Microbial Distribution and Antibiotic Susceptibility of Bloodstream Infections in Different Intensive Care

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Research

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Abstract

Background: Bloodstream infection (BSI) is an increasing public health concern worldwide, representing a serious infection with significant morbidity and mortality, especially in children and elderly. The predominant microbial distribution and antibiotic susceptibility were investigated among BSIs in the pediatric intensive care unit (PICU), surgical intensive care unit (SICU), cardiac intensive care unit (CICU), respiratory intensive care unit (RICU) and geriatric intensive care unit (GICU) in order to achieve more efficient and appropriate therapies for patients in various ICUs.

Methods: In this retrospective cross-sectional study, 516 positive cultures out of 6597 blood specimens among BSIs in the five ICUs from 2017 to 2020 were analyzed for pathogen incidence and drug-susceptibility.

Results: The incidence of BSIs was the highest in the RICU (9.48%) followed by the PICU (8.36%). The total prevalence of Gram-positive (G⁺) bacterial strains (especially *Staphylococcus spp.* and *Enterococcus spp.*) in the PICU (44.55%), SICU (57.58%), CICU (55.00%) and GICU (49.06%) was higher than Gram-negative (G⁻) bacteria. The major bacterial strain was *Acinetobacter baumannii* (G⁻) in the PICU (21.82%), *Klebsiella pneumoniae* (G⁻) in the SICU (12.88%), CICU (30.00%) and RICU (30.39%), and *Escherichia coli* (G⁻) in GICU (20.75%). *Staphylococcus hominis* of BSIs remained highly susceptible (>70%) to gentamicin, linezolid, daptomycin, teicoplanin, vancomycin, tigecycline and rifampicin in all the ICUs. Its antibiotic sensitivity to levofloxacin was moderate in the PICU and CICU, but mild (<30%) in the SICU, RICU and GICU. *K. pneumoniae* was highly susceptible to doxycycline, minocycline, tigecycline in all the ICUs except RICU, and its antibiotic sensitivity to imipenem, meropenem, amikacin, ciprofloxacin and levofloxacin in the GICU was high/moderate in PICU, CICU and GICU, but mild in the SICU and RICU.

Conclusions: The current study demonstrated the distribution of prevalent microorganisms and their antimicrobial susceptibility exhibited a high divergence among BSIs in PICU, SICU, CICU, RICU and GICU from a tertiary hospital in Beijing. Therefore, different antibiotic therapies for various wards and distinct age groups (especially between pediatric and elderly patients) should be considered to control the emergence and spread of highly antibiotic-resistant infections.

Background

Bloodstream infection (BSI), a serious infection with significant morbidity and mortality, becomes an increasing public health concern worldwide. Population-based studies in North America and Europe demonstrate that the BSI incidence ranged between 113 and 204 per 100000 population [1, 2]. A previous research based on the Swiss antibiotic resistance surveillance system (ANRESIS) described temporal trends and revealed a rise in the incidence rate of BSIs (increased by 14%, from 211 in 2008 to 240 per 100 000 population in 2014), especially among elderly patient (≥ 65 years) [3]. Moreover, it is also reported that BSIs remained one of the leading causes of death with an overall estimated fatality rate of 12.7% in the pediatric population [4]. Antimicrobial agents are commonly administered to treat BSIs, but the clinical management is not so effective because of antibiotic resistance.

In recent years, a rising incidence of multi-drug resistant pathogens is one of the most serious global public health threats, and World Health Organization (WHO) has published the first global report on surveillance of antimicrobial resistance, showing the extent of this phenomenon in many parts of the world [5]. Empirical therapeutics is often started immediately in suspected BSI to reduce associated morbidity and mortality because of the routine delays in receiving blood culture and antibiotic susceptibility analysis. However, the current international guidelines are not suitable for all regions and generic recommended antimicrobial therapy is sometimes not adapted to local susceptibility patterns in developing countries [6, 7]. Changing antimicrobial resistance rates, pathogen distribution, demographics, and medical care delivery all may affect the epidemiology of BSI. Therefore, updated trends in the microbiology of BSI pathogens and the antibiotic susceptibility are required to support therapeutic guidelines for appropriate therapies.

