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ORIGINAL ARTICLE

Clinical Characteristics, Distribution, and Antibiotic Resistance of Pathogens in Bloodstream Infection in Lianyungang City, China, From 2020 Through 2025

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ABSTRACT

Background: **Clinical characteristics, distribution, and antibiotic resistance of pathogens from inpatients with bloodstream infection (BSI) in Lianyungang City, Jiangsu Province, China, from August 2020 through August 2025 were analyzed to provide a reference basis of the rational antibiotic use for clinical treatments.**
Methods: **A retrospective analysis was conducted at the First People's Hospital of Lianyungang City and Ganyu District People's Hospital of Lianyungang City from August 2020 through August 2025. The data of 4,616 inpatients with BSI were randomly selected, and clinical characteristics, distribution, and antibiotic resistance of pathogens were analyzed. Data collection was performed from the hospital's laboratory information system, and statistical analysis was processed with SPSS 27.0 software.**
Results: **Over the past five years, the positivity rate of BSI has been on the rise year by year. The positivity rate has increased from the initial 3.22 percent to 6.63 percent. Among 88,942 inpatients who sent blood samples for examination, 4,616 inpatients were positive, and the positivity rate was 5.19%. A total of non-repetitive 4,616 strains of Gram-positive and Gram-negative bacteria and fungi were isolated, among which 3,069 (66.49%) were Gram-negative bacteria, 1,311 (28.40%) were Gram-positive bacteria, and 236 (5.11%) were fungi. The pathogens were mainly distributed in the ICU (776 strains, 16.81%), followed by Department of Infectious Diseases (422 strains, 9.14%) and Department of Respiratory and Critical Care Medicine (403 strains, 8.73%). *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa,* and *Candida albicans* ranked as the top six. Most of the Gram-negative and Gram-positive bacteria were resistant to a lot of the antibiotics but highly sensitive to carbapenems, except multiresistant *Acinetobacter baumannii.* More than half of *Acinetobacter baumannii* were resistant to carbapenems, and no resistance to tigecycline was found. Most Gram-positive bacteria were highly sensitive to vancomycin, linezolid, teicoplanin, and tetracycline, and most fungi were resistant to fluconazole, itraconazole, and voriconazole and sensitive to 5-flucytosine and amphotericin B.**
Conclusions: **Over the past five years, the positivity rate of BSI has risen year by year. The pathogens causing BSIs of inpatients in Lianyungang city were mainly Gram-negative bacteria, and the resistance rate of *Acinetobacter baumannii* to carbapenems was obviously high. Dynamic monitoring of the changes in clinical characteristics, distribution, and antibiotic resistance of pathogens from inpatients with BSI was beneficial to clinical diagnosis and treatment.**
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KEYWORDS

bloodstream infection (BSI), clinical characteristic, distribution, antibiotic resistance, Lianyungang

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INTRODUCTION

BSI is caused by microorganisms or toxins which enter the bloodstream and can spread throughout the body. It is a severe infectious disease with a high morbidity rate. It often causes fever, chills, shock, multiple organ failure, and even death [1,2]. Due to the improper use of antibiotics, invasive surgical procedures, and the extensive use of hormones in clinical treatment, the number of inpatients with BSI remains high. Literature reports show that the mortality rate of BSI is also high [3,4]. At present, some BSIs are caused by pathogens which are multi-drug resistant. It is a thorny issue in clinical diagnosis and treatment, and the available antibiotics are limited, leading to a high mortality rate. Timely detection of pathogens causing BSI could be an effective measure for reducing medical costs and the economic burden for patients. Blood culture of suspected inpatients is the internationally recognized gold standard for diagnosing BSI, but the culture time is relatively long. So, it still fails to completely meet the clinical demand of timely targeted treatment [5,6]. The epidemic data of the clinical characteristics, distribution, and antibiotic resistance of pathogens in BSI and the changes in antibiotic resistance rates can be obtained from the clinical experience of using antibiotics, which could provide a reference for early intervention and treatment of inpatients [7-9]. This article analyzed the data of 4,616 inpatients with BSI in the First People's Hospital of Lianyungang City and Ganyu District People's Hospital of Lianyungang City from August 2020 through August 2025, because the composition and antibiotic resistance rate of the isolated pathogens in the blood cultures are the basis of clinical diagnosis and treatment in this region. This might offer some reference for rational antibiotic use in the clinic.

