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ORIGINAL RESEARCH

Distribution and Antibiotic Resistance Analysis of Bloodstream Infection Pathogens in Yibin, Sichuan

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Purpose: To determine the distribution and antimicrobial resistance patterns of bloodstream infection (BSI) pathogens in Yibin, China, and to provide evidence for optimizing local empirical therapy and infection-control strategies.

Methods: A retrospective study was performed on 4431 non-duplicate bloodstream isolates recovered from 32569 patients at Yibin Second People's Hospital between January 2017 and December 2024. Organisms were identified and tested for antimicrobial susceptibility by Kirby-Bauer disk diffusion or VITEK-2 Compact. Antibiotic resistance to selected agents (eg polymyxins, vancomycin) were evaluated by broth micro-dilution and analysed based on CLSI M100-S34.

Results: Gram-negative bacteria became the dominant isolates (51.4%), with their proportion significantly increasing during the study period. The main pathogens were *Escherichia coli* (27.4%), coagulase-negative *Staphylococci* (CoNS, 20.4% combined), and *Klebsiella pneumoniae* (9.7%). Among *Enterobacteriaceae*, ESBL-producing *E. coli* was highly prevalent (63.6%), and *carbapenem-resistant K. pneumoniae* (CRKP) emerged at 8.7%. Critically, *Acinetobacter* baumannii showed extensive drug resistance, with carbapenem resistance at 62.1–65.3% and carbapenem-resistant isolates (CRAB) exhibiting >70% resistance to most tested agents. Among Gram-positive pathogens, while methicillin resistance in CoNS was high (78%), no resistance to vancomycin or linezolid was detected in any Staphylococcus or Enterococcus isolate.

Conclusion: Bloodstream infections in Yibin are increasingly dominated by Gram-negative organisms, with ESBL-producing *E. coli* and multidrug-resistant *A. baumannii* posing critical therapeutic challenges. Continuous local surveillance and antimicrobial stewardship are imperative to optimize empirical therapy and improve patient outcomes.

Keywords: blood flow infection, pathogenic bacteria, antibacterial, drug resistance

Introduction

Bloodstream infections (BSI) are serious community- and hospital-acquired infections with notable incidence and mortality rates, posing a major threat to public health.[1] With the widespread use of antimicrobial agents, hormones, and immunosuppressants, coupled with an increasing population of immunocompromised individuals and those undergoing interventional or invasive procedures, BSI have become increasingly frequent and severe infectious diseases.[2] Appropriate and timely anti-infective treatment is critical to lower patient mortality rates. However, as blood culture positive rates are generally low, identifying the causative pathogen and performing drug susceptibility testing often requires considerable time.[3] Clinicians must therefore select empirical antimicrobial agents before definitive test results become available. Familiarity with the local distribution and resistance profiles of pathogens in BSI constitutes an important guide for initial antimicrobial therapy.

In recent years, data from nationwide multicentre surveillance have consistently shown that antimicrobial resistance in Southwest China is particularly severe.[4] Yang analyzed 13272 bloodstream-infection isolates collected between 2012 and 2017 from 12 hospitals in the Southwest and found that the rate of carbapenem-resistance for *Klebsiella pneumoniae*

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rose from 6.0% to 18.4%.[4] Over the same period, among the 27899 blood-culture-positive isolates gathered from 18 provinces in the Bacterial Resistant Investigation Collaborative System (BRICS) program, the Southwest region, including Sichuan Province where Yibin is located, showed a significantly higher proportion of multidrug-resistant organisms when compared to the eastern coastal region. For example, the multi-drug resistance (MDR) rate for *Acinetobacter baumannii* is 71.1% in the southwest region vs 54.3% in the east.[5]

Although the data for Yibin is not reported separately, its status as the referral hub for southern Sichuan indicates that its patient-transfer network and resistance landscape closely mirror the surveillance findings. Concurrently, a "low blood-culture positivity rate" is a frequently overlooked parameter but poses a formidable challenge for primary and secondary hospitals in Yibin. Multiple domestic retrospective studies place the overall positivity rate of blood cultures at only 8%-12%,[6,7] and it is even lower in southern Sichuan (≈ 7%), far below the ≥ 15% recommended in the Blood Culture Practice Guidelines.

Faced with these dual challenges - a heavy regional multi-drug resistance burden and low numbers of reported positive blood-cultures, this study retrospectively analyzed the distribution and resistance patterns of 4431 BSI pathogens identified at the Second People's Hospital in Yibin City, Sichuan Province, isolated between January 2017 to December 2024. The systematic description of the major BSI pathogens in Yibin and their resistance profiles presents immediate clinical significance. Such data will help refine empirical antimicrobial regimens, enhance first-dose matching accuracy, and provide quantitative evidence to improve detection and identification of BSI pathogens in local microbiology laboratories.

Materials and Methods

Source of Strains

From January 2017 to December 2024, a total of 72246 blood-culture sets (each set comprising paired aerobic and anaerobic bottles) were collected from 32569 patients who presented with diverse symptoms, although not all were febrile. Growth was detected in 4982 sets obtained from 4331 patients, giving an overall positivity rate of 6.9%. After removing duplicate isolates obtained from the same patient within a 7-day window, 4431 non-duplicate bloodstream isolates were included in the final analysis.

