Infection and Drug Resistance

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SHORT REPORT

Multicenter Surveillance of *Pseudomonas aeruginosa* Isolates From Blood: Clinical Distribution Characteristics and Antibiotic Resistance Trends in Hebei Province, China (2016–2021)

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Purpose: To analyze the clinical distribution and antimicrobial resistance of *Pseudomonas aeruginosa* (*P. aeruginosa*) isolated from blood specimens in 75 hospitals in Hebei Province from 2016 to 2021 to aid in the rational selection of antimicrobial drugs.

Patients and Methods: WHONET 5.6 and SPSS 24.0 were used to retrospectively analyze clinical distribution characteristics and variations in drug-resistance.

Results: Between 2016 and 2021, 2208 *P. aeruginosa* strains were detected in blood specimens from Hebei Province. The median age of the patients with isolated *P. aeruginosa* was 63 years, with a male-to-female ratio of 2.1:1. Predominantly, patients were in the hematology (20.7%) and critical care medicine (18.4%) departments. During the monitoring period, the resistance rate of *P. aeruginosa* to various antibacterial drugs, such as aminoglycosides, fluoroquinolones, and carbapenems, decreased to varying degrees, with an average resistance rate of less than 20.0% over six years. Resistance rates were notably higher in pediatric and intensive care medicine, particularly in neonatal patients, where resistance to antimicrobial drugs, such as piperacillin/tazobactam, gentamicin, ciprofloxacin, and levofloxacin, exceeded 75%.

Conclusion: The main isolates of *P. aeruginosa* were from elderly and intensive care patients, with a male predominance. From 2016 to 2021, the resistance rate of *P. aeruginosa* isolated from blood specimens in Hebei Province to various antibiotics such as aminoglycosides, fluoroquinolones, and carbapenems decreased to varying degrees. The resistance rates are high in pediatric and intensive care medicine, especially among neonatal patients. However, resistance to antibiotics varies with age and department, necessitating tailored antimicrobial administration. The issue of antibacterial drug resistance in newborn patients is concerning, and special attention is needed when during treatment.

Keywords: *Pseudomonas aeruginosa*, blood specimens, antibiotic resistance, carbapenem resistance, bloodstream infection

Introduction

Pseudomonas aeruginosa (*P. aeruginosa*) is prevalent in human skin, respiratory and digestive tracts and is a common non-fermenting gram-negative bacillus causing bloodstream infections in hospitals.[1,2] These infections progress rapidly, carrying a high mortality rate of up to 30%, imposing significant medical and economic burdens worldwide.[3–7] *P. aeruginosa* has shown resistance to a broad range of widely used beta-lactam antibiotics. During clinical treatment,

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this strain may also develop resistance to other classes of antibiotics, such as carbapenems.[8,9] Delayed, inappropriate empirical treatment at the initial stage of bloodstream infections is a risk factor for carbapenem resistance in *P. aeruginosa* and correlates with poor prognosis.[3,8,9] Due to its complex material transport and metabolic system, *P. aeruginosa* is inherently resistant to many antibiotics, and prolonged antibiotic use often induces drug-resistant mutations.[3] Acquiring resistance heightens the challenge of treating *P. aeruginosa* bloodstream infections and independently raises the risk of mortality.[10,11] Therefore, judicious antibiotic use is vital to curb the development of resistance and enhance patient outcomes.[3,5,6,9] The antibacterial resistance patterns of *P. aeruginosa* vary in relation to regional medication preferences.[1,12–14] Resistance of *P. aeruginosa* from bloodstream infections varies globally.[5,7,9] This study retrospectively analyzed clinical distribution patterns and drug resistance in *P. aeruginosa* isolated from blood specimens in 75 hebei Province hospitals from 2016 to 2021. The goal is to analyze the antibiotic resistance trends in Hebei Province, to provide guidance for prudent antimicrobial drug utilization in clinical practice and inform anti-infective decision-making.

Material and Methods

Bacterial Origin

P. aeruginosa was isolated from blood specimens of 75 hospitals across Hebei Province, China, between 2016 and 2021. Duplicate strains from the same patient were excluded, and 2208 strains were obtained.

Bacterial Identification and Antibiotic Susceptibility Assays

We used the Vitek 2 system (bioMérieux, France), Phoenix 100 system (BD Biosciences, USA), and the disc agar diffusion test was performed using Mueller–Hinton (MH) medium (Oxoid, UK) according to CLSI M100 2022[15] for isolate identification and antimicrobial susceptibility testing. *P. aeruginosa* ATCC27853 served as the quality control strain. Carbapenem-resistant *P. aeruginosa* (CRPA) was defined as an isolate resistant to imipenem and/or meropenem.