The effective selection and use of antibiotics lately has become a huge challenge for all physicians. However, a comparison of relative frequency and microbiological characteristics of the pathogens in patients with BSIs in different intensive care units (ICU) was seldom investigated thoroughly in China, particularly in elderly (> 60 years) and pediatric patients. In the this study, the microbial distribution and antibiotic sensitivity of BSIs in the pediatric intensive care unit (PICU), surgical intensive care unit (SICU), cardiac intensive care unit (CICU), respiratory intensive care unit (RICU), and geriatric intensive care unit (GICU) was investigated to achieve more efficient treatment protocols and better recovery in our hospital.

Methods

Subjects

We conducted a retrospective cross-sectional study in Department of PICU, Department of SICU, Department of CICU, Department of RICU and Department of GICU in Peking University First Hospital (a large-scale tertiary general hospital) from 1 January, 2017 to 30 June, 2020. 516 positive culture samples from 6597 blood samples were obtained from patients with BSIs in PICU, SICU, CICU, RICU and GICU (Table 1). The blood samples were collected before antimicrobial treatment. BSIs are defined by the presence of an organism within the bloodstream with or without signs or symptoms of an infection. This study has been reviewed and approved by Institutional Ethics Committee of Peking University First Hospital, and a review in terms of patient consent was not needed because of the retrospective observational design according to the committee decision.

Table 1
Blood Cultures of Patients in Different Intensive Care Units

	PICU	SICU	CICU	RICU	GICU
Male (%)	51.67	61.11	55.45	60.53	70.34
Age (years)	4.69 ± 1.61	58.78 ± 11.52	68.57 ± 16.54	68.43 ± 16.53	84.33 ± 9.72
Blood cultures					
Total samples (N)	1316	2160	541	1909	671
Positive isolates (n)	110	132	40	181	53
Prevalence (%)	8.36	6.11	7.39	9.48	7.90
Continuous values are expressed as mean ± SD.					
PICU, pediatric intensive care unit; SICU, surgical intensive care unit; CICU, cardiac intensive care unit; RICU, respiratory intensive care unit; GICU, geriatric intensive care unit.					

Microorganism identification and drug-susceptibility test

Microorganism cultures were conducted according to the routine standard operation procedure (SOP) by the Department of Clinical Laboratory in our hospital as described previously [8]: blood specimen was inoculated into a commercial culture bottle and analyzed by an automated monitoring system for bacterial detection (BD BACTEC™, BD, USA). The incubation was continued until a positive culture was observed or up to a maximum of 5 days. Positive bacterial cultures from patients' blood samples collected within the first 24 h of admission were tested for type of pathogens and sensitivity to antibiotics. The microorganisms were identified to species level by standard biochemical methods including matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS) (Bruker Daltonics, USA) and automated methods using the VITEK system (BioMérieux, France). The bacterial isolates were tested for antimicrobial susceptibility by VITEK 2 Compact (BioMérieux, France) or the manual Kirby–Bauer (K-B) disc diffusion method. The selection of VITEK susceptibility card types (BioMérieux, France) was as follows: AST-P639 for Gram-positive bacteria and AST-N335 for other Gram-negative bacteria according to the needs of clinicians. Interpretation of drug susceptibility data were based on the Clinical Laboratory Standards Institute (CLSI, USA) standard.

Statistic analysis

Continuous values are expressed as mean ± SD. Microbial distribution and antibiotic susceptibility data were presented as percentages. The Chi-square (χ^2) or Fisher exact tests were performed to compare differences between groups using SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA). A $P < 0.05$ was considered statistically significant.

Results

Prevalence of positive blood cultures in different intensive care units

From 1 January, 2017 to 30 June, 2020, the frequencies of reportedly positive cultures was 110 (8.36%) out of 1316 blood samples in the PICU; 132 (6.11%) out of 2160 blood cultures in the SICU; 40 (7.39%) out of 541 blood cultures in the CICU; 181 (9.48%) out of 1909 blood cultures in the RICU; and 53 (7.90%) out of 671 blood cultures in the GICU. The prevalence of positive blood cultures of the patients in different ICUs was summarized in Table 1. RICU cultures had the highest positive frequency, significantly higher than that in other ICUs (all $P < 0.05$).