MATERIALS AND METHODS

Study population

All 4,616 inpatients were randomly selected in the First People's Hospital of Lianyungang City and Ganyu District People's Hospital of Lianyungang City from August 2020 through August 2025. The data was taken from the hospital's laboratory information system.

Instruments and reagents

BD BACTEC™ FX blood culture system and accompanying blood culture bottles (Becton Dickinson, USA), VITEK® 2 Compact system for direct identification and antimicrobial susceptibility testing and accompanying reagents (bioMérieux, France), and Matrix-assisted Laser Desorption/Ionization Time of Flight Mass Spectrometry (MALDI-TOF MS) and accompanying reagents were purchased from bioMérieux Company (bioMérieux, France). Bacterial and fungal culture medium and MH medium used for antibiotic susceptibility testing were purchased from bioMérieux Company (bioMérieux, France) and Zhengzhou Antu Company (Antu, China), and KB paper was purchased from Oxoid Company (Oxoid, United Kingdom). Quality control strains were, respectively, *Escherichia coli* ATCC25922, *Staphylococcus aureus* ATCC25923, *Pseudomonas aeruginosa* ATCC27853, *Enterococcus faecalis* ATCC29212, and *Candida albicans* ATCC90028, which were purchased from National Center for Clinical Laboratories.

Identification of bacteria and fungi

A toothpick was used to pick up the single fungal or bacterial colony. Then the colony was put into a sterile Eppendorf tube, and 10 μL of formic acid (70%) was added into the tube. The sample suspension was vortexed and 1 μL of it was smeared on the target plate. At last, 0.5 μL of matrix solution was added on the target plate, and the target plate was taken to the machine for testing after drying. Software of MALDI-TOF MS automatically matched the mass spectrogram of sample to the standard mass spectrogram in the database.

Antibiotic susceptibility testing

VITEK® 2 Compact automatic microbial identification and susceptibility analysis system and the KB paper method were used for bacterial susceptibility testing, and ATB Fungus 3 susceptibility strip was used for fungal susceptibility testing. Sensitivity and resistance criteria were based on Document M100 compiled by Clinical and Laboratory Standards Research Institute (CLSI), published in different years [10].

Statistical analysis

All statistical analyses were performed using SPSS 27.0 software (IBM, USA). Data of the categorical variables were expressed as rate (%) and analyzed with the chi-squared test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Analysis of the positivity rate of BSI over the past five years

Over the past five years, the positivity rate of BSI was 3.22%, 4.34%, 5.16%, 5.71%, and 6.63%, respectively. It was on the rise year by year and exhibited significant difference ($p < 0.05$), as shown in Figure 1.

Clinical characteristics of study population

Among 88,942 inpatients with detection of BSI in the past five years, the average age of the study population was 56.86 years, with an age range of 28 - 92 years. All inpatients included 51,308 males and 37,634 females, with no significant differences (57.69% vs. 42.31%, $p > 0.05$).

Table 1. Distribution of inpatients with blood infection in different genders and departments.

	Number of BSI test inpatients	Number of BSI positive inpatients	Positivity rate (%)
Gender			
Male	**51,308**	**2,591**	**5.05**
Female	**37,634**	**2,025**	**5.38**
Department (top three)	**All BSI positive inpatients**	**Number of BSI positive inpatients**	**Composition ratio (%)**
ICU	**4,616**	**776**	**16.81**
Infectious diseases	**4,616**	**422**	**9.14**
Respiratory and critical care medicine	**4,616**	**403**	**8.73**

Table 2. Overall analysis of main pathogenic bacteria and fungi.