Age Group

Patients were categorized into five age groups according to the criteria of the International Standard Interim Guidelines for Age Classification[16] and the China Antimicrobial Resistance Surveillance Trial: newborns (≤28 days), children (28 days to 14 years), young adults (15–47 years), middle-aged adults (48–64 years), and older adults (≥65 years).[17]

Statistical Analysis

Statistical analysis was conducted using WHONET 5.6 and SPSS 24.0. The R × C chi-square test was used to compare drug resistance rates between the groups, and Fisher's precision probability test was applied when necessary. Trend chi-square tests were used to compare changes in bacterial resistance rates across different years. Statistical significance was set at $P<0.05$.

Results

Patient Distribution of *P. aeruginosa* Bloodstream Infections

A total of 2208 *P. aeruginosa* strains were detected in blood specimens from 2016 to 2021. As shown in Table 1, *P. aeruginosa* was mainly isolated from male patients, with a male-to-female ratio of 2.1:1. These infections were more common in middle-aged and older individuals, with those aged 48 years and above accounting for 76.0% of cases. The median age of the patients was 63 years. Most patients were seen in the hematology (20.7%) and intensive care medicine (18.4%) departments. Patients were distributed as follows: internal medicine (38.8%), surgery (22.7%), gynecology (0.4%), pediatrics (5.9%), intensive care medicine (18.4%), outpatient emergency (5.2%), and other (8.5%).

Antibacterial Resistance Patterns and Their Changing Trends

P. aeruginosa isolates exhibited low-to-moderate resistance (ranging from 3.8 to 26.8%) to commonly used antibiotics between 2016 and 2021. Except for ticarcillin/clavulanic acid (26.8%) and aztreonam (22.8%), the 6-year average resistance rates of the remaining antibiotics were below 20.0%. Among these, polymyxin B and amikacin showed good in vitro bacterial inhibitory

Table 1 General Data of Patients With *P. aeruginosa* Infection

Programe	No. of Strains	Proportion (%)
Gender		
Male	1485	67.3
Female	723	32.7
Age Group		
Newborn	70	3.2
Child	128	5.8
Young	332	15.0
Middle-aged	675	30.6
Elderly	1003	45.4
Patient Source		
Hematology	458	20.7
Intensive Care Unit	407	18.4
General Surgery	166	7.5
Urology Surgery	166	7.5
Respiratory Medicine	91	4.1
Emergency Department	78	3.5
Neonatology	77	3.5
Others	765	34.6

activities, with low resistance rates of 3.5% and 4.8%, respectively (Table 2). Over the six-year period, resistance rates decreased significantly for aminoglycosides, fluoroquinolones, and carbapenems, but resistance to ticarcillin/clavulanic acid increased by 15.1% (Table 3, Figure 1). CRPA decreased from 19.6% in 2016 to 17.9% in 2021, indicating an overall declining trend (χ^2=18.423, p=0.002) (Figure 2).

Departmental Variation in Antibacterial Resistance

As shown in Table 4, Figure 3, except for polymyxin B, there were significant differences in the resistance rates of other antibiotics to *P. aeruginosa* in different departments. The resistance rates of the isolates to meropenem, imipenem and

Table 2 Resistant Rates, MIC50 and MIC90 of *P. aeruginosa* Isolated From Blood Specimens to Antimicrobial Agents in Hebei Province, 2016–2021

Antimicrobial Agents	Break Points (μg/mL)	MIC (μg/mL)		No. of Strains (R%)
		MIC50	MIC90	
Piperacillin	S<=16 R>=128	8	128	1659 (18.4)
Cefoperazone/Sulbactam	S<=16 R>=64	16	64	904 (11.9)
Ticarcillin/Clavulanic acid	S<=16 R>=128	32	128	671 (26.8)
Piperacillin/Tazobactam	S<=16 R>=128	8	128	2122 (13.1)
Ceftazidime	S<=8 R>=32	4	32	2132 (13.6)
Cefepime	S<=8 R>=32	4	32	2141 (13.3)
Aztreonam	S<=8 R>=32	8	32	1210 (22.8)
Imipenem	S<=2 R>=8	2	16	2145 (16.8)
Meropenem	S<=2 R>=8	1	16	2020 (15.3)
Amikacin	S<=16 R>=64	4	16	2105 (4.8)
Gentamicin	S<=4 R>=16	2	16	1997 (14.6)
Tobramycin	S<=4 R>=16	1	16	1658 (11)
Ciprofloxacin	S<=0.5 R>=2	0.25	4	2048 (17.7)
Levofloxacin	S<=1 R>=4	1	8	2006 (19.7)
Polymyxin B	S<=2 R>=4	2	2	628 (3.5)
CRPA	-	-	-	2192 (18.0)

