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Five-Year Surveillance of Central Line Associated Bloodstream Infection in an Intensive Care Unit Population—A Retrospective Analysis

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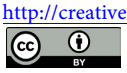

Abstract

Background: Central venous catheters (CVCs) are essential to current intensive care unit (ICU) practices as a tool for treating critically ill patients. However, the use of CVCs is associated with substantial risk of infection. Central line associated bloodstream infection (CLABSI) is increasing in prevalence each year and is among the major causes of bloodstream infection in ICU patients. Therefore, investigating the epidemiology and risk factors of CLABSI in ICU patients is important. **Objective**: This study aimed to investigate the incidence rates, causative pathogens and risk factors of CLABSI in an ICU population. **Methods**: A retrospective observational study was performed in an ICU at Qilu Hospital of Shandong University in China from January 2016 to December 2020. Patients with at least one CVC were enrolled, and information relevant to CVC use was recorded. The prevalence was calculated, and related risk factors were analyzed. **Results:** A total of 1920 catheters were identified, 507 of which were eligible for analysis. For each of the years 2016-2020, the incidence rates of CLABSI were 1.91, 3.18, 1.69, 2.97 and 1.27 per 1000 catheter days, respectively. The yeast *Candida albicans* was the most prevalent pathogen (16 [(3.2%]), followed by Gram-positive methicillin-resistant *Staphylococcus aureus* (11 [2.2%]) and the Gram-negative multidrug-resistant pathogen *Acinetobacter baumanii*. Risk factors associated with CLABSI development were age, ($p = 0.05$), Charlson comorbidity index > 5 ($p < 0.01$) and duration of CVC placement ($p = 0.01$). **Conclusion**: *Candida albicans* was the most common causative microorganism, which was followed by Gram positive methicillin resistant *Staphylococcus*, MDR *K. pneumoniae* and *Aci-*

netobacter baumanii.

Keywords

Central Venous Catheter, Insertion Site, Bloodstream Infection, ICU, Catheter Days

1. Introduction

Central venous catheters (CVCs) are extensively used for fluid resuscitation, intravenous medication delivery, hemodynamic monitoring and parenteral nutrition in the rescue and treatment of critically ill patients [1] [2] [3]. Indwelling CVCs promote effective treatment and avoid the pain of repeated puncture for patients. However, central venous access can have life threatening complications, most commonly nosocomial bloodstream infection caused by the colonization of implanted catheters or contamination of the catheter hub or infusate administered through the device. CVC has been estimated to lead to 250,000 - 500,000 episodes of bloodstream infections in the USA annually [4]. Central line associated bloodstream infections (CLABSIs) dynamically vary in each center over time. In 2017, 24,265 CLABSIs were reported by 3576 acute care hospitals in the USA [2]. The rate of CLABSIs in Western European hospitals has been compared with that in the US national health care safety network; among patients in European intensive care units, 3.5% have been found to develop CLABSI (1.7/1000 catheter days) [5]. In another study, the frequency of CLABSI has been found to be 5.9% (country range: 2.9% - 10.0%). The CLABSI rate has been reported to be 7% in tertiary hospitals [6]. In various studies conducted in China, 2631 cases have been reported across seven ICUs, and the estimated CLABSI rate was 7.66/1000 in August 2008 and July 2010 in four hospitals. The characteristics of microorganisms vary among patients differing in age, immunity status and disease severity [7]. The causative pathogens of CLABSI are mainly Gram positive bacteria, including coagulase negative *Staphylococcus aureus*, methicillin resistant *Staphylococcus aureus*, methicillin sensitive *Staphylococcus aureus* and *Enterococcus faecalis*; Gram negative bacteria, such as *Eshcerichia coli*, *Enterobacter* species, *Klebsiella* species; and yeasts [8]. Despite the early diagnosis of CLABSI and improvements in insertion techniques with the use of ultrasound, CLABSIs continue to pose a substantial risk of morbidity and mortality. CLABSI is potentially associated with poor patient outcomes, longer lengths of hospital stay and higher medical costs [9] [10] [11]. Measures to prevent CLABSI are most likely to be effective if they are guided by full understanding of the pathogenesis and epidemiology of these infections. Moreover, surveillance of CLABSI is an important part of infection control and has been accepted worldwide as a primary step toward prevention. Therefore, each center should determine its own distribution of CLABSI, causative agents and risk factors to guide the development of infection control policies. In this study, we aimed to evaluate the

incidence rates of laboratory confirmed CLABSIs, infectious agents and risk factors in the ICU population over a period of 5 years.