Distribution and comparison of microorganisms in blood cultures

The profile of microorganisms isolated from BSI patients was summarized in Fig. 1. In the PICU, the most common bacterial strains in blood samples were *Acinetobacter baumannii* (n = 24, 21.82%) and *Staphylococcus epidermidis* (n = 13, 11.82%), followed by *Enterococcus faecalis* (n = 9, 8.18%) and *Staphylococcus hominis* (n = 8, 7.27%). In the SICU, the four most frequent pathogens were *Klebsiella pneumoniae* (n = 17, 12.88%), *E. faecalis* (n = 16, 12.12%), *S. hominis* (n = 12, 9.09%) and *S. epidermidis* (n = 10, 7.58%) among blood cultures. Gram-positive bacteria (n = 22, 55.00%) accounted for over 50% in blood specimens of patients admitted to the CICU, but Gram-negative *Klebsiella pneumoniae* (n = 12, 30.00%) was the dominant microorganism. *Staphylococcus aureus* (n = 8, 20.00%) was the second most common bacterium, followed by *S. hominis* (n = 5, 12.50%) and *S. epidermidis* (n = 4, 10.00%). In the RICU, Gram-negative bacteria (n = 76, 41.99%) remained the major pathogens of patients' blood cultures, and the five most frequent bacterial strains were *K. pneumoniae* (n = 55, 30.39%), *S. hominis* (n = 16, 8.84%), *S. epidermidis* (n = 13, 7.18%), *Staphylococcus capitis* (n = 11, 6.08%) and *A. baumannii* (n = 10, 5.52%). The most predominant microorganism in the GICU was *Escherichia coli* (n = 11) with an isolation rate of 20.75%, followed by *K. pneumoniae* (n = 10, 18.87%), *S. hominis* (n = 7, 13.21%) and *Enterococcus faecium* (n = 7, 13.21%).

Among the blood cultures, the frequency of Gram-positive bacterial strains (especially *Staphylococcus spp.* and *Enterococcus spp.*) was higher than Gram-negative bacterial strains in the PICU (n = 49, 44.55%), SICU (n = 76, 57.58%), CICU (n = 22, 55.00%) and GICU (n = 26, 49.06%), of which, however, Gram-negative *A. baumannii*, *K. pneumoniae* and *E. coli* were the most prevalent. In addition, *K. pneumoniae* was the dominant pathogen in three of the five ICUs, such as the SICU, CICU and RICU. Fungal pathogens in the PICU, SICU, CICU, RICU and GICU were respectively at 23.64 %, 8.33%, 2.50%, 19.34% and 5.66%, and *Candida albicans* and *Candida parapsilosis* were the most common fungi.

Antibiotic susceptibility of major bacterial of BSIs

Drug-susceptibility of Gram-positive *S. hominis*, *S. aureus* and *E. faecium* was selected as shown in Table 2 and Fig. 2. As the predominant Gram-positive bacterium, *S. hominis* remained highly susceptible (> 70%) to gentamicin, linezolid, daptomycin, teicoplanin, vancomycin, tigecycline, and rifampicin in all the ICUs, moderately susceptible to clindamycin apart from the GICU. Its antibiotic sensitivity to levofloxacin was moderate in the PICU and CICU, but mild (< 30%) in the SICU, RICU and GICU. *S. aureus* was highly susceptible to linezolid, daptomycin, teicoplanin, vancomycin, tigecycline, and rifampicin in all the ICUs, moderately susceptible to erythromycin and clindamycin except GICU and RICU. And the susceptibility to oxacillin, gentamicin, levofloxacin and moxifloxacin was high in PICU, high or moderate in SICU and CICU, while mild in the RICU and GICU. *E. faecium* exhibited highly sensitive to linezolid and vancomycin, mild sensitive to benzylpenicilli and erythromycin in all the ICUs, and it was highly sensitive to teicoplanin and tigecycline in PICU, SICU and GICU (except RICU and CICU). Its drug-susceptibility to ampicillin and gentamicin was moderate in PICU and mild in other ICUs.