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Table 3 Antibacterial Resistant Rates of *P. aeruginosa* Isolated From Blood Specimens in Hebei Province, 2016–2021

Antimicrobial Agents	No. of Strains (R%)						Changing Trend	χ^2	*P*-value
	2016	2017	2018	2019	2020	2021			
Piperacillin	290 (22.4)	292(23.3)	294(18)	216(15.3)	294(13.3)	273(17.6)	↓	8.9	0.003
Cefoperazone/Sulbactam	139 (10.8)	91(12.1)	147(21.8)	130(12.3)	192(5.2)	205(11.7)	-	1.955	0.162
Ticarcillin/Clavulanic acid	103(20.4)	63(23.8)	108(27.8)	77(27.3)	151(21.9)	169(35.5)	↑	4.772	0.029
Piperacillin/Tazobactam	305(17.7)	305(17.4)	341(16.1)	325(11.7)	418(7.9)	428(10.7)	↓	20.155	<0.001
Ceftazidime	294(13.9)	308(15.6)	332(13)	320(13.1)	433(9.9)	445(16.6)	-	0.004	0.947
Cefepime	306(18.3)	318(20.4)	335(14.9)	328(12.2)	422(7.6)	432(9.5)	↓	32.497	<0.001
Aztreonam	211(28)	183(29.5)	196(21.9)	139(20.1)	256(16.8)	225(21.8)	↓	8.536	0.003
Imipenem	304(17.4)	315(22.9)	347(18.4)	327(13.5)	419(13.4)	433(16.6)	↓	4.822	0.028
Meropenem	288(14.9)	301(17.9)	336(17.9)	299(12.7)	383(12)	413(16.5)	-	0.759	0.384
Amikacin	286(7)	304(7.2)	328(7)	324(3.4)	426(3.5)	437(2.5)	↓	15.319	<0.001
Gentamicin	302(21.5)	315(24.4)	329(16.1)	307(11.4)	376(7.7)	368(8.7)	↓	54.306	<0.001
Tobramycin	190(15.3)	207(13)	258(19.8)	251(7.6)	362(6.6)	390(8.2)	↓	18.781	<0.001
Ciprofloxacin	289(23.5)	306(25.2)	350(20.3)	320(14.7)	423(11.3)	360(14.2)	↓	29.427	<0.001
Levofloxacin	286(26.2)	290(27.6)	325(22.5)	327(15.3)	413(12.6)	365(17.8)	↓	26.084	<0.001
Polymyxin B	105(3.8)	80(3.8)	126(5.6)	81(1.2)	116(4.3)	120(1.7)	-	0.859	0.354

Note: "-" indicates that the drug resistance rate has remained stable for 6 years without a trend of change; "↓" indicates that the drug resistance rate has declined in 6 years; "↑" indicates that the drug resistance rate has increased in 6 years.

amikacin were highest in the department of critical care medicine. In addition to the aforementioned antibiotics, the resistance rates of isolates to β-lactamase inhibitors, cephalosporins, aminoglycosides, and fluoroquinolones were highest in the pediatric department.

Age-Related Antibacterial Resistance Patterns

As shown in Table 5, Figure 4, while resistance rates to ceftazidime, amikacin, and polymyxin were consistent across different age groups, newborn patients showed severe drug resistance rates (>75.0%) to piperacillin, piperacillin/tazobactam, aztreonam, gentamicin, ciprofloxacin, and levofloxacin. In contrast, pediatric patients exhibited relatively low resistance rates (<10.0%) to these antibiotics.