Methods

Specimen Collection

Collection and transport of blood specimens for culture were carried out in accordance with the 4th edition of the National Clinical Laboratory Operating Procedures.[8] This study involved only a single medical institution. All specimens were transported within the hospital and collected and transported strictly in accordance with the National Clinical Laboratory Procedures (4th Edition). Blood cultures were collected as paired sets (aerobic/anaerobic bottles). After assigning a unique identifier, they were transported using leak-proof containers and triple packaging that meet regulatory requirements and were delivered promptly to the microbiology laboratory for incubation. Upon receipt, labels were checked for consistency with the requisition form, as well as for integrity and timeliness; nonconforming specimens were handled according to established procedures. Applicable biosafety regulations and technical standards: Operations followed the biosafety and procedural specifications of the National Clinical Laboratory Procedures (4th Edition). Microbial identification and antimicrobial susceptibility testing were conducted using standardized workflows, and results were interpreted according to CLSI M100 (2024 edition). The experimental process complied with relevant biosafety management requirements, and quality-controlled standard strains (ATCC) were used for internal quality control. Sample storage: During culture and testing, samples and isolated strains were stored under compliant conditions. Strains required for susceptibility testing and verification were preserved short-term, with strict ledger recording and restricted access. Post-study sample handling: Upon completion of the study, remaining samples and isolates were disposed of in compliance with hospital and project management requirements: after necessary quality traceability, they were sterilized and destroyed or centrally treated as biohazardous waste. All disposal steps were documented and traceable.

Ethical Review

This study was approved by the Ethics Committee of Yibin Second People's Hospital (Approval No.: 2021-FY-10). Given the retrospective nature of the study, the Ethics Committee did not require formal informed consent from participants. All anonymized patient information was derived from strain isolation data provided by the hospital's microbiology laboratory. This study strictly adhered to the guiding principles of the Declaration of Helsinki.

Bacterial Culture, Identification, and Antimicrobial Susceptibility Testing

All specimens were cultured using standardized microbiological techniques, including specimen collection, transport, receipt, matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF), antimicrobial susceptibility testing, quality assurance, quality control, and laboratory documentation. The standard workflow included collection and transport of blood specimens for culture in accordance with the 4th edition of the National Clinical Laboratory Procedures. Specimens were promptly delivered to the clinical microbiology laboratory within one hour of collection. Samples were then inoculated onto blood agar, MacConkey agar, and nalidixic acid/cefixime (NAC) agar plates. MacConkey agar is a mildly selective medium used for identifying non-fermenters (eg, Pseudomonas spp. and Acinetobacter spp). NAC agar is specifically used for the isolation and cultivation of Pseudomonas aeruginosa. Plates were incubated at 35°C under aerobic conditions for 18–24 hours until colony size and morphological characteristics could be observed. Based on differences in colony morphology and color, single colonies were selected and streaked onto blood agar plates using sterile loops for isolation and purification. To ensure the reliability and accuracy of the test results, the following quality control strains were used: Escherichia coli ATCC 25922, Pseudomonas aeruginosa ATCC 27853, Staphylococcus aureus ATCC 25923, and K. pneumoniae ATCC 700603. Upon completion of all testing, bacterial isolates were stored in cryopreservative at −80°C.

Antimicrobial susceptibility testing results were analyzed using WHONET 5.6 software developed by the World Health Organization (WHO) in Geneva. The resistance rate was calculated as: number of resistant isolates/total number of isolates tested × 100%. Statistical analyses were performed using IBM SPSS Statistics 22.0 (IBM Corp., Chicago, USA). Clinical data were downloaded from the electronic medical record system and collated by screening for potential risk factor data. Categorical variables were presented as counts and percentages, with the chi-square test or Fisher's exact test used for between-group comparisons as appropriate, and the nonparametric Mann–Whitney *U*-test used for between-group comparisons. Examples include: trends in the distribution of pathogens across different years (eg, changes in the proportions of Gram-negative versus Gram-positive bacteria), differences in bloodstream infection positivity rates between departments (ICU vs non-ICU), and comparisons of resistance rates between groups. A two-sided p-value < 0.05 was considered statistically significant.

The VITEK-2 Compact automated system was utilised to identify the bacterial pathogens of the 4431 BSI isolates and perform antimicrobial susceptibility tests. Further antimicrobial susceptibility testing for all isolates was also performed with the Kirby-Bauer disc-diffusion assay. Antibiotic concentrations and disc potencies were prepared or purchased in accordance with CLSI.M100-S34 (2024).[9] Standard discs used were as follows: ampicillin 10 μg; piperacillin/tazobactam 100/10 μg; ceftriaxone 30 μg; ceftazidime 30 μg; imipenem 10 μg; meropenem 10 μg; ciprofloxacin 5 μg; levofloxacin 5 μg; amikacin 30 μg; gentamicin 10 μg; trimethoprim-sulfamethoxazole 1.25/23.75 μg; and tigecycline 15 μg. For polymyxins (polymyxin B and colistin), vancomycin, daptomycin, and other agents, disc diffusion tests can be unreliable, therefore, minimum inhibitory concentrations (MICs) were determined by broth microdilution with a twofold dilution range of 0.06–64 μg mL^{-1}, and interpreted using CLSI breakpoints. Quality-control strains with acceptable QC ranges included *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, *Staphylococcus aureus* ATCC 25923, and *K. pneumoniae* ATCC 700603. Susceptibility results were categorized as susceptible (S), intermediate (I), or resistant (R) according to the CLSI.M100-S34 (2024).

Statistical Analysis

Statistical analyses were performed using WHONET 5.6 (https://whonet.org/software.html), SPSS version 22.0 and R version 3.5.3. Categorical variables were expressed as counts and percentages and compared using the $\chi 2$ test or Fisher's exact test as appropriate. Includes trends in the proportions of pathogen distribution across different years (eg, changes in the proportions of Gram-negative versus Gram-positive bacteria), differences in bloodstream infection positivity rates between departments (ICU vs non-ICU), and comparisons of resistance rates between groups.