Table 2
Drug-susceptibility of Major Gram-positive Bacteria of Bloodstream Infections in Different Intensive Care Units (%)

Antibacterials	<i>Staphylococcus hominis</i>					<i>Staphylococcus aureus</i>					<i>Enterococcus faecium</i>				
	PICU	SICU	CICU	RICU	GICU	PICU	SICU	CICU	RICU	GICU	PICU	SICU	CICU	RICU	GICU
	(n = 8)	(n = 12)	(n = 5)	(n = 16)	(n = 7)	(n = 2)	(n = 3)	(n = 8)	(n = 6)	(n = 1)	(n = 3)	(n = 6)	(n = 3)	(n = 6)	(n = 7)
Benzylpenicilli	0	0	0	0	0	0	66.67	0	16.67	0	0	0	0	16.67	28.57
Ampicillin	-	-	-	-	-	-	-	-	-	-	66.67	16.67	0	33.33	28.57
Oxacillin	0	0	0	6.25	0	100	66.67	100	16.67	0	-	-	-	-	-
Gentamicin	100	91.67	100	100	71.43	100	100	62.5	16.67	0	66.67	16.67	33.33	50	57.14
Levofloxacin	62.5	25	40	6.25	0	100	66.67	100	16.67	0	100	33.33	0	16.67	0
Moxifloxacin	25	25	40	6.25	0	100	66.67	100	16.67	0	-	-	-	-	-
Erythromycin	12.50	16.67	0	6.25	0	50	66.67	62.5	16.67	0	33.33	0	33.33	16.67	0
Clindamycin	37.5	33.33	40	31.25	0	50	66.67	37.5	16.67	0	-	-	-	-	-
Linezolid	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daptomycin	100	100	100	100	100	100	100	100	100	100	-	-	-	-	-
Teicoplanin	100	100	100	100	100	100	100	100	100	100	100	100	66.67	100	100
Vancomycin	100	100	100	100	100	100	100	100	100	100	100	100	66.67	66.67	100
Tigecycline	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Rifampicin	100	83.33	100	100	71.43	100	100	100	100	0	-	-	-	-	-
Trimethoprim/ Sulfamethoxazole	0	8.33	100	37.5	28.57	100	100	37.5	83.33	100	-	-	-	-	-

The antibiotic sensitivity of Gram-negative *K. pneumoniae*, *E. coli* and *A. baumannii* was selected as shown in Table 3 and Fig. 3. *K. pneumoniae* of BSIs remained highly sensitive to doxycycline, minocycline, tigecycline in all the ICUs except RICU, moderately susceptible to piperacillin/tazobactam, ceftazidime, cefoperazone/sulbactam, cefepime, aztreonam in PICU, CICU and GICU apart from the SICU and RICU. Its antibiotic sensitivity to imipenem, meropenem, amikacin was high in PICU, CICU and GICU, but mild in the SICU and RICU. Moreover, the susceptibility to ciprofloxacin and levofloxacin was high in the PICU and CICU, moderate in the GICU, and still mild in the SICU and RICU. *E. coli* was highly susceptible to the tested antibiotics in the CICU, whereas it exhibited moderate or relatively low drug-susceptibility to antibiotics except doxycycline, minocycline and tigecycline in the PICU, SICU and GICU. *A. baumannii* was highly sensitive to tigecycline, mildly susceptible to piperacillin/tazobactam, cefoperazone/sulbactam, imipenem, meropenem, amikacin, ciprofloxacin, trimethoprim/sulfamethoxaz in the ICUs. And its susceptibility to ceftazidime, cefepime, tobramycin, levofloxacin, doxycycline and minocycline was moderate in PICU, but mild in the SICU and RICU.

Table 3
Drug-susceptibility of Major Gram-negative Bacteria of Bloodstream Infections in Different Intensive Care Units (%)