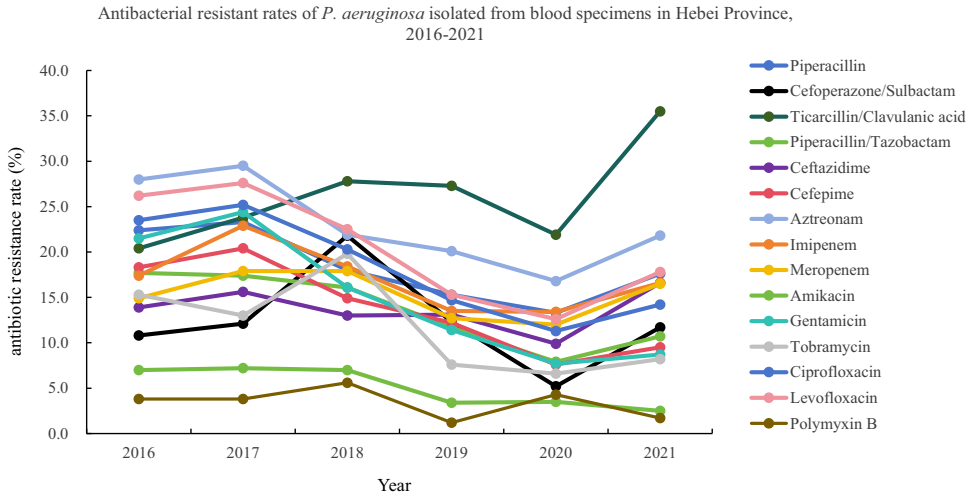

Figure 1 Line graph illustrating the antibiotic resistance rates of *P. aeruginosa* isolates from blood specimens in Hebei Province from 2016 to 2021. The graph displays the percentage of resistant isolates for each year against antibiotics. Each data point represents the annual resistance rate, and the lines connect these points to show trends over the six-year period. The legend inset provides a key to the different antibiotics, with each line styled uniquely for clarity.

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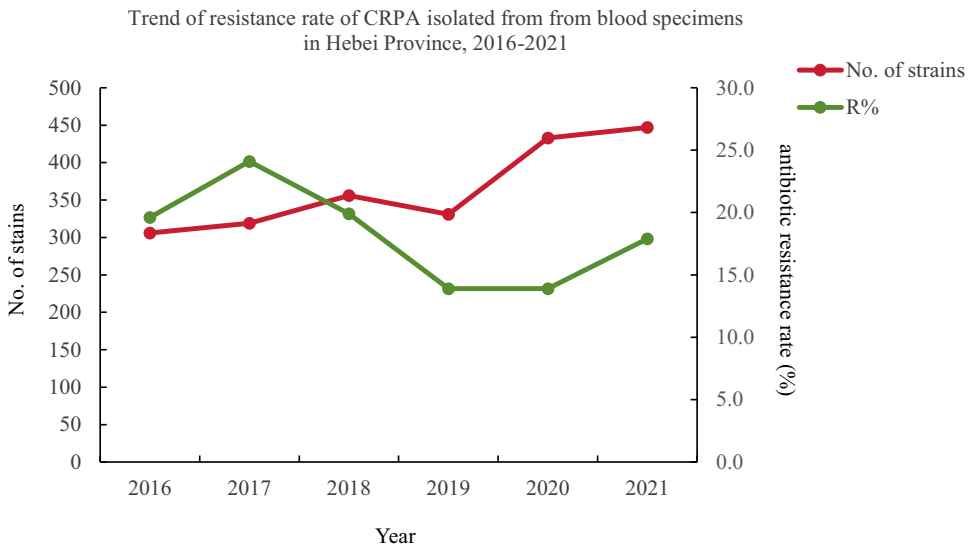

Figure 2 The trend of CRPA resistance rates. From 2016 to 2021, the resistance rate of CRPA decreased from 19.6% in 2016 to 17.9% in 2021, indicating an overall downward trend.
Abbreviation: CRPA, Carbapenem-resistant *P. aeruginosa.*

Discussion

P. aeruginosa bloodstream infections are prevalent in immunocompromised patients,[10,18] particularly in hematology inpatients with hematopoietic malignancies such as leukemia and lymphomas. This study found that, from 2016 to 2021, a total of 2208 non-repetitive *P. aeruginosa* strains were isolated from blood specimens in Hebei province. Patients were mainly attending haematology (20.7%) and intensive care medicine (18.4%) departments and were predominantly middle-aged and elderly (≥48 years old, accounting for 76.0% of the total) and male (accounting for 67.3% of the total). These patients have impaired immune function due to chemotherapy.[19] Some studies have found that gram-negative bloodstream infections occur in approximately 50% of hematologic disorder patients, often due to *P. aeruginosa*.[10,18] ICU patients, who are critically ill and frequently subjected to invasive diagnostic and therapeutic procedures, are also at high risk for bloodstream infections.[11] Notably, as seen in previous studies,[11,20,21] male patients in this study significantly outnumbered females, suggesting higher susceptibility to *P. aeruginosa* bloodstream infections among males.