2. Methods

2.1. Study Design

We conducted a retrospective study at Qilu Hospital of Shandong University, a tertiary teaching hospital in Shandong province, China. Eligible patients (≥18 years of age) included those who were admitted to our ICU between January 2016 and December 2020, were treated with a CVC, and had culture results from the peripheral blood and central venous catheter tip. Patients with more than one CVC were included in the study. We excluded patients whose catheters were placed outside our hospital, and patients whose cultures from the peripheral blood or central venous catheter tip were not taken, or for whom data were missing for the primary endpoint.

2.2. Data Collection

Patient data were extracted from the electronic medical records. Clinical data included demographics, sequential organ failure assessment (SOFA) score, acute physiological and chronic health evaluation II (APACHEII) score, Charlson comorbidity index (CCI) score, date of catheter insertion and removal, date of ICU discharge and death, mechanical ventilation and reason for catheter removal. We also extracted laboratory data, including catheter tip and blood culture information.

2.3. Definitions

1) The CLABSI rate was defined as the number of CLABSIs in the ICU/number of central line days in the ICU × 1000 [12]. The diagnosis was demonstrated to be CVC related BSI if the same microorganism was grown from one percutaneous blood culture and from a culture of the catheter tip segment, and the catheter had been in place for more than 2 days.

2) Catheter colonization was defined as a culture with at least > 15 colony forming units per milliliter from the catheter tip segment [13].

3) Central line days were defined as the total number of days during which the central line was in place for each patient in the ICU, calculated from the start date of catheter insertion until CVC removal.

4) For patients with CLABSI, central line days were calculated from the start date of catheter insertion to the date of CLABSI.

5) CLABSI incidence was defined as the number of central line infections per 1000 catheter days.

2.4. Ethical Considerations

This study was conducted in accordance with the amended Declaration of Helsinki. The Research Ethics Commission of Qilu Hospital of Shandong University

approved the protocol used in this study.

2.5. Statistical Analysis

Categorical variables were expressed as counts (percentages) and were compared with chi-square or Fisher's exact test. A descriptive analysis was conducted up to the time of the CLABSI. To identify the variables confounding the risk factors for CLABSIs, we used univariate analysis to compare the groups with and without infection. Multivariate analysis was performed with a logistic regression model with 95% confidence intervals (CIs) to identify independent risk factors associated with the development of CLABSI according to the results of univariate analysis. Proportional hazard ratios were applied to determine the occurrence of CLABSIs. Fisher's exact test was used to identify any statistically significant differences among CLABSIs at the three insertion sites. The outcome of interest was the incidence rate of CLABSI, which was reported per 1000 catheter days. The CLABSI rate was calculated by dividing the number of confirmed catheter-associated infections by the total number of appropriate catheters in situ days and multiplying the result by 1000 to determine the number of events per 1000 catheter days.

The measures of association are presented with odds ratios (ORs) and 95% CIs. All tests were two-sided, and p-values < 0.05 were considered significant. Statistical analysis was performed in IBM SPSS statistical software version 25.0.