Antibacterials	<i>Klebsiella pneumoniae</i>					<i>Escherichia coli</i>					<i>Acinetobacter baumannii</i>				
	PICU	SICU	CICU	RICU	GICU	PICU	SICU	CICU	RICU	GICU	PICU	SICU	CICU	RICU	
	(n = 5)	(n = 17)	(n = 12)	(n = 55)	(n = 10)	(n = 2)	(n = 7)	(n = 3)	(n = 0)	(n = 11)	(n = 24)	(n = 4)	(n = 0)	(n = 10)	
Piperacillin/Tazobactam	60.00	0	66.67	3.64	60.00	50.00	85.71	100	-	100	14.29	0	-	10.00	
Ceftazidime	60.00	0	66.67	0	60.00	50.00	85.71	100	-	63.64	41.67	50.00	-	10.00	
Cefoperazone/Sulbactam	20.00	0	66.67	0	60.00	50.00	71.43	100	-	90.91	29.17	25.00	-	0	
Cefepime	60.00	0	66.67	3.64	60.00	50.00	42.85	100	-	63.64	45.83	25.00	-	10.00	
Aztreonam	60.00	0	66.67	0	60.00	50.00	42.85	100	-	63.64	-	-	-	-	
Imipenem	80.00	0	66.67	3.64	70.00	50.00	100	100	-	100	8.33	0	-	10.00	
Meropenem	80.00	0	66.67	3.64	70.00	50.00	100	100	-	100	8.33	0	-	10.00	
Amikacin	80.00	35.29	75.00	10.91	80.00	100	42.85	100	-	100	25.00	25.00	-	10.00	
Tobramycin	40.00	35.29	75.00	7.27	70.00	10.00	42.85	100	-	63.64	45.83	25.00	-	30.00	
Ciprofloxacin	80.00	0	75.00	0	60.00	50.00	42.85	66.67	-	36.36	29.17	25.00	-	10.00	
Levofloxacin	80.00	0	75.00	0	60.00	50.00	42.85	66.67	-	54.55	54.17	25.00	-	10.00	
Trimethoprim/Sulfamethoxaz	40.00	64.71	100	0	70.00	100	0	100	-	0	16.67	0	-	20.00	
Doxycycline	80.00	90.91	83.33	18.18	80.00	100	100	100	-	81.81	54.17	25.00	-	10.00	
Minocycline	80.00	72.73	83.33	18.18	90.00	100	100	100	-	100	62.50	25.00	-	20.00	
Tigecycline	100	82.35	100	78.18	100	100	100	100	-	100	87.50	75.00	-	70.00	

Discussion

In the present study, we carried out a retrospective cross-sectional study from 1 January, 2017 to 30 June, 2020 in Department of PICU, SICU, CICU and GICU to analyze the positive blood cultures isolated from patients with BSIs. The current study demonstrated that the microbial distribution and antibiotic susceptibility exhibited a high divergence among BSIs in different ICUs. Therefore, different antibiotic therapies for various wards and distinct age groups were suggested to prevent highly antibiotic-resistant infections, especially in RICU and GICU.

BSIs comprise a wide variety of pathogens and clinical syndromes with quite diverse risk factors, therapeutic implications and outcomes. The infections occur when one or more pathogens invade the bloodstream, usually causing a systemic inflammatory response syndrome (SIRS) [9]. BSIs were defined as the isolation of pathogenic organisms from at least one blood culture sample. The detection of the causing pathogen by using molecular techniques has been proven suboptimal and blood culture remains the gold standard and first line tool in the pathogen diagnostics of BSIs and sepsis [10]. Microbiological cultures of blood specimens provided clinically relevant information concerning the identity and analysis of microorganisms with their susceptibility to antibiotics. We found that blood specimens of the RICU had the highest positive frequency (9.48%), similar to the finding in an India tertiary care institute where SIRS-related sepsis and BSI were 11.5% in the RICU [11]. Previous studies have observed a percentage of positive blood culture from 7 to 9.89% in children [12, 13], and the presence of BSIs was also relatively high (8.36%) in our PICU, probably due to the immature state of children's immune system predisposing them to infections.

