based on recommended of the US CDC's definition of burn infection, including changes in the appearance or characteristics of burn wound. The inflammatory response is one of the criteria for judging burn infection; however, our database could not display data on inflammatory responses. Third, it was a retrospective non–randomized study which might have some potential biases; for this reason, multiple regression analysis was used to control confounding variables for reducing the bias of prognostic mortality. Finally, the isolated microbes were not further subjected to molecular typing, due to there being no outbreak event during the study period.

5. Conclusions

The occurrence of HAI in burn patients is an important clinical issue and challenge in treatment and care. The incidence of infection and site of involvement is likely to be dependent on a number of factors including technique, indications for procedures, antibiograms, time to debridement and delays until surgical cover. Fortunately, effective integrated care and appropriate infection control can reduce infection and death. This study found that burn patients with BSI and CLABSI were the most common HAI sites. Prognostic factors of mortality in addition to TBSA, ICU and BSI were also a significant independent factor. The operation of invasive vascular devices and the care of injection sites require close monitoring of signs of infection during indwelling.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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