Over a period of six years, the resistance rates of *P. aeruginosa* in Hebei to aminoglycosides, fluoroquinolones, and various antimicrobial drugs (aminoglycosides, fluoroquinolones, and carbapenems) declined but susceptibility levels remained high nevertheless. Surveillance data from 2021 showed that, except for relatively high resistance rates to ticarcillin/clavulanic acid (35.5%) and amitrazine (21.8%), the resistance rates of *P. aeruginosa* to all commonly used antimicrobials remained below 18%. These rates were lower than those reported by the Drug Resistance Surveillance Network in the United States,[22] hospitals in Yazd, Iran,[23] and northeastern Ethiopia,[24] but slightly higher than those reported in Fujian,[25] Guangzhou,[13] and Ningxia,[26] China. We observed a lower rate of resistance to aminoglycosides, which remained below 10%. Aminoglycosides such as amikacin alone have limited efficacy in treating bloodstream infections and may increase patient mortality.[6] Combining them with β-lactams, which remain active, can improve a patient's prognosis.[14,27]

CRPA is classified by the WHO as one of the bacteria for which new treatment strategies are most critically needed.[28] In this study, CRPA increased from 19.6% (2016–2017) to 24.1% but decreased year by year, reaching 13.9% by 2020, which is lower than the national average.[1,29] However, a 4.0% increase in CRPA from 2020 to 2021 warrants vigilance. Prolonged carbapenem use, particularly imipenem, can induce resistance in *P. aeruginosa* through loss of membrane pore proteins or efflux system overexpression.[12] Bacterial resistance elevates patient mortality.[3–5] Combining carbapenems and fluoroquinolones can reduce the risk of resistance and improve prognosis.[8,30]

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Table 4 Antibacterial Resistant Rates of *P. aeruginosa* Isolated From Blood Specimens by Different Departments in Hebei Province, 2016–2021

Antimicrobial Agents	No. of Strains (R%)							χ^2	*P*-value
	Internal Medicine	Surgery Department	Gynaecology and Obstetrics	Pediatric Department	Outpatient and Emergency Department	Department of Critical Care Medicine	Others		
Piperacillin	646 (13)	359 (10.9)	6 (16.7)	113 (58.4)	100 (20)	297 (28.3)	138(8.7)	174.4	<0.001
Cefoperazone/Sulbactam	386 (6.2)	178 (9)	4 (0)	49 (32.7)	49 (10.2)	166 (24.7)	72(8.3)	60.734	<0.001
Ticarcillin/Clavulanic acid	245 (23.3)	159 (19.5)	1 (0)	43 (62.8)	34 (17.6)	129 (36.4)	60(20)	43.585	<0.001
Piperacillin/Tazobactam	825 (6.2)	484 (8.5)	8 (12.5)	128 (60.9)	113 (15)	382 (21.2)	182(5.5)	331.734	<0.001
Ceftazidime	830 (8.9)	471 (9.6)	9 (11.1)	130 (26.2)	114 (15.8)	396 (24.7)	182(11.5)	82.292	<0.001
Cefepime	832 (8.5)	481 (8.3)	9 (11.1)	130 (41.5)	114 (11.4)	395(22.8)	180(8.3)	152.051	<0.001
Aztreonam	471 (14.9)	251 (16.7)	6 (16.7)	110 (69.1)	61 (16.4)	211(29.4)	100(15)	166.178	<0.001
Imipenem	831 (12.3)	489 (12.9)	9 (0)	128 (16.4)	113 (21.2)	394(35.5)	181(6.1)	134.583	<0.001
Meropenem	791 (11.4)	446 (9.6)	7 (0)	129 (10.1)	106 (21.7)	374(34.8)	167(6)	148.219	<0.001
Amikacin	811 (2.5)	469 (5.3)	8 (0)	130 (3.1)	111 (5.4)	397(11.1)	179(1.7)	48.963	<0.001
Gentamicin	770 (8.4)	454 (13.2)	9 (0)	121 (43.8)	112 (17)	362(23.8)	169(4.7)	146.686	<0.001
Tobramycin	663 (7.4)	385 (12.2)	5 (0)	73 (19.2)	97 (14.4)	294(17.7)	141(4.3)	36.215	<0.001
Ciprofloxacin	792 (11.2)	472 (15)	7 (0)	126 (49.2)	105 (21)	374(28.3)	172(7)	155.946	<0.001
Levofloxacin	763 (12.6)	470 (16.6)	8 (25)	118 (51.7)	100 (26)	376(31.1)	171(8.8)	150.255	<0.001
Polymyxin B	229 (5.2)	145 (0.7)	2 (0)	34 (2.9)	32 (3.1)	134(3)	52(5.8)	6.454	0.374