3. Results

3.1. Demographics and Clinical Characteristics

During the 5-year period of this study, a total of 1920 catheters were identified, of which 507 met our inclusion criteria and were included in the final analysis (**Figure 1**). The mean age of the patients in this study was 60.31 ± 16.64 years, and 355 (70%) of the patients were men. The reasons for CVC placement included infusion of fluids and blood products (201 [39.6%]), continuous renal replacement therapy (CRRT) (216 [42.6%]), hemodynamic monitoring (53 [10.5%]), extracorporeal membrane oxygenation (ECMO) (26 [5.1%]), parenteral nutrition (1 [0.2%]), double plasma molecular adsorption system (DPMAS) (1 [0.2%]) and plasma exchange (8 [1.6%]). The reasons for CVC removal were suspicion of CLABSI (172 [33.9%]), continuous renal replacement therapy withdrawal (38 [7.5%]), ECMO withdrawal (16 [3.2%]), catheter thrombosis (12 [2.4%]), catheter no longer being needed (37 [7.3%]), discharge of the patient (103 [20.3%]), mechanical complication (15 [3.0%]), prevention of CLABSI (16 [3.2%]), death of the patient (97 [19.1%]) or ulceration at the insertion site (1 [0.2%]). The overall patient demographics and clinical characteristics are presented in **Table 1**.

3.2. Site of CVC

In the study, 101 catheters were inserted at the internal jugular site, 113 catheters