Gram-negative bacteria (total of 3,069 strains)	Number of strains	Composition ratio (%)
Escherichia coli	**1,399**	**45.58**
Klebsiella pneumoniae	**635**	**20.69**
Acinetobacter baumannii	**189**	**6.16**
Pseudomonas aeruginosa	**152**	**4.95**
Enterobacter cloacae	**48**	**1.56**
Gram-positive bacteria (total of 1,311 strains)	**Number of strains**	**Composition ratio (%)**
Staphylococcus aureus	**663**	**50.57**
Enterococcus faecium	**137**	**10.45**
Enterococcus faecalis	**122**	**9.31**
Streptococcus agalactiae	**36**	**2.75**
Staphylococcus haemolyticus	**19**	**1.45**
Fungi (total of 236 strains)	**Number of strains**	**Composition ratio (%)**
Candida albicans	**116**	**49.15**
Candida tropicalis	**76**	**32.20**
Candida glabrata	**23**	**9.75**

Distribution of inpatients with BSI in different genders and departments

Among 88,942 inpatients, a total of 4,616 were detected as positive, and the whole positivity rate was 5.19%. In all 51,308 male inpatients, 2,591 were positive, and the positivity rate was 5.05%. In all 37,634 female inpatients, 2,025 were positive, and the positivity rate was 5.38%. There was no significant difference (5.05% vs. 5.38%, $p > 0.05$). Regarding the distribution of department, the top three departments were ICU (776 strains, 16.81%), followed by Department of Infectious Diseases (422 strains, 9.14%) and Department of Respiratory and Critical Care Medicine (403 strains, 8.73%). Among the top three departments, Department of ICU had the highest positivity rate, which was 16.81%, as listed in Table 1.

Distribution of pathogenic bacteria and fungi

From August 2020 through August 2025, in all BSI samples, a total of 4,616 non-repetitive strains of pathogenic bacteria and fungi were isolated, out of which 3,069 (66.49%) were Gram-negative bacteria, 1,311 (28.40%) were Gram-positive bacteria, and 236 (5.11%) were fungi. There were more than 22 species of pathogens detected, and 17 species had a relatively large number, which included 7 species of Gram-negative bacteria, 6 species of Gram-positive bacteria, and 4 species of fungi. *Escherichia coli* (1,399 strains), *Klebsiella pneumoniae* (635 strains), *Acinetobacter baumannii* (189 strains), *Pseudomonas aeruginosa* (152 strains), and *Enterobacter cloacae* (48 strains) were top five in all Gram-negative bacteria. *Staphylococcus aureus* (663 strains), *Enterococcus faecium* (137 strains), *Enterococ-*

Table 3. Antibiotic resistance of Gram-negative bacteria.

Antibiotic	*Escherichia coli*	*Klebsiella pneumoniae*	*Acinetobacter baumannii*	*Pseudomonas aeruginosa*	*Enterobacter cloacae*
Amoxicillin/Clavulanic acid	673 (48.1)	352 (54.4)	161 (85.2)	152 (100.0)	29 (60.4)
Piperacillin/Tazobactam	148 (10.6)	89 (13.8)	158 (83.6)	18 (11.8)	8 (16.7)
Ampicillin/Sulbactam	597 (42.7)	322 (49.8)	159 (84.1)	14 (9.2)	23 (47.9)
Cefuroxime	1,348 (96.4)	639 (98.8)	188 (99.5)	152 (100.0)	47 (97.9)
Cefuroxime Axetil	1,287 (92.0)	639 (98.8)	188 (99.5)	152 (100.0)	47 (97.9)
Cefotaxime	736 (52.6)	352 (54.4)	147 (77.8)	112 (73.7)	43 (89.6)
Ceftazidime	782 (55.9)	367 (56.7)	149 (78.8)	17 (11.2)	34 (70.8)
Ceftriaxone	742 (53.0)	370 (57.2)	148 (78.3)	19 (12.5)	35 (72.9)
Ceftizoxime	751 (53.7)	372 (57.5)	150 (79.4)	18 (11.8)	33 (68.8))
Meropenem	31 (2.2)	46 (7.1)	122 (64.5)	14 (9.2)	3 (6.3)
Imipenem	33 (2.4)	47 (7.3)	124 (65.6)	15 (9.9)	3 (6.3)
Amikacin	16 (1.1)	14 (2.2)	168 (88.9)	12 (7.9)	38 (79.2)
Ciprofloxacin	18 (1.3)	15 (2.3)	169 (89.4)	13 (8.6)	38 (79.2)
Tigecycline	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Compound Sulfamethoxazole	747 (53.4)	336 (51.9)	163 (86.2)	152 (100.0)	29 (60.4)