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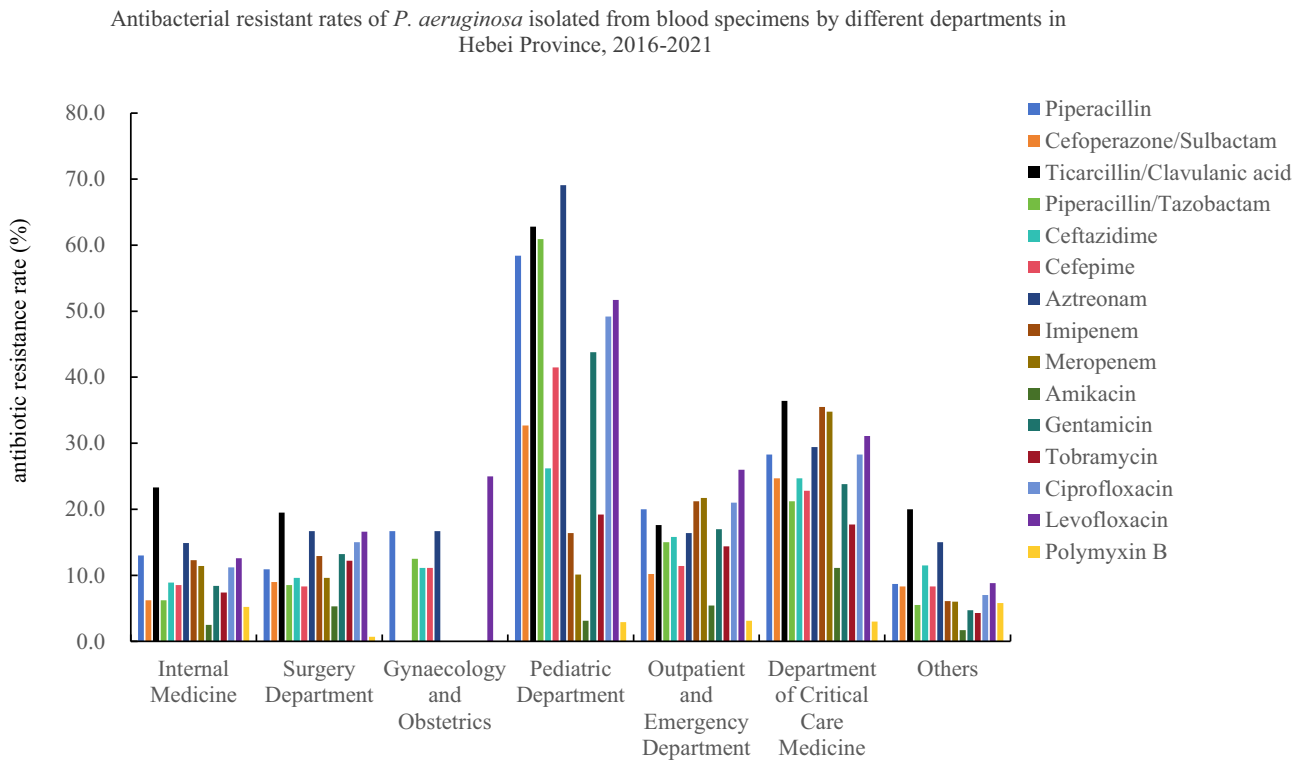

Figure 3 Departmental variation in antibacterial resistance. The bar chart shows the distribution of drug-resistant *P. aeruginosa* isolated from blood specimens in various departments in Hebei Province from 2016 to 2021. X-axis labels indicate different departments, and Y-axis indicates the rate of resistance, where strains isolated from Department of Critical Care Medicine and Pediatric department were multi-drug resistant strains.

Drug-resistant bacteria rates are higher in intensive care patients due to extended disease duration and increased antibiotic use.[31] In this study, resistance to *P. aeruginosa* in intensive care was higher than that in other departments for only three antibiotics: meropenem, imipenem, and amikacin. However, resistance to other commonly used antimicrobials is high in pediatric patients. Neonatal *P. aeruginosa* isolates are generally highly resistant, with resistance rates to some

Table 5 Antibacterial Resistance Rate of *P. aeruginosa* Isolated From Blood Specimens of Patients of Different Age Groups in Hebei Province, 2016–2021