In this study, the distribution of microorganisms isolated from blood specimens showed that the total proportions of Gram-positive bacteria in the PICU, SICU, CICU and GICU were all much higher than Gram-negative bacterial strains. Among these positive blood cultures, several frequently isolated pathogens were *S. hominis*, *S. epidermidis* and *S. capitis* which belong to coagulase-negative staphylococci (CoNS). In recent years, CoNS have become true pathogens, rather than simply culture contaminants, causing BSIs and cardiovascular infections among other conditions [14]. Another research also reported a similar finding that CoNS were the common causative agents of BSI in European populations [15]. Moreover, *Enterococcus spp.* (such as *E. faecalis* and *E. faecium*) was one of the prevalent organisms in the PICU, SICU and GICU, and *S. aureus* was the second most frequent bacterium in CICU, which might indicate that skin, soft tissue, bone and joint sources of infection caused BSI by Gram-positive cocci such as *S. aureus*, enterococci, and streptococci. In our PICU, the major bacterium was Gram-negative *Acinetobacter baumannii*, followed by *S. epidermidis* and *E. faecalis*. However, Singhi S *et al.* from India [16] and Maham S *et al.* from Iran [17] observed Gram-negative bacteria as the predominant isolates of pediatric BSIs, common being *K. pneumoniae* (20.1% and 8.8%) and *Acinetobacter spp.* (8.6% and 7.9%). The difference between our research and theirs may be due to the distinct social, economic and environmental factors in these regions. *K. pneumoniae* was the most frequent pathogen in three of the five ICUs (SICU, CICU and RICU), consistent with a recent review showed that *Klebsiella spp.*, the second (behind *E. coli*) overall cause of Gram-negative BSI, have been and remain one of key pathogens from high income countries [1]. In the GICU, the dominant microorganism was *E. coli* which was also reported as the most prevalent pathogen by a previous research based on the Swiss ANRESIS, revealing the incidence of BSIs increased throughout the study period 2008–2014, especially among geriatric patients [3]. According to our study, there was a high divergence between pediatric and geriatric patients. A 3-year multicenter retrospective study showed that individuals aged 0–5 years and ≥ 40 years old were the main demographics at risk of infection by *E. coli*, *K. pneumoniae*, *A. baumannii*, while individuals aged 0–5 years were the major demographic at risk of

infection by *S. aureus*, *E. faecalis*, *E. faecium*, etc [18]. RICU was the only ICU where Gram-negative bacteria remained the key microorganisms involved in BSIs because *Enterobacteriaceae* spp. (such as *K. pneumoniae*) might be the predominant microorganisms in respiratory tract infection patients [8, 19].

In the hospital setting, intensive and prolonged use of antimicrobial drugs introduces the emergence and spread of highly antibiotic-resistant infections [20]. Currently, antimicrobial resistance is one of the most serious global public health threats which call for action from all of society. In order to achieve appropriate therapeutics, updated epidemiology of antimicrobial sensitivity is required to support therapeutic guidelines. In the present study, we observed that *S. hominis* of BSIs remained highly susceptible (> 70%) to gentamicin, linezolid, daptomycin, teicoplanin, vancomycin, tigecycline and rifampicin in all the ICUs. Its antibiotic sensitivity to levofloxacin was moderate in the PICU and CICU, but mild (< 30%) in the SICU, RICU and GICU. Moreover, methicillin-resistant coagulase-negative *Staphylococcus* (MRCNS) was one of the major resistance patterns of positive isolates from the ICUs in our hospital, and a four-year retrospective survey in a Japanese tertiary hospital revealed that MRCNS bacteremia (diagnosed as two or more positive blood cultures on the same day with clinical signs of infection) was associated with a low mortality rate, and suggested that glycopeptides, especially teicoplanin, must be used appropriately to prevent antibiotic resistance in MRCNS [14]. It is vital to treat staphylococci infections as the increasing proportion of CoNS isolates presented as methicillin-resistant. *S. aureus* was highly susceptible to linezolid, daptomycin, teicoplanin, vancomycin, tigecycline and rifampicin in all the ICUs, and the susceptibility to oxacillin, gentamicin, levofloxacin and moxifloxacin was high in PICU, high or moderate in CICU and SICU, while mild in the RICU and GICU. A review of 15 studies showed that between 13 and 74% of worldwide *S. aureus* infections are methicillin-resistant *Staphylococcus aureus* (MRSA) [21], and the mortality rate from MRSA BSI was 25.3% [22], which remain a major healthcare issue. In general, for both *S. hominis* and *S. aureus* isolated from BSIs, RICU and GICU exhibited more serious antibiotic resistance than other ICUs (such as PICU and CICU) in our hospital. *E. faecium* exhibited highly susceptible to linezolid and tigecycline in all the ICUs, and it was highly susceptible to teicoplanin and vancomycin in PICU, SICU and GICU (except RICU and CICU). A meta-analyses revealed that the prevalence of vancomycin-resistant *Enterococcus* (VRE) infections in Iran was 9.4 % among culture-positive cases for *Enterococcus* spp, and the prevalence of VRE in developed countries, such as Germany, the United Kingdom (UK), and Italy was 11.2 %, 8.5–12.5 %, and 9 % respectively [23]. Olivier CN *et al* observed that of the 768 patients colonized with VRE, 4.0% usually developed VRE bloodstream infections due to a related strain [24]; therefore, continuously monitoring trends in the microbiology of BSI pathogens is very important. As a predominant Gram-negative bacterium in blood cultures, *K. pneumoniae* was highly susceptible to doxycycline, minocycline, tigecycline in all the ICUs except RICU, and its antibiotic sensitivity to imipenem, meropenem, amikacin, ciprofloxacin and levofloxacin in the GICU was high or moderate in PICU, CICU and GICU, but mild in the SICU and RICU. *K. pneumoniae* is common causes of health care- and ICU-acquired infections, and one of key pathogens from bacterial BSIs [1]. Increasingly used carbapenem has contributed significantly to the emergence and rapid dissemination of carbapenem-resistant *K. pneumoniae* (CRKP) strains [25, 26]. The resistance patterns such as carbapenem-resistant *Enterobacteriaceae* (CRE) (including CRKP, carbapenem-resistant *Pseudomonas aeruginosa* [CRPA], etc.) and carbapenem-resistant *A. baumannii* (CRAB) have been increasing in recent years. In the ICUs of our hospital, *A. baumannii* only exhibited highly susceptible to tigecycline, and mildly sensitive to imipenem and meropenem. And its susceptibility to ceftazidime, cefepime, tobramycin, levofloxacin, doxycycline and minocycline was moderate in PICU, but mild in the SICU and RICU. Liu Y *et al* conducted a prospective multi-center study in China and suggested that carbapenem resistance has a significant impact on mortality for patients with *A. baumannii* complex BSI [27]. *E. coli* was highly susceptible to the tested antibiotics in the CICU, whereas it exhibited moderate or relatively low drug-susceptibility to the antibiotics (except doxycycline, minocycline and tigecycline) in the PICU, SICU and GICU. In our study, for *K. pneumoniae*, *A. baumannii* and *E. coli* isolated from BSIs, RICU, SICU and GICU exhibited more serious antibiotic resistance than other ICUs. The phenomenon may result from inadequate empirical use of antimicrobials for patients with respiratory tract infections or to avoid suspected infection surgical operations. And age probably a main contributor to the multidrug-resistant bacteria emerged among the geriatric patients undergoing prolonged treatments with broad-spectrum antibiotics.