Table 4. Antibiotic resistance of Gram-positive bacteria.

Antibiotic	*Staphylococcus aureus*	*Enterococcus faecium*	*Enterococcus faecalis*	*Streptococcus agalactiae*	*Staphylococcus haemolyticus*
Benzylpenicillin	328 (49.5)	66 (48.2)	59 (48.4)	13 (36.1)	9 (47.4)
Ampicillin	-	33 (24.1)	46 (37.7)	9 (25.0)	8 (42.1)
Gentamicin	143 (21.6)	36 (26.3)	29 (23.8)	10 (27.8)	6 (31.6)
Levofloxacin	209 (31.5)	49 (35.8)	43 (35.2)	12 (33.3)	7 (36.9)
Erythrocin	663 (100)	125 (91.2)	112 (91.8)	35 (97.2)	18 (94.7)
Clindamycin	628 (94.7)	-	-	-	-
Linezolid	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Teicoplanin	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Vancomycin	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tigecycline	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

"-" means no antibiotic sensitivity data.

cus faecalis (122 strains), *Streptococcus agalactiae* (36 strains), and *Staphylococcus haemolyticus* (19 strains) ranked in the top five in all Gram-positive bacteria. *Candida albicans* (116 strains), *Candida tropicalis* (76 strains), and *Candida glabrata* (23 strains) were top three in all fungi. In all 4,616 pathogenic bacteria and fungi, the top five pathogens were *Escherichia coli* (1,399 strains), *Staphylococcus aureus* (663 strains), *Klebsiella pneumoniae* (635 strains), *Acinetobacter baumannii* (189 strains), and *Pseudomonas aeruginosa* (152 strains), as shown in Table 2.

Antibiotic resistance of pathogenic bacteria and fungi

Gram-negative bacteria were mainly resistant to cefuroxime and cefuroxime axetil, and the antibiotic resistance rate was above 90.0%, which is shown in Table 3. All of them were highly sensitive to tigecycline, and no antibiotic resistance had emerged yet. Most of them were sensitive to carbapenems, such as imipenem and meropenem. Gram-positive bacteria were mainly resistant to erythromycin and benzylpenicillin, which is shown in Table 4. All of them were highly sensitive to linezolid,

Table 5. Antibiotic resistance of fungi.

Antibiotic	*Candida albicans*	*Candida tropicalis*	*Candida glabrata*
5-Flucytosine	5 (4.3)	5 (6.6)	2 (8.7)
Amphotericin B	3 (2.6)	4 (5.3)	1 (4.3)
Fluconazole	15 (12.9)	14 (18.4)	3 (13.0)
Itraconazole	16 (13.8)	15 (19.7)	4 (17.4)
Voriconazole	17 (14.7)	15 (19.7)	3 (13.0)