Continuous variables were presented as medians with interquartile ranges and compared by the Mann–Whitney *U*-test. Temporal trends were assessed by the Cochran-Armitage trend test and linear-by-linear association. A two-sided p-value < 0.05 was considered statistically significant.

Results

Composition of Bloodstream Infection Pathogens and Distribution Within Hospital Departments

From 2017 to 2024, a total of 4431 pathogenic strains were detected from blood cultures at Yibin Second People's Hospital (Figure 1). Among these, 2278 were Gram-negative bacteria, accounting for 51.4% of the total, and 2153 (48.6%) were Gram-positive bacteria (Figure 2). The main pathogens were Escherichia coli (27.4%), coagulase-negative

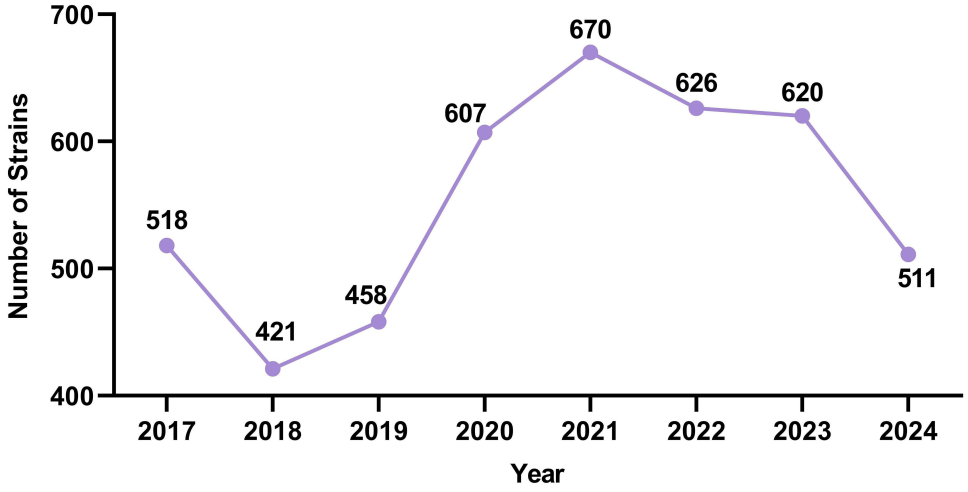

Figure 1 Number and isolation rates of positive bacteria in blood culture from 2017 to 2024.

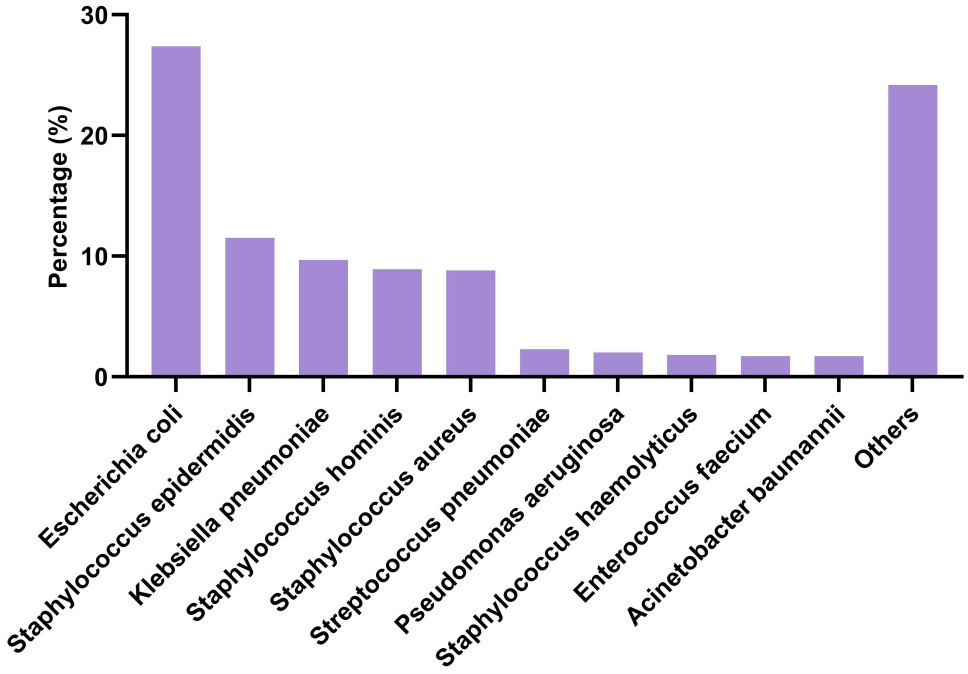

Figure 2 Distribution and frequency of pathogens isolated from bloodstream infections. The figures in brackets correspond to number of isolates from a total of 4431.