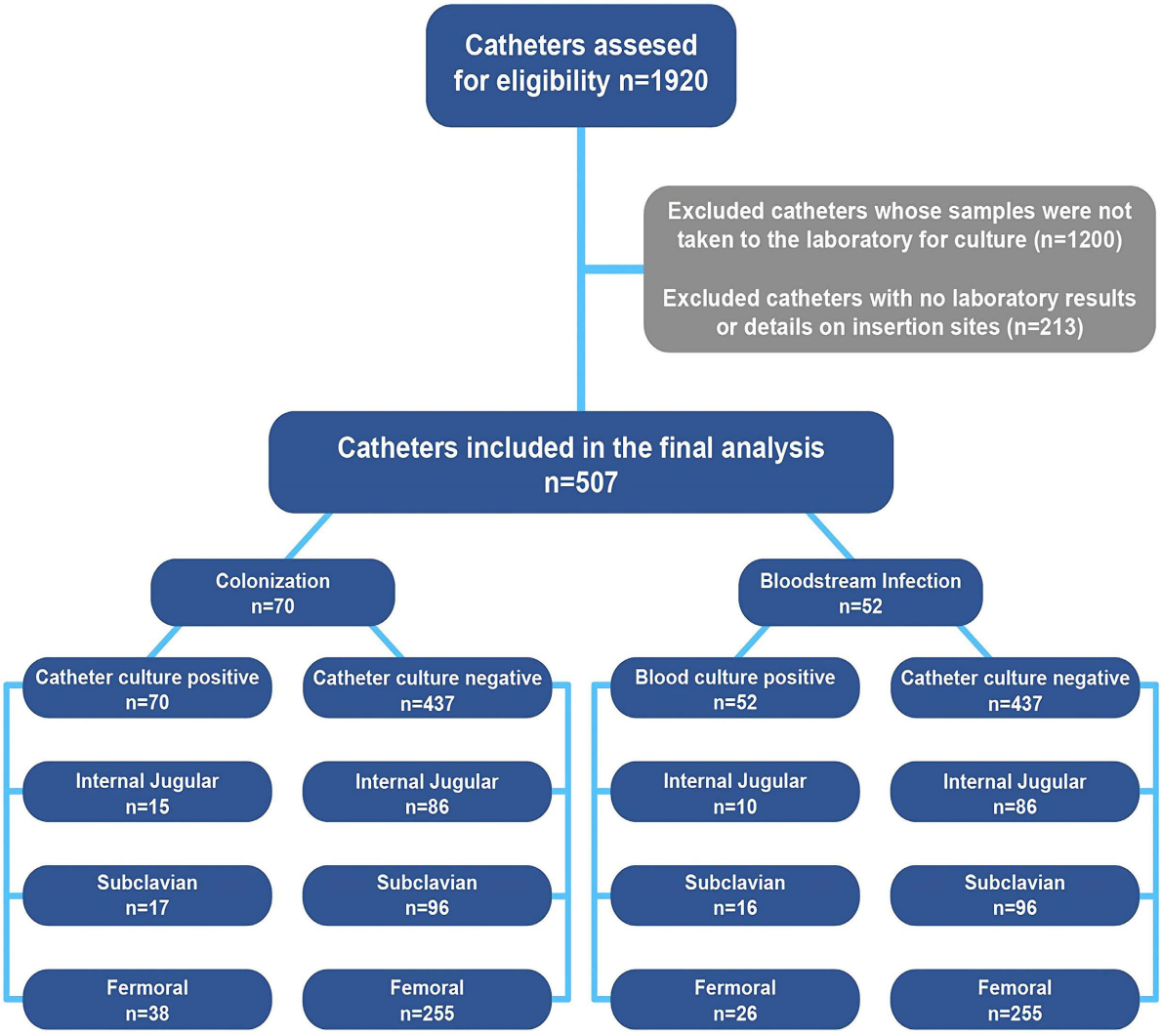

Figure 1. Showing inclusion criteria to the study.

Table 1. Baseline characteristics of patients and CVCs.

Variable	Value (%)
Age (y, Mean ± SD)	60.31 ± 16.64
Male	355 (70)
APACHE II Score	
0 - 35	439 (86.5)
>35	68 (13.4)
SOFA Score	
0 - 15	459 (90.5)
16 - 24	48 (9.5)
Charlson Comorbidity Index	
1 - 4	286 (56.4)
>5	221 (43.6)

Continued

Catheter insertion site	
Femoral	293 (57.8)
Internal Jugular	101 (19.9)
Subclavian	113 (22.3)
Reason for catheter Insertion	
CRRT	216 (42.6)
Infusion of fluids, drugs and blood products	201 (39.6)
Extracorporeal membrane oxygenation	26 (5.1)
Hemodynamic monitoring	53 (10.5)
Parenteral nutrition	1 (0.2)
DPMAS	1 (0.2)
Plasmapheresis	1 (0.2)
Plasma exchange	8 (1.6)
Reasons for catheter withdrawal	
Suspicion of CLABSI	172 (33.9)
CRRT withdrawal	38 (7.5)
ECMO withdrawal	16 (3.2)
Catheter thrombosis	12 (2.4)
Catheter no longer needed	37 (7.3)
Discharge of the patient	103 (20.3)
Mechanical complication	15 (3.0)
Prevention of CLABSI	16 (3.2)
Death of patient	97 (19.1)
Ulceration at insertion site	1 (0.2)
Duration of catheter stay before development of CLABSI	
Mean ± SD	1.60 ± 5.72
Duration of catheter stay before development of colonization	
Mean ± SD	1.88 ± 6.04
CLABSI	
Negative	455 (89.7)
Positive	52 (10.3)
Catheter culture	
Negative	437 (86.2)
Positive	70 (13.8)
Days of catheter placement (IQR)	
Femoral	2575 (0 - 38)
Internal jugular	1001 (0 - 36)
Subclavian	1134 (0 - 38)

were inserted at the subclavian site, and 293 catheters were inserted at the femoral venous site (Table 1).

3.3. Incidence of CLABSI

Among 507 analyzed catheters, 52 had CLABSI episodes and 70 had colonization episodes. The mean duration of catheter placement until the development of infection was 1.60 ± 5.72 in CLABSI cases and 1.88 ± 6.04 in colonization cases (Table 1).

The incidence of CLABSI was observed to be higher for the internal jugular site than for the two other sites, although this difference was not statistically significant. The annual CLABSI incidence rates from 2016 to 2020 are shown in Table 2.

The incidence of CLABSI at the three sites for the 5-year period was analyzed (Table 2). The annual CLABSI incidence for each of the five years at the three insertion sites was as follows: internal jugular site, 1.99, 4.99, 0.99, 5.99 and 3.99 infections per 1000 catheter days; subclavian site, 1.76, 2.65, 1.76, 2.65 and 0.3 infections per 1000 catheter days; and femoral site, 1.94, 2.72, 1.94, 1.94 and 0.77 infections per 1000 catheter days. The duration of catheterization (in days) was longer in the femoral group than in the other groups (Table 1).