However, our research has certain limitations, partly because it was only focused on BSIs from one tertiary hospital in Beijing, which might have led to enrollment bias considering the geographic location.

Conclusions

The distribution of prevalent microorganisms and their antibiotic susceptibility revealed a high divergence among BSIs in PICU, SICU, CICU, RICU and GICU from our hospital. RICU and GICU exhibited more serious antibiotic resistance than other ICUs. Therefore, different antibiotic therapies for various wards and distinct age groups were suggested, further strengthening the importance of active prevention and control strategies for the emergence and spread of highly antibiotic-resistant infections.

Declarations

Ethics approval and consent to participate: This study was reviewed and approved by the Institutional Ethics Committee of Peking University First Hospital.

Consent for publication: A review in terms of patient consent was not needed because of the retrospective observational design according to the committee decision.

Availability of data and materials: All the data relevant to this report are included in the manuscript.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: ND designed the study, carried out data collection, drafted the initial manuscript, and reviewed and revised the manuscript. LYS carried out data collection, and reviewed and revised the manuscript. CWH coordinated data collection, and reviewed the manuscript. HXL designed the study, and critically reviewed the manuscript for important intellectual content. All the authors have read and approved the manuscript.

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Figures

Figure 1

Distribution of microorganisms of bloodstream infections patients from different intensive care units (ICU). Gram-positive bacteria remained the major pathogens among the blood cultures except the respiratory intensive care unit (RICU).

Figure 2

Major Gram-positive bacteria isolated and their drug-susceptibility rates in patients with bloodstream infections from different intensive care units (ICU). The antimicrobial susceptibility performed by VITEK 2 Compact or the manual Kirby-Bauer (K-B) disc diffusion method.

Figure 3

Major Gram-negative bacteria isolated and their drug-susceptibility rates in patients with bloodstream infections from different intensive care units (ICU). The antimicrobial susceptibility performed by VITEK 2 Compact or the manual Kirby-Bauer (K-B) disc diffusion method.