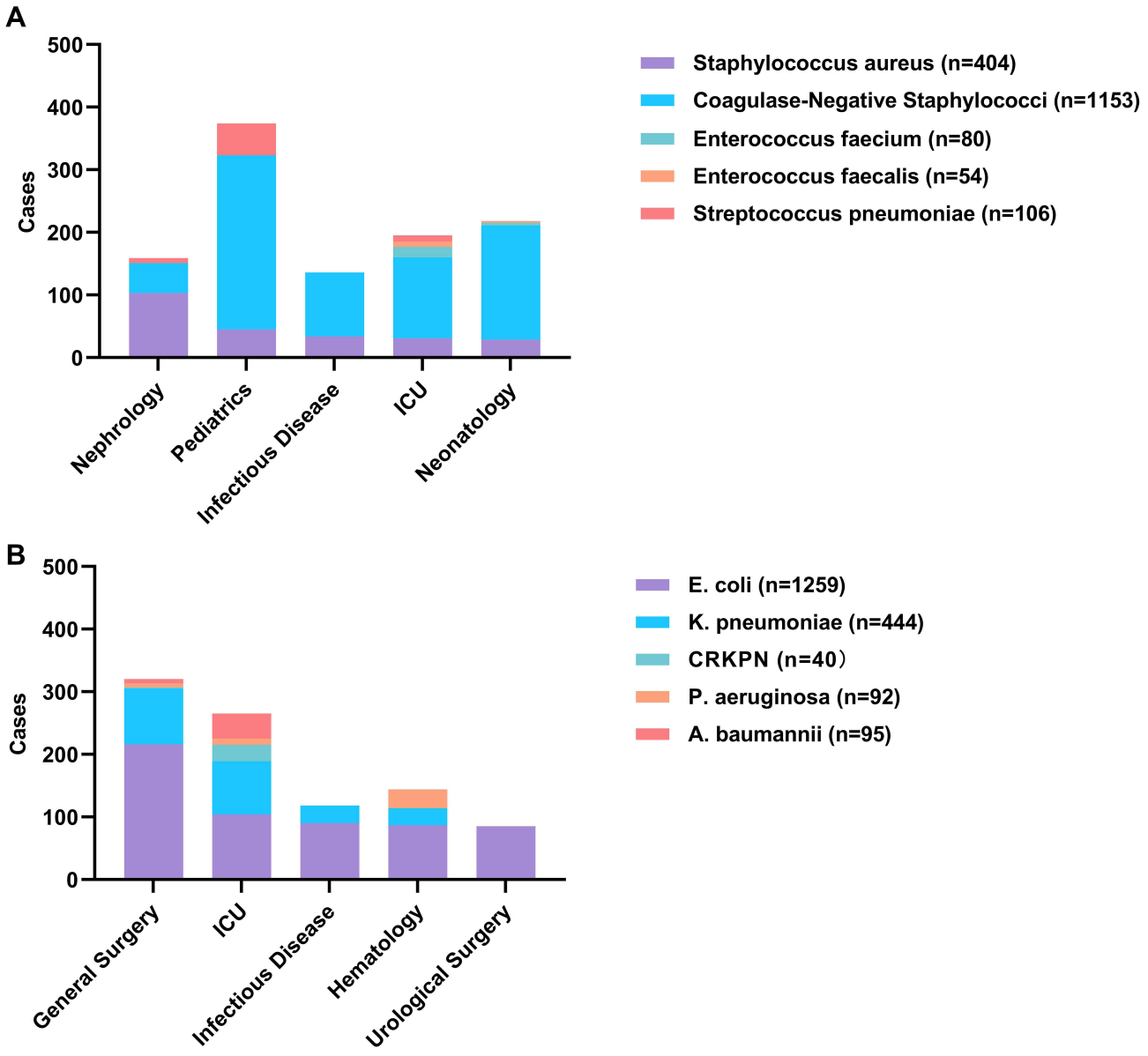

Figure 3 Distribution of (**A**) Gram-positive bacteria and (**B**) Gram-negative bacteria by department.

staphylococci (CoNS, totaling 20.4%), and Klebsiella pneumoniae (9.7%). The hospital departments with higher positivity rates included the Intensive Care Unit (ICU), General Surgery, Paediatrics, and Infectious Diseases (Figure 3). Across hospital departments, the BSI positivity rate differed significantly (ICU vs non-ICU: $\chi^2 = 45.3$, $p < 0.001$). The proportion of Gram-negative isolates rose from 48.2% in 2017–2018 to 54.7% in 2023–2024, and a Cochran-Armitage trend test confirmed a significant upward trend ($Z = 2.85$, $p = 0.004$).

Antibiotic Resistance of Major Pathogens in Bloodstream Infections

Staphylococcus

In this study, a total of 404 S. *aureus* isolates were obtained, of which methicillin-resistant S. *aureus* (MRSA) accounted for 25% (101 isolates). Methicillin-susceptible S. *aureus* (MSSA) presented relatively high susceptibility to oxacillin, amikacin, rifampin, and quinolones; however, susceptibility to erythromycin, clindamycin, and azithromycin was less satisfactory. Among the MRSA isolates, resistance rates to rifampin and trimethoprim-sulfamethoxazole were 19.8% and 28.7%, respectively, and this observation deserves close clinical attention. The MRSA detection rates showed no

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Table 1 Resistance Rates of Staphylococcus Isolates in Bloodstream Infections (%)

Antimicrobial	MRSA (%)	MSSA (%)	MRCNS (%)	MSCNS (%)
Penicillin G	100	88	98.9	78.2
Oxacillin	100	0	100	0
Tetracycline	36.9	17.4	–	–
Doxycycline	13.8	8.2	–	–
Azithromycin	–	57.3	–	–
Cefoxitin	–	8.3	–	–
Amikacin	20	0.5	–	–
Gentamicin	29.7	9.4	37.3	8.1
Rifampin	19.8	0.7	11.1	3.2
Ciprofloxacin	44.6	9.4	–	–
Levofloxacin	44.5	8	48.7	14.1
Moxifloxacin	29.6	4.9	–	–
Tigecycline	0	0	–	–
TMP-SMX	28.7	19.4	63.6	34.7
Clindamycin	74.3	31.6	47.4	18.5
Erythromycin	83.2	52.2	88.7	63.2
Linezolid	0	0	0	0
Vancomycin	0	0	0	0
Teicoplanin	0	0	0	0
Chloramphenicol	23.1	10.7	-	-
Minocycline	1	0	-	-

significant variation across the study periods ($\chi^2 = 5.2$, $p = 0.16$), indicating a stable prevalence of methicillin resistance. Furthermore, 1153 CoNS were isolated, with 78% (899 isolates) found to be methicillin-resistant. Fortunately, no strains resistant to vancomycin, teicoplanin, or linezolid were identified in the Yibin region to date (Table 1).