3.4. Microbial Characteristics

Ten microorganisms were responsible for the 70 cases of colonization and 52 cases of CLABSI. The microorganisms responsible for the three types of catheter infection are presented in Table 3.

For CLABSIs, the distribution was as follows. Gram-negative bacteria: MDR *K. pneumoniae* 8 (1.6%), MDR *Acinetobacter baumanii* 8 (1.6%), non-MDR *K. pneumoniae* 0 (0.0%), carbapenem resistant *Enterobacteriaceae* 2 (0.4%), *Burkholderia cepacia* 1 (0.2%); Gram-positive bacteria: methicillin resistant *Staphylococcus aureus* 11 (2.2%), methicillin sensitive *Staphylococcus aureus* 1 (0.2%), *Corynebacterium striata* 1 (0.2%), *Enterococcus faecalis* 4 (0.8%); yeasts: *Candida albicans* 16 (3.2%). No growth of microorganisms was found in 455 (89.7%)

Table 2. Incidence of CLABSI over a period of five years.

Year	Annual CLABSI Incidence/1000 catheter days	Incidence of CLABSI according to the catheter site			p-value
		SC	IJ	FEM	
2016	9 (1.91)	2 (1.76)	2 (1.99)	5 (1.94)	0.915
2017	15 (3.18)	3 (2.65)	5 (4.99)	7 (2.72)	0.295
2018	8 (1.69)	2 (1.76)	1 (0.99)	5 (1.94)	0.695
2019	14 (2.97)	3 (2.65)	6 (5.99)	5 (1.94)	0.170
2020	6 (1.27)	0 (0)	4 (3.99)	2 (0.77)	0.321

CLABSI: central line associated bloodstream infection, SC: subclavian, IJ: internal jugular, Fem: femoral.

Table 3. Distribution of microorganisms' distribution associated with the CLABSI and catheter colonization.

Isolated microoganisms associated with Development of CLABSI	Total n (%)
Gram negative bacteria	
MDR K. pneumonaie	8 (1.6)
MDR Acinetobacter baumannii	8 (1.6)
Non-MDR K. pneumoniae	0 (0.0)
Carbapenem resistant Enterobacteriaceae	2 (0.4)
Burkholderia cepacia	1 (0.2)
Gram positive bacteria	
Methicillin resistant staphylococcus aureus	11 (2.2)
Methicillin sensitive Staphylococcus aureus	1 (0.2)
Corynebacterium striata	1 (0.2)
Enterococcus faecalis	4 (0.8)
Yeasts	
Candida albicans	16 (3.2)
No growth	455 (89.7)
Isolated Microorganisms associated with Development of catheter colonization.	**Total**
Gram-Negative bacteria	
MDR K. Pneumoniae	8 (1.6)
MDR Acinetobacter Baumanii	10 (2.0)
Carbapenem Resistant Enterobacterioacae	2 (0.4)
Burkhoderia Cepacia	1 (0.2)
Gram-positive bacteria	
Methicillin resistant staphylococcus aureus	11 (2.2)
Methycillin sensitive staphylococcus aureus	4 (0.8)
Corynebacterium Striata	1 (0.2)
Enterococcus fecalis	6 (1.2)
Yeasts	
Candida albicans	20 (3.9)
No growth	444 (87.6)

samples. For colonization, the distribution was as follows. Gram negative: MDR *K. pneumonia*e 8 (1.6%), MDR *Acinetobacter baumanii* 10 (2.0%), carbapenem resistant *Enterobacteriaceae* 2 (0.4%), *Burkholderia cepacia* 1 (0.2%); Gram-positive: methicillin resistant *Staphylococcus aureus* 11 (2.2%), methicillin sensitive *Staphylococcus aureus* 4 (0.8%), *Corynebacterium striata* 1 (0.2%), *Enterococcus faecalis* 6 (1.2%); yeasts: *Candida albicans* 20 (3.9%). No growth of mi-

croorganisms was observed in 437 (86.2%) catheter tip samples.

