Antimicrobial resistance of *Klebsiella Pneumoniae* Pathogens in 2019 of Shaoxing City, Zhejiang Province: A Multi-Centre, Retrospective Study

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Abstract

Background: The detection rate and drug resistance rate of *K. pneumoniae* increased year by year in China. Understanding the drug resistance situation will help guide prevention and control of *K. pneumoniae* infection.

Methods: This study collected the results of drug susceptibility of *K. pneumoniae* from six tertiary hospitals in Shaoxing city in 2019 and analyzed the differences in drug resistance among different hospitals, genders, ages, and specimens.

Results: A total of 1954 strains were collected, all of which were most sensitive to amikacin, with a resistance rate of 4.42%. The resistance rate to carbapenems and tigecycline was less than 10%. Nitrofurantoin had the highest resistance rate (36.18%). The drug resistance rate of Shaoxing traditional Chinese medicine hospital and Shaoxing maternity and child health care hospital was lower, and the drug resistance rate of the affiliated hospital of Shaoxing University was the highest. In addition to the Shaoxing maternity and child health care hospital, specimens were mainly from elderly and male patients, the drug resistance rate increased with age, and no carbapenem-resistant strains were found in patients under 17 years old. The specimens were mostly from the respiratory tract and urinary tract, but the CRKP rate was the highest in blood, the ESBL rate was the highest in other sterile body fluids except for blood, and the high ESBL and CR rates in urine were also detected.

Conclusions: The above results indicated that there were significant differences in drug resistance rates of strains among different hospitals, genders, ages, and specimen sources, and clinical empirical medication should be incorporated into the reference.

Introduction

Klebsiella pneumoniae is one of the most important and challenging pathogens from the community- and hospital-acquired infections, as it expresses multidrug resistance (MDR) phenotypes and causes infections with high mortality. Carbapenems are mainly used to treat strains that produce extended-spectrum β -lactamases, but the resistance rate of *K. pneumoniae* is increasing year by year. According to data from the China Carbapenem-resistant Enterobacteriaceae (CRE) Network, 73.9% of CRE strains are Carbapenem-resistant *K. pneumoniae* (CRKP)[1]. The resistance rate of *K. pneumoniae* to imipenem and meropenem fluctuated around 18.6% and 64.1% by China antimicrobial surveillance network(CHINET)[2]. CRKP, Carbapenem-resistant *P. aeruginosa* (CRPA), and Carbapenem-resistant *A. baumannii*(CRAB) were recognized as critical priority pathogens by the World Health Organization (WHO)[3]. Among them, CRKP had the larger impact on economic cost and mortality rate by a China multi-center study [4].

A critical trait of *K. pneumoniae* is its ongoing evolution by acquiring new mobile genetic elements associated with antimicrobial resistance[5]. The most problematic are genes that encode extended-spectrum β -lactamases (ESBLs) (e.g., SHV, CTX-M, and TEM) and carbapenemases (KPC, NDM, IMP, OXA, etc). Among them, KPC-2 is the most important carbapenemase, in addition to NDM-1, OXA-48-like carbapenemases, etc[6].

The distribution and antibiotic susceptibilities of *K. pneumoniae* vary in different regions and hospitals. Empiric antibiotic treatments should be selected based on susceptibility data. We conducted drug resistance monitoring of *K. pneumoniae* clinically isolated from six hospitals in Shaoxing City from January 1 to December 31, 2019, to guide the application of empirical antibiotics.

Materials And Methods

Sample size and source

Six tertiary hospitals in Shaoxing, Zhejiang province, were investigated in 2019. There are three general hospitals (Shaoxing people's hospital (SPH), The affiliated hospital of Shaoxing University (SUH), Shaoxing second hospital (2nd H)), and three specialist hospitals (Shaoxing traditional Chinese medicine hospital (TCM), Shaoxing maternity and child health care hospital (SMCH), Shaoxing seventh hospital (7th H)). A total of 1954 *K. pneumoniae* strains were collected. 870 strains were isolated from Shaoxing people's hospital, 289 from Shaoxing second hospital, 289 from Shaoxing maternity and child health care hospital, 261 from the affiliated hospital of Shaoxing University, 166 from traditional Chinese medicine hospital, and 79 from Shaoxing seventh hospitals. There were 1,149 strains from male patients and 805 strains from female patients. Age from 1 day to 99 years, divided into three groups: ≤ 17 years, 18–64 years, ≥ 65 years.