Enterococcus

A total of 80 *Enterococcus* faecalis isolates and 54 *E. faecium* isolates were identified, and none of the strains were resistant to vancomycin, linezolid, or teicoplanin. *E. faecalis* was detected at higher rates and also showed higher resistance to multiple antimicrobial agents. For example, *E. faecalis* resistance rates towards ampicillin, levofloxacin, and penicillin G were 73.7%, 70%, and 71.8%, respectively, while *E. faecium* resistance towards the same three drugs was significantly lower at 13%, 27.8%, and 25.9%, respectively (Figure 4A).

Streptococcus pneumoniae

S. pneumoniae demonstrated high sensitivity to penicillin, with sensitivity rates of 99% in adults and 97.7% in children. This strain also exhibited good sensitivity to fluoroquinolones, with resistance rates below 1.5%. However, > 90% isolates from children showed high resistance to erythromycin and clindamycin. No *S. pneumoniae* strains were resistant to linezolid or vancomycin (Figure 4B).

Enterobacteriaceae

The rate of isolation of *E. coli* producing extended-spectrum β-lactamases (ESBLs) reached as high as 63.6% (Table 2, Figure 5), significantly higher than that of *K. pneumoniae* (30.9%). Notably, although *E. coli* remained highly sensitive to carbapenems, *Klebsiella* resistance rates towards carbapenems were between 7.6–9.8%, a phenomenon meriting the attention of clinicians. *Enterobacteriaceae* demonstrated relatively low resistance to amikacin (3.2–8.2%), making it a potential alternative for treating infections caused by multidrug-resistant bacteria. In the analysis of resistance to fluoroquinolones, *E. coli* exhibited the highest resistance rate at 55.1%, while other Enterobacteriaceae showed rates of

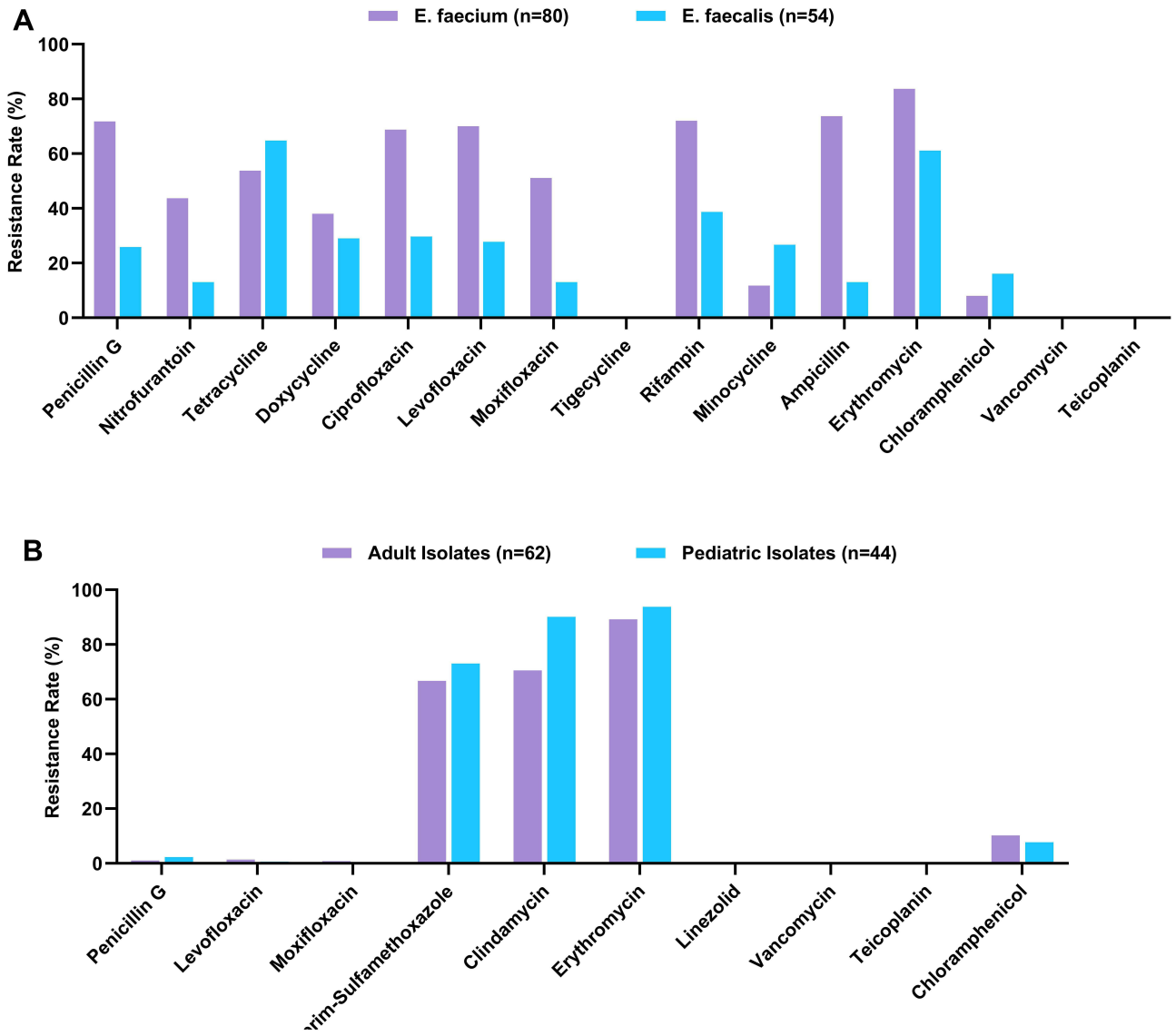

Figure 4 Resistance rates (%) for (**A**) Enterococcus strains; (**B**) S. *pneumoniae* in bloodstream infections.