3.5. Risk Factors

Table 4 shows differences between the patients with CLABSI and No CLABSI. Patients with CLABSI were older, males, greater CCI score, and longer catheter days ($p = 0.026$, $p = 0.143$, $p < 0.01$, and $p < 0.01$).

Multivariable logistic regression analysis was performed to identify the independent risk factors associated with the development of CLABSI. Age (p-value = 0.04), Charlson comorbidity index (p-value < 0.01) and duration of CVC placement (p-value = 0.001) were associated with an elevated risk of CLABSI. For every 1-year increase in patient age, a 3.3% increase was observed in the odds of developing CLABSI. Each unit increase in the Charlson comorbidity index score was associated with a 3.207-fold higher risk of developing CLABSI. Regarding CVC days, for each 1-day increase in the duration of catheter placement, the risk of developing CLABSI was 1.095 times higher (95%CI) than when the duration decreased (Table 5).

Table 4. Univariate analysis of the confounding variables associated with CLABSI.

Variables	CLABSI	NCLABSI	p-value
	N = 52 (10.2%)	N = 455 (89.7%)	
Age			
<62	17 (7.0%)	223 (93.0%)	0.026
>62	35 (13.1%)	232 (86.9%)	
Sex			
Female	11 (7.23%)	141 (93.0%)	0.143
Male	41 (11.54%)	314 (88.4%)	
SOFA score			
<24	45 (10.32%)	391 (89.6%)	0.944
>24	7 (10.6%)	59 (89.3%)	
APACHE score			
<35	46 (10.5%)	391 (89.4%)	0.721
>35	6 (9.09)	60 (91.0)	
CCI index			
<5	12 (4.16%)	276 (96.0%)	0.000
>5	40 (18.3%)	179 (82.0%)	
IJ			
yes	8 (8.0%)	92 (92.0%)	0.457
no	44 (10.8)	363 (89.2)	
SC			
yes	11 (9.8%)	101 (89.6%)	0.865
no	41 (10.4%)	354 (90.2%)	

Continued

FEM			
yes	21 (9.7%)	196 (89.3%)	0.71
no	31 (10.7%)	259 (90.6%)	
TPN			
yes	26 (10.5%)	234 (90.0%)	0.845
no	26 (10.0%)	221 (89.5%)	
Invasive			
yes	50 (10.6%)	422 (89.4%)	0.563
no	2 (5.7%)	33 (94.3%)	
Candida albicans			
yes	9 (64.3%)	5 (35.7%)	0.000
no	47 (9.5%)	446 (90.5%)	
Methicillin resistant staphylococcus			
yes	8 (72.7%)	3 (27.3%)	0.093
no	3 (27.3%)	447 (90.1%)	
Acinetobacter Baumanii			
yes	7 (77.8%)	2 (22.2%)	0.233
no	50 (10.0%)	448 (90.0%)	
Klebsiella. Pneumonia			
yes	6 (75.0%)	2 (25.0%)	0.194
no	50 (10.0%)	449 (90.0%)	
Methicillin sensitive Staphylococcus Aureus			
yes	1 (100.0%)	0 (0.00%)	0.103
no	51 (10.1%)	455 (89.0%	
Carbapenem resistant Enterobacterioacae			
yes	1 (50.0%)	1 (50.0%)	0.195
no	51 (10.0%	454 (89.7%)	
Catheter day			
<8 days	13 (5.15%)	239 (95.0%)	0.000
>8 days	39 (15.3%)	216 (84.7%)	
CRRT			
yes	23 (10.7%)	192 (89.3%)	0.779
no	29 (9.9%)	263 (90.1%)	

Table 5. Binary logistic regression analysis for independent risk factors associated with the development of CLABSI.