Antimicrobial Agents	No. of Strains (R%)					χ^2	*P*-value
	Elderly	Middle-Aged	Young	Child	Newborn		
Piperacillin	748 (16.4)	503 (14.1)	257 (17.5)	93 (22.6)	58 (79.3)	152.304	<0.001
Cefoperazone/Sulbactam	377 (10.9)	264 (11)	172 (12.2)	74 (8.1)	17 (64.7)	46.674	<0.001
Ticarcillin/Clavulanic acid	330 (23.9)	179 (25.1)	101 (28.7)	46 (39.1)	15 (60)	13.801	0.008
Piperacillin/Tazobactam	957 (11.5)	647 (8.8)	322 (9.9)	126 (19)	70 (80)	293.661	<0.001
Ceftazidime	965 (13.4)	650 (13.4)	320 (12.2)	127 (19.7)	70 (15.7)	4.862	0.302
Cefepime	963 (12.8)	660 (10.2)	320 (12.2)	128 (5.5)	70 (68.6)	198.951	<0.001
Aztreonam	478 (19.5)	376 (17.6)	194 (21.1)	104 (26)	58 (84.5)	135.145	<0.001
Imipenem	966 (18.8)	661 (13.6)	322 (18.9)	127 (8.7)	69 (24.6)	17.756	0.001
Meropenem	911 (17.8)	614 (12.2)	299 (18.4)	126 (7.1)	70 (11.4)	18.334	0.001
Amikacin	952 (6.1)	640 (3.8)	317 (5)	126 (0.8)	70 (4.3)	9.438	0.051
Gentamicin	892 (15.2)	619 (10)	306 (12.7)	119 (4.2)	61 (80.3)	233.624	<0.001
Tobramycin	777 (11.8)	500 (8.8)	263 (11.8)	99 (4)	19 (57.9)	50.868	<0.001
Ciprofloxacin	932 (18)	613 (13.2)	319 (15.4)	115 (5.2)	69 (84.1)	230.859	<0.001
Levofloxacin	915 (20.2)	611 (15.7)	306 (16.7)	107 (4.7)	67 (86.6)	212.8	<0.001
Polymyxin B	290 (4.5)	199 (2)	93 (3.2)	42 (2.4)	4 (25)	7.78	0.1

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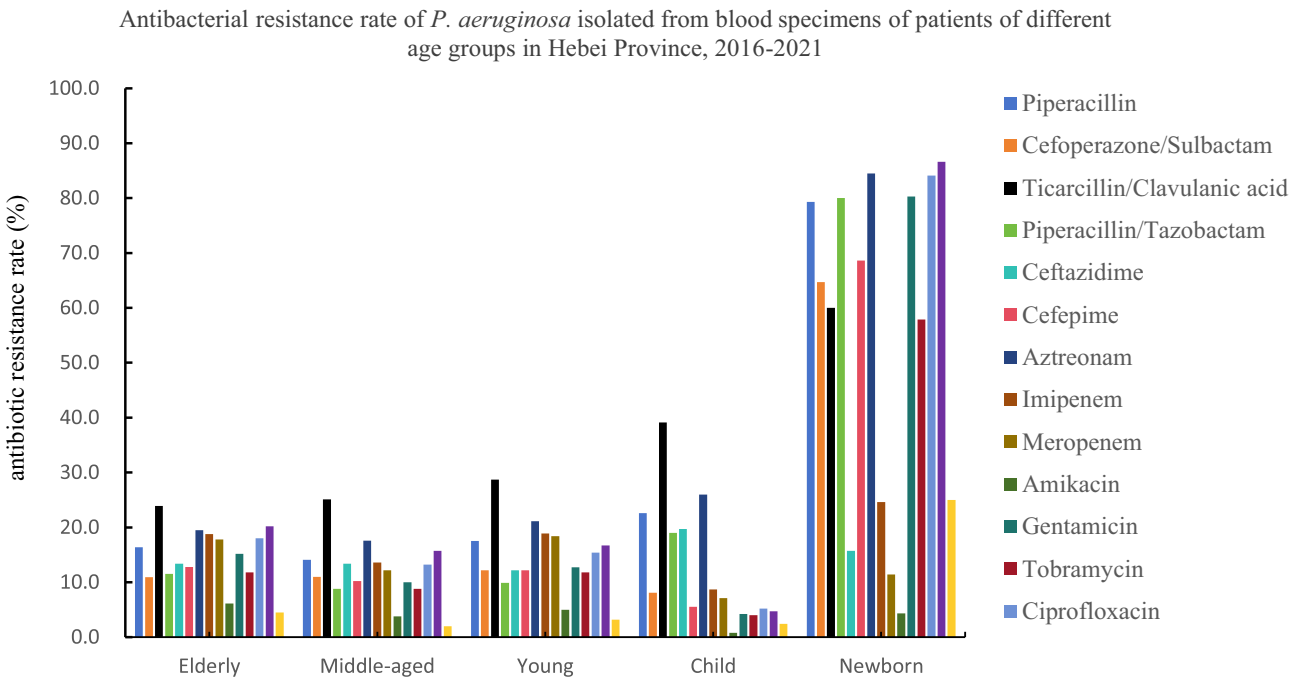