4.9–29.3% (Table 2, Figure 5). For *E. coli, Serratia spp*., and *Proteus spp*., the resistance rates to piperacillin-tazobactam and cefoperazone-sulbactam were below 7%. *Salmonella typhi* and S. para*typhi* sensitivity towards levofloxacin and ceftriaxone were high and these antibiotics could be considered first-line empirical treatments. Among carbapenemase-producing Enterobacteriaceae, the isolation rate of carbapenem-resistant *K. pneumoniae* (CRKPN) (8.7%) exceeded that of carbapenem-resistant *E. coli* (0.89%). Of particular concern, CRKPN exhibited 100% resistance to ceftazidime, cefotaxime, and cefepime, along with a 95% resistance rate to fluoroquinolones, representing a significant challenge for clinical treatment (Table 2, Figure 5).

Non-Fermenting Gram-Negative Bacteria

In an analysis of 92 strains of *P. aeruginosa*, resistance rates to fluoroquinolones, cefepime, and ceftazidime were all below 10%. Resistance to β-lactamase-inhibitor combinations (piperacillin/tazobactam, ampicillin/sulbactam, and amoxicillin/clavulanate) ranged from 6.5% to 15.5%, while carbapenem resistance ranged from 4.4% to 6.5%. In addition, *P. aeruginosa* demonstrated relatively high sensitivity to amikacin. However, the resistance profile for the 95

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Table 2 Bacterial Resistance Rates of Gram-Negative Bacilli in Bloodstream Infections (%)

Antimicrobial	*E. coli*	*K. pneumoniae*	*P. aeruginosa*	*A. baumannii*
Ampicillin	82.8	–	–	–
Piperacillin	81.5	39.9	16.3	44.6
Piperacillin/Tazobactam	5.7	15.6	6.5	24.2
Cefazolin	58	36.6	–	–
Cefuroxime	52.6	34.5	–	–
Ceftazidime	21.2	22.6	6.6	68.9
Cefotaxime	51.7	30.1	–	50
Cefepime	21.4	18.7	4.3	48.4
Cefoxitin	7.8	17.3	–	–
Aztreonam	30	23	10.4	66.2
Imipenem	1.2	8.5	6.5	42.1
Ertapenem	0.6	7.6	–	–
Ampicillin/Sulbactam	25.5	17.4	–	–
Amoxicillin/Clavulanate	6	11.7	–	–
Ceftriaxone	52.4	31.7	–	–
Tobramycin	28.6	19.5	6.5	–
Meropenem	1.2	9.8	4.4	45.3
Amikacin	3.2	8.2	2.2	34.3
Gentamicin	37	21.2	–	46.3
Ciprofloxacin	47.2	23.6	7.6	48.4
Levofloxacin	55.1	29.3	9.8	35.8
Trimethoprim/ Sulfamethoxazole	48	40.1	–	35.8
Tetracycline	54.7	27.7	–	36.1
Minocycline	–	–	–	3.7

Acinetobacter isolates is worrisome. Apart from piperacillin-tazobactam and minocycline (with resistance rates under 30%), resistance to all other tested agents was above 45% (Table 2, Figure 5A). Notably, carbapenem resistance reached 62.1%-65.3%, suggesting that carbapenems may no longer be appropriate for empirical treatment of *Acinetobacter* infections. Of even greater concern is that carbapenem-resistant *A. baumannii* (CRAB) exhibited resistance rates of over 70% to all classes of antimicrobial agents, posing a significant challenge to clinical therapy (Table 2, Figure 5A). Stenotrophomonas maltophilia was isolated in only 28 cases, so no bacterial resistance analysis was conducted.

Discussion

In this study, the detection rate of Gram-negative bacteria was slightly higher than that of Gram-positive bacteria, which differs to some extent from findings reported by other domestic and international studies. The primary pathogens causing bloodstream infections were *E. coli*, *K. pneumoniae*, and S. *aureus*, in that order (Figure 2). Carbapenems remain reliable for *E. coli* but are inadequate for *Acinetobacter*; amikacin and β-lactam/β-lactamase-inhibitor combinations retain activity against most Enterobacteriaceae. Penicillin continues to be effective for pneumococcal BSI, whereas vancomycin or linezolid are required for methicillin-resistant *Staphylococci*. This pattern of pathogen distribution not only differs from reports in other regions of China,[10,11] but also from findings in Europe and the United States.[12] Possible reasons for these differences may include the study period, geographic location, underlying conditions of the patients, and empirical treatment regimens. In light of regional variations in bloodstream infections pathogen distribution, timely publication of local bloodstream infections epidemiological data is essential to guide clinical decision-making.