	95% CI Lower	95% CI Upper	Odd Ratio	p-value
Age	1.01	1.056	1.033	0.004
Gender (female)	0.738	3.321	1.565	0.243
SOFA Score	0.988	1.616	1.231	0.134
CCI	1.85	5.561	3.207	0.00
Duration of catheter stay > 8 days	1.055	1.136	1.095	0.001
APACHE II Score > 35	0.674	1.131	0.873	0.303

4. Discussion

According to the data from our hospital, the annual incidence rates of CLABSI in the medical surgical ICU from 2016 to 2020 were 1.91, 3.18, 1.69, 2.97 and 1.27 infections per 1000 catheter days. A recent multi-center prospective study conducted in 79 ICUs in China has reported CLABSI incidence rates of 1.50/1000 catheter days, which are lower than the CLABSI rates in our ICU. According to data from the National Health Surveillance Network in 2016, the US CLABSI infection rate was 0.5 infections per 1000 catheter days [14]. Although we use CLABSI prevention bundles in our ICU, gaps in compliance are likely to exist in terms of the implementation and maintenance of these bundles. Several studies conducted in Qatar have reported a decrease in CLABSI incidence rates from four and six in 2015 and 2016, respectively, to zero in 2017 and 2018 after strict compliance with CLABSI care bundles was instituted. We recommend that all physicians receive continual training and education through simulation techniques. In addition, continual surveillance and display of data relating to hand hygiene, bundle compliance and CLABSI rates are necessary to maintain a sense of urgency and momentum. A possible explanation for the lower incidence of CLABSI in 2020 is the Coronavirus disease 2019 (COVID-19) pandemic, which might have increased emphasis on infection control practices and hand hygiene, which was encouraged both inside and outside hospitals, as well as training in donning and donning of personal protective equipment.

Specifically, we observed a trend toward a greater rate of CLABSI for the internal jugular site than the other two sites. Although most CVCs were inserted in the femoral site (57.8%), their contribution to catheter infection was low. The difference in the incidence rates of catheter infection according to the insertion site was small; however, we cannot state that all three sites have a statistically equivalent risk of infection, because our sample size was not sufficiently large to support this conclusion. The literature has reported conflicting data regarding the risk of catheter infection for the three venous sites of catheterization. Most studies have indicated a higher risk at the femoral site and a lower risk at the subclavian site [15] [16] [17], whereas others have reported no difference [8]

[18] [19]. Many clinical practice guidelines have suggested that the femoral site should be avoided because of an anticipated higher risk of catheter-associated bloodstream infection; nonetheless, the preferred site for insertion is complex and depends on the skills of the operator. We suggest a preference for the subclavian vein for CVC insertion and the use of chlorhexidine for cleaning the site of catheter placement.

Candida albicans has been reported to be a causative agent of CLABSI, followed by Gram-positive methicillin resistant *S. aureus* and Gram-negative MDR *K. pneumoniae* and *A. baumanii*. According to the international CLABSI pathogen distribution reported in previous studies, the pathogens causing catheter-associated infections arise from the normal resident flora of the skin at the site of insertion, e.g., *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Enterococcus* and fungi [13] [20] [21]. However, a concerning trend of increased multidrug-resistant organisms, e.g., methicillin-resistant *S. aureus* and fluconazole-resistant *Candida* species causing CLABSI has recently been observed [16] [22] [23]. Soriano *et al.* have identified *Acinetobacter baumanii* as the main causative microorganism, followed by *S. epidermidis* and *Candida albicans* [20]. One prospective study in Poland has found an increase in Gram negative bacteria and *Candida* among neutropenic patients with CLABSI [24]. Recently, bloodstream infection caused by *Candida* species has also become a concerning trend in China. A large-scale prospective study in China has reported an incidence of all candidemia in the ICU of 9.86% [25]. In previous studies, *Candida parapilosis* has been found to be more prevalent in patients with CLABSI admitted in the ICU than in patients admitted in other hospital units [25]; however, in the present study, *Candida albicans* was the most prevalent pathogen 16 (3.2%). A recent study has demonstrated that a delay in catheter removal or initiation of antifungal therapy is associated with poor outcomes in patients with CLABSI [26] [27].