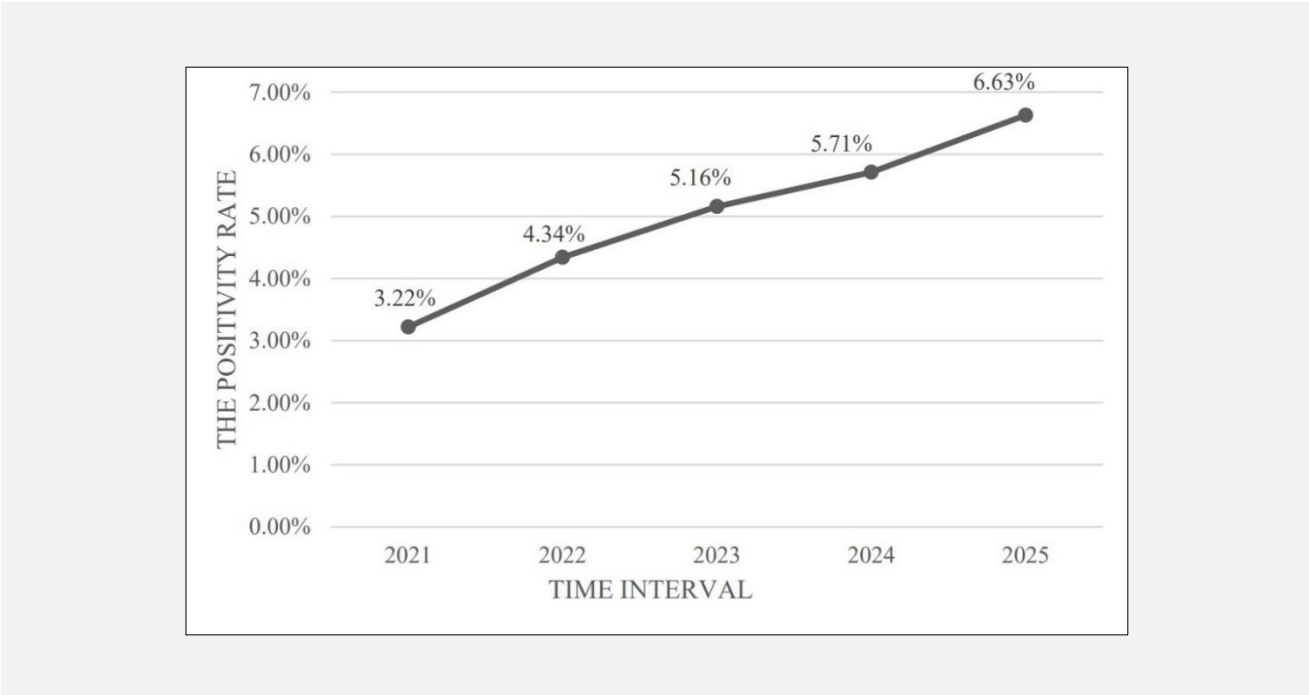


Figure 1. Analysis of the positivity rate of BSI over the past five years.

teicoplanin, tigecycline, and vancomycin. Most of pathogenic fungi were resistant to fluconazole, itraconazole, and voriconazole, and they were sensitive to 5-flucytosine and amphotericin B, as listed in Table 5.

DISCUSSION

BSI is a serious disease with rapid progression and high mortality. Many retrospective studies show that BSI is one of the most common causes of death every year, and the mortality rate is increasing year by year [11,12]. Factors such as immunodeficiency disorders, antibiotic abuse, and ICU admission are the main causes of BSI. And the problem of aging population and low immunity also contributes to the cause [13,14]. Over the past five years, the positivity rate of BSI in Lianyungang city has been in an increasing trend year by year, which is consist with other studies in China and even other studies in the world. In the research of Zhou et al., the researchers explored the clinical characteristics of hematological malignancy patients with carbapenem-resistant Gram-negative organism BSIs in a multicenter case-control study in China and tried to elucidate the prognostic risk factors. They found that carbapenem-resistant Gram-negative organism isolates are multiresistant to conventional antimicrobials and poorly susceptive to novel antimicrobials related to carbapenemases and species and that the antimicrobial resistance is very critical [15]. Mun et al. analyzed community-acquired, healthcare-associated, and hospital-acquired BSI cases and compared their antibiotic resistance and the appropriateness of empirical antimicrobial therapy in two teaching hospitals in South Korea. They reported that the positivity