Departments with higher detection rates of blood culture pathogens primarily include the Intensive Care Unit, General Surgery, Paediatrics, and Infectious Diseases (Figure 3). This may be related to the types of clinical cases admitted to

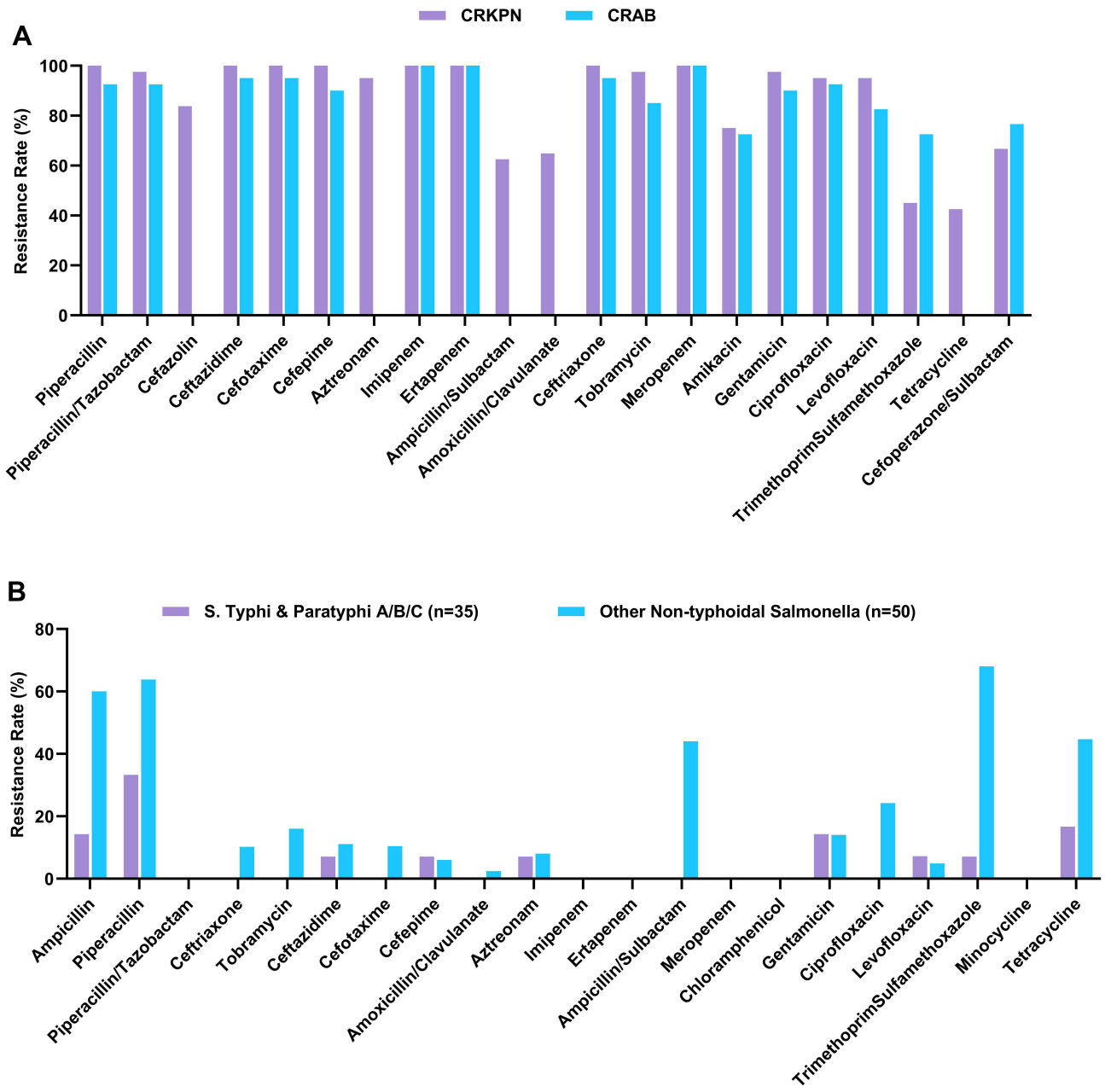

Figure 5 Bacterial resistance rates (%) of (**A**) CRKPN and CRAB and (**B**) *Salmonella* isolated from bloodstream infections towards different antibiotics tested.

these departments. However, ranking of different strains by department is varied. For instance, *A. baumannii*, especially CRAB, is predominantly detected in the Intensive Care Unit, likely because most patients there require invasive mechanical ventilation and have a history of extensive antibiotic exposure. Enterobacteriaceae bacteria primarily originate from patients in the General Surgery department, possibly due to the types of diseases treated and the use of intestinal-related catheters and invasive procedures common to that department. In contrast, CoNS and *S. pneumoniae* were mainly isolated from the Paediatrics department, which, as noted above, may be explained by the weaker skin and mucosal barriers as well as the under-developed immune function of children and infants, making them more susceptible to infections caused by microbial translocation. In this study, CoNS such as *S. epidermidis* and S. hominis were detected at relatively high rates (Figure 2). However, these species are common colonizers of human skin and mucosal surfaces and frequently appear as contaminants in blood cultures.[13] Therefore, when interpreting culture results for these bacteria,

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it is essential to exercise caution and incorporate the patient's clinical presentation and other ancillary examination findings for a comprehensive analysis.

In the paediatric group, Pneumococci strains were highly resistant to erythromycin and clindamycin, with resistance rates exceeding 90% (Figure 4B). This phenomenon may be associated with the extensive use of antibiotics among children,[14] suggesting that clinicians treating paediatric pneumococcal infections should exercise caution when prescribing macrolides and lincosamides to prevent further selective pressure for resistant strains. Based on the findings of this study, we recommend prioritizing penicillin-class antibiotics for both adult and paediatric pneumococcal infections in the Yibin area. For paediatric patients in particular, the high resistance to erythromycin and clindamycin warrants vigilant selection of antimicrobial regimens. In cases involving multidrug-resistant strains, linezolid and vancomycin can serve as salvage therapy options.