Figure 4 Age-related antibacterial resistance patterns. The bar chart shows the distribution of drug-resistant *P. aeruginosa* isolates from blood specimens of patients across different age groups in Hebei Province from 2016 to 2021. The X-axis labels indicate the age groups, and Y-axis indicates the rate of resistance. The newborn group showed extremely high resistance rates to piperacillin, piperacillin/tazobactam, aztreonam, gentamicin, ciprofloxacin, and levofloxacin, all exceeding 75.0%.

beta-lactamase inhibitors, aminoglycosides, and fluoroquinolones exceeding 75%, whereas resistance rates in children are relatively low. These results suggest that patients of different age groups may require different treatment regimens. In Hebei province, the empirical treatment of *P. aeruginosa* bloodstream infections with β-lactamase inhibitor analogs may increase the risk of treatment failure or delayed treatment in newborns. In the field of neonatal bloodstream infection treatment, the World Health Organization (WHO) recommends the combined use of ampicillin and gentamicin or the selection of third-generation cephalosporins (such as cefotaxime, ceftriaxone) as the preferred treatment regimen.[32,33] However, in recent years, the incidence of global neonatal multidrug-resistant bacterial infections has significantly increased.[32,34] Bacterial resistance to current empirical treatment regimens is growing stronger, leading to persistently high mortality rates from neonatal sepsis and meningitis. Therefore, there is an urgent need to develop new empirical treatment regimens.[32–35] However, due to CRPA, such as the loss of porin proteins, high expression of efflux pumps, mutations in penicillin-binding proteins, and enzyme production, the survey results from the Chinese Antimicrobial Resistance Surveillance Network (CHINET) show that the sensitivity of CRPA to ceftazidime/avibactam is 65.7%.[36] Studies indicate that immunosuppressants can promote the evolutionary pathways of bacterial resistance and treatment failure,[37] and the neonatal immune system is not fully developed. Additionally, neonatal care units more frequently use broad-spectrum antibiotics, which may be related to the significant resistance seen in neonates. Unfortunately, the reasons for the differences in drug resistance between neonates and children remain unclear. In future, we will conduct a molecular epidemiological investigation of *P. aeruginosa* from blood specimens of pediatric patients and initially explore the potential causes of the resistance discrepancy in conjunction with clinical information and antibiotic use in children.

The increasing resistance of *P. aeruginosa* to ticarcillin/clavulanic acid and aztreonam poses new challenges to clinical treatment. Ticarcillin/clavulanic acid and aztreonam, as beta-lactam antibiotics, have previously had good effects in treating infections caused by *P. aeruginosa*. However, with the rise in resistance, the effectiveness of these drugs is limited, and doctors must be more cautious when choosing treatment options. We need to strengthen monitoring and data sharing between provinces to better understand the spread of antibiotic resistance strains.

The limitations of this study are mainly reflected in the analysis of the resistance and resistance rate of *P. aeruginosa* isolated from blood samples collected in Hebei Province, without exploration of the molecular analysis to identify the mechanisms of resistance. Future research urgently needs to study the resistance mechanisms of *P. aeruginosa* in order to more accurately grasp the development trend and transmission pathways of its resistance.

Conclusions

In summary, this study indicates that *P. aeruginosa* bloodstream infections in Hebei Province primarily affected hematology and intensive care patients, mainly those who are middle-aged, elderly, and male. Overall antibacterial resistance to *P. aeruginosa* showed a downward trend from 2016 to 2021. However, there were variations in drug resistance patterns across departments and age groups. Studies have found that *P. aeruginosa* isolated from neonatal bloodstream infections exhibits high resistance to certain beta-lactamase inhibitors, aminoglycosides, and fluoroquinolones. Therefore, clinicians should be particularly cautious when prescribing drugs based on clinical experience to avoid exacerbating the risk of generating and spreading resistant strains. These findings emphasize the need for tailored treatment strategies and vigilant antimicrobial stewardship efforts to effectively combat *P. aeruginosa* infection in this region.

Availability of Data and Materials

The datasets analyzed in this study are available from the corresponding author upon request.

Ethics Approval and Informed Consent

The study protocol was reviewed by the Ethics Committee (IRB) of the Second Hospital of Hebei Medical University. As the project is an observational study and all bacterial strains are cultured from residual samples used in clinical diagnosis, it involves ensuring the confidentiality of patient data and compliance with the Declaration of Helsinki. As the data did not affect patient care, the exemption criteria were met. After consulting the IRB of the Second Hospital of Hebei Medical University, a formal ethical review was approved, and written informed consent was not required (ethical approval No.: 2023-R660).

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Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas, took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that this research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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