In this study, multidrug-resistant pathogens, e.g., methicillin-resistant *S. aureus*, *Acinetobacter baumanii* and *Klebsiella pneumoniae*, were isolated with a prevalence of 2.2%, 1.6% and 1.6%, respectively. The incidence of MDR Gram-negative bacteria in the ICU is usually higher than that in other hospital units, and antibiotic use has been identified as a crucial factor in the emergence of antibiotic resistance. According to the China antimicrobial resistance network (CHI-NET), the resistance rate of *A. baumanii* increased to 62.8% and 59.8% in 2013 and 77.1% and 78.1% in 2018 [16] [28]. This trend may explain the distribution of microorganisms in our study, which was identical to that reported in a Greek ICU profile of CVC colonization and causative pathogens, in which the incidence of *A. baumanii* was high because of the predominance of Gram-negative organisms [29] [30]. In Italy, the incidence of *A. baumanii* and *K. pneumoniae* in CVC-bacteremia has been found to be higher in patients with COVID-19 and patients with longer ventilator durations [30] [31] [32]. The predominance of multidrug-resistant CVC-bacteremia has introduced challenges in treatment modali-

ties, thus resulting in prolonged ICU stays and increased mortality and inpatient costs. However, those factors were not examined in this study.

Logistic regression analysis based on a binomial distribution identified three independent predictors of CVC-associated bloodstream infection: age (OR = 1.033, 95% CI 1.01 - 1.056), Charlson comorbidity index (OR = 3.207, 95% CI 1.85 - 5.561) and a duration of catheter placement > 8 days (OR = 1.095 95% CI 1.055 - 1.136) (**Table 5**). These variables may provide physicians with real-time information to aid in decision-making to decrease the rate of CLABSI.

CLABSI was found to be more likely to occur in patients with advanced age: every 1-year increase in age was associated with a 3.3% increase in the risk of CLABSI. The Charlson comorbidity index is a method of categorizing patient comorbidity according to International Classification diagnosis codes. A score of 0 indicates no comorbidities found. The higher the score, the higher the likelihood of mortality. Binary logistic regression indicated that the Charlson comorbidity index was an independent risk factor associated with CLABSI. This result is consistent with the findings of Pepin *et al.* [18] [22] [33]. Moreover, a study by Ruhe *et al.* aiming to identify the clinical significance of *Staphylococcus aureus* in CVC culture tips has also shown that a higher Charlson comorbidity index is associated with severe septic complications in the presence of CLABSI [34]. To prevent septic complications, physicians must prevent CLABSI when managing patients with serious comorbid conditions. As reported in previous studies, catheter duration is associated with CLABSI development. Although antimicrobial and antiseptic impregnated catheters were used in this study, an increase in catheter days resulted in more infection cases. The need for central line catheterization should be assessed daily; through stating the line day (e.g., line day 4) during the rounds. The catheter should also be removed immediately once it is no longer necessary. To avoid the risk of CLABSI, CVCs should be changed after 8 days if they remain necessary.

We identified several potential limitations in our study designs and methods. The clearest limitation is that our study was retrospective. Therefore, missing data could not be avoided, although in the final analysis, the sample size in the three catheter groups was sufficiently large for a final analysis. Second, our study was a single-center study; therefore, it does not represent the status of ICUs in China. Third, the correlations among CLABSI and ICU length of stay, survivors and non-survivors, and in-hospital costs were not assessed. Fourth, the computer information system in our hospital does not report the results of the catheter tip culture from the site at which the catheter tip sample was taken, thus hindering interpretation of most of the catheter tip culture results.

In conclusion, our study determined the long-term incidence of CLABSI, risk factors and the epidemiology of microorganisms associated with CLABSI in an ICU population over a 5-year period. *Candida albicans* was the most common causative microorganism, which was followed by methicillin resistant *Staphylococcus aureus*, MDR *K. pneumoniae* and *A. baumanii*. This study identified sev-

eral risk factors in our ICU, and future studies will be required after infection control measures have been implemented.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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