Among Gram-negative bacteria, the observed *E. coli* resistance to carbapenem antibiotics is close to the national average (1.2% vs 2%). This is in contrast to *K. pneumoniae* resistance to carbapenems which was below the national average (8.5% vs 20.5%). According to data from the China Antimicrobial Resistance Surveillance Network (CHINET) for 2023,[15] *K. pneumoniae* resistance rates towards imipenem and meropenem were 11.9 and 12.1 percentage points lower than the national average, respectively. However, CRKPN resistance is highly concerning. The resistance rates to trimethoprim-sulfamethoxazole and tetracycline for CRKPN are slightly below 50%, but the strain shows high resistance to many other drugs. Such strains often exhibit extensive resistance characteristics, and are largely unresponsive to most conventional antimicrobials while remaining susceptible to only a limited number of agents such as tigecycline, polymyxins, and ceftazidime-avibactam.[16] According to previous reports, the predominant mechanism underlying carbapenem resistance in Enterobacteriaceae is the production of carbapenemases. Studies have revealed that ceftazidime-avibactam exhibits significant antibacterial activity against *K. pneumoniae* carbapenemase (KPC) or OXA-48 carbapenemases producing strains but is less effective against strains harboring New Delhi metallo-beta-lactamase (NDM) genes.[17] In light of this, it is strongly recommended that microbiology laboratories in tertiary hospitals implement widespread testing for carbapenem-resistant phenotypes and actively conduct combination antibiotic susceptibility testing. For instance, in carbapenem-resistant strains that produce KPC enzymes, combination antibiotic susceptibility testing with imipenem and clavulanic acid is recommended to provide clinicians with more accurate,[18] targeted treatment options.

When our data were compared with data on drug resistance from CHINET and other provinces, *P. aeruginosa* isolated from blood cultures in the Yibin region demonstrated lower rates of resistance and fewer multidrug-resistant strains were isolated. In this study, *P. aeruginosa* isolates showed resistance rates of less than 10% to quinolones and carbapenems, and less than 5% to amikacin (Table 2), indicating high susceptibility and significantly lower resistance rates compared to the national average (21.3%).[19] This may be related to the relatively low usage of these types of antibiotics in the Second People's Hospital of Yibin City, as well as their frequent combination with other antimicrobial agents. However, according to CHINET and data from other regions in China, *P. aeruginosa* resistance can vary geographically. Relying solely on national or external data - or purely on empirical therapy - may lead to inappropriate administration of antibiotics, including overuse or misuse, thereby exacerbating bacterial resistance. Therefore, to prevent such outcomes, clinicians should exercise increased caution and customise treatment strategies based on local conditions.

Among Gram-positive bacteria, CoNS and S. *aureus* predominate. This study's findings indicate that among BSIs caused by S. *aureus*, patients in the Nephrology department accounted for the highest proportion. The likely reason is that most nephrology patients require central venous catheter placement for hemodialysis, which places them at higher risk of catheter-related bloodstream infections caused by S. *aureus*.[6,20,21] In this study, the detection rates of methicillin-resistant CoNS (MRCNS) and MRSA were 78% and 25%, respectively, which are similar or lower than the national average (78.5% and 81.9%, respectively).[18] Notably, MRCNS maintained 100% susceptibility to vancomycin and linezolid, making these agents the first choice for MRCNS infections. In contrast, MRSA strains showed resistance rates towards clindamycin and erythromycin as high as 74.3% and 83.2%, respectively (Figure 3), suggesting that these medications are no longer suitable to treat MRSA infections in this region. However, MRSA exhibited high susceptibility to rifampicin, trimethoprim-sulfamethoxazole and doxycycline, indicating that these drugs could serve as effective alternatives or be used in combination to treat MRSA infections. Furthermore, the study found that penicillin retains

good antimicrobial activity for patients with pneumococcal infections (Figure 3A) and can continue to be used in clinical practice.

A limitation of this study is that we did not conduct further analysis of the disease status and underlying conditions of patients who tested positive for CoNS to identify which strains are truly pathogenic. In the blood cultures, a total of 124 fungal isolates were also detected, primarily *Candida* species (42 strains of *Candida Candida* and 13 strains of *C. glabrata*), along with 49 isolates of *Cryptococcus neoformans*, which are frequently observed in immunocompromised individuals and those admitted to Intensive Care Units. Due to unavoidable constraints such as limited reagents and other issues, antifungal susceptibility testing was not performed for all fungal isolates. Hence, a further limitation of this study is lack of compiled total susceptibility data for all BSI pathogens. Plans are in place to refine this aspect of the analysis in future research.

Conclusion

Given the wide variety of pathogens causing bloodstream infections and the relatively low blood culture positivity rate at the study hospital (6.9%), we will optimize workflows around standardized blood collection volume and number of sets, as well as time-to-incubation, in an effort to increase the positivity rate of blood cultures. We found a significant upward trend in the proportion of Gram-negative bacteria, warranting continued annual updates and stratified tracking by department. For critical resistance phenotypes, such as the high proportion of ESBL-producing Escherichia coli, we recommend ongoing monitoring of fluctuations and the impact of related empirical therapy. The detection rate of CRKP was 8.7%, with high resistance to multiple classes of drugs; moving forward, we will add carbapenemase typing (KPC/OXA-48/NDM) and susceptibility testing for combination and novel agents to refine treatment recommendations. As resistance profiles vary across strains and regions, sustained long-term surveillance in specific locales is essential. By tracking trends in bacterial resistance in real time, we can develop more individualized treatment regimens for patients with bloodstream infections, thereby improving outcomes and safeguarding patient health.

Ethics Approval and Consent to Participate

This study was approved by the Second People's Hospital of Yibin, Sichuan Province The Ethics Committee waived the need for written informed consent from the participants and the data used in this study was anonymised before its use. This study complies with the Declaration of Helsinki.

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Disclosure

The authors declare no conflicts of interest. Xiangtian Zhou and Rong Hu are co-first authors and contributed equally to this work.

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