rate of BSI was 15.1% and that the epidemiology related to mortality had unique characteristics according to the acquisition site. We should put more emphasis on the infection control and the antibiotics stewardship [16]. Curley et al. conducted a retrospective cohort study in adults who had cardiac surgery at a cardiac surgery center between July 1, 2018, and June 30, 2023, in Virginia, United States of America. Patients had at least one postoperative blood culture sent during their index hospitalization, and the positivity rate of BSI was 8.9% [17]. Amanati et al. did a retrospective study at a referral oncology hospital from July 2015 through August 2019 in Shiraz, Iran, including all adults with confirmed BSI. They reported that the positivity rate of BSI was 17.3% and the incidence of multi-drug resistance of Gram-negative BSI increased annually during 2015 - 2018. The mortality rate of Gram-negative BSI remained unchanged at about 20%, and the mortality rate of Gram-positive BSI was significantly greater at about 35.4%.

In our study, over the past five years, the positivity rate of BSI has been rising year by year (3.22% to 6.63%), and the whole positivity rate was 5.19%. Among all 4,616 strains of isolated pathogens, the proportion of Gram-negative bacteria was the highest, with 66,49%. It is consistent with many other reports of BSI [18-20]. It suggests that Gram-negative bacteria are the main bacteria isolated from blood samples, so it is speculated that opportunistic pathogens colonizing other sites would invade into the bloodstream leading to infection when the body's immunity is reduced. In addition, the clinical diagnosis and treatment require multiple invasive procedures; it is easy to infect with Gram-negative bacteria, and BSI was prone to occur. In the distribution of department, the highest positivity rate of BSI was found in ICU. The reason might be due to the fact that most inpatients in ICU were critically ill, had glucocorticoid treatment, and invasive surgical procedures [21]. The distribution of pathogens in the department usually varied by region, underlying disease, autoimmune status, and age [22,23]. The top six pathogens were all common clinical bacteria, such as *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, etc. In recent years, several literatures have reported that Gram-negative bacteria are resistant to carbapenems, and Gram-negative bacteria isolated from BSI also faced a tough challenge [24,25]. In our study, most of Gram-negative and Gram-positive bacteria were highly sensitive to carbapenems except multiresistant *Acinetobacter baumannii,* and over half of *Acinetobacter baumannii* were resistant to carbapenems. Fortunately, they were not found to be resistant to tigecycline. The finding is in agreement with the study by Luo [26]. Luo et al. reported that *Acinetobacter baumannii* has become a major global nosocomial pathogen the mortality rate of BSI caused by *Acinetobacter baumannii* is over 60% and imposes a substantial economic burden in recent decades. They analyzed 1,506 non-repetitive *Acinetobacter baumannii* isolates from 76 Chinese hospitals from 2011 through 2021. Their findings had critical implications for infection control and public health policies. Most Gram-positive bacteria were highly sensitive to vancomycin, linezolid, teicoplanin, and tetracycline, and most fungi were highly sensitive to 5-flucytosine and amphotericin B. Therefore, these sensitive antibiotics could preferentially be selected for clinical treatment.

CONCLUSION

In conclusion, the positivity rate of BSI had been rising year by year in Lianyungang City, Jiangsu Province, China, from August 2020 through August 2025. Gram-negative bacteria were the main pathogens causing BSI of inpatients, and the resistance rate of *Acinetobacter baumannii* to carbapenems was obviously high. More attention should be paid to the dynamic monitoring of the changes in clinical characteristics, distribution, and antibiotic resistance of pathogens from inpatients with BSI.

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Data Availability Statement:
The datasets used and/or analyzed during the study are available from the corresponding author on reasonable request.

Ethical Approval:
This research was reviewed and approved by the Ethics Committee of Ganyu District People's Hospital of Lianyungang City (number: GYLLWHY-LW-2025038).

Declaration of Generative AI in Scientific Writing:
The authors confirm that this manuscript is the original work of the human authors and that no generative Al was used in the writing process.

Declaration of Interest:
The authors have no conflicts of interest to declare.

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