The main sources of specimens include respiratory specimens, urine, blood, sterile body fluids, and non-sterile body fluids. The sterile body fluids include bile, cerebrospinal fluid, ascites, pleural fluid, etc. Non-sterile body fluids include wound secretions, lochia, cervical secretions, drainage, pus, etc.

Antimicrobial susceptibility testing

Isolates identification and antibiotic susceptibility testing were carried out using an automated Vitek-2 compact system by bioMérieux company France. K-B disk method was used for meropenem, ceftazidime, cefoperazone/sulbactam. In this study, the susceptibility interpretations are based on CLSI clinical breakpoints [7]. Carbapenem-Resistant *K. pneumoniae* (CRKP) was defined according to the recommendation of CLSI as *K. pneumoniae* strains resistant to at least one carbapenem agent such as ertapenem, imipenem, or meropenem [8]. Extended-spectrum β -lactamase *K. pneumoniae* (ESBL-KP) strain was determined by the standard double-disc synergy test with cefotaxime (30 ug) and ceftazidime (30 ug) alone and in combination with clavulanic acid (10 ug; Oxoid Limited, UK) as recommended by CLSI. The *E. coli* American Type Culture Collection (ATCC) 25922 (negative control) and *K. pneumoniae* ATCC 700603 (positive ESBL control) were used as quality control (QC) strains. Data were only included when the QC test results were in acceptable ranges.

Statistical analysis

Data collected by WHONET 5.6 software. The SPSS 17.0 statistical software was used for data analysis after the data were exported and verified. Counting data are expressed in percentages. The χ^2 test was used to assess the differences with data comparison. The statistical significance level was set at $p < 0.05$.

Results

Distribution of *K. pneumoniae* strains

Among the 1954 isolated strains, ≤ 17 years, 18–64 years, ≥ 65 years of patients accounted for 5.32%, 41.10%, 53.58%, respectively. Except for Shaoxing maternity and child health care hospital, the detection rate of men was higher than that of women. The detection rate of men in TCM hospital was the highest which is 71.08%. *K. pneumoniae* isolated from respiratory tract samples such as sputum accounted for 52.61%, *K. pneumoniae* isolated from non-sterile body fluids such as secretions is 15.56%, sterile body fluids such as urine, bile, and

blood accounted for 15.51%, 11.82%, 4.50%, respectively. The detection rate of *K. pneumoniae* in ≤ 17 y group in the Shaoxing maternity and child health care hospital was 33.22%, and we didn't isolate strains in elderly patients and the blood samples. The detection rate of *K. pneumoniae* in non-sterile body fluids was 67.13%, of which mainly vaginal secretions (61.94%), as shown in Table 1.

Table 1
The detection rate (%) of *K. pneumoniae* strains in various hospitals

Hospital	Age ^a	Male	≤ 17 y	18~64y	≥ 65 y	Respiratory tract samples	Urine	Blood	Sterile body fluids	Non-sterile body fluids
SPH	66.79 $\pm$ 14.75	68.74	0.69	38.16	61.15	62.76	12.76	4.37	9.31	10.80
2ndH	65.62 $\pm$ 17.87	61.59	0.69	38.75	60.55	33.91	22.84	9.00	5.88	28.37
SUH	70.68 $\pm$ 16.29	63.60	0.00	35.63	64.37	54.79	22.99	5.75	6.90	9.58
TCM	68.67 $\pm$ 16.56	71.08	0.00	35.54	64.46	77.71	4.82	4.82	0	12.65
7thH	75.65 $\pm$ 15.13	50.63	0.00	17.72	82.28	69.62	27.85	1.27	0.0	1.27
SMCH	27.51 $\pm$ 21.83	16.96	33.22	66.78	0.00	19.72	12.46	0.00	0.35	67.47
Mean	61.85 $\pm$ 22.17	58.80	5.32	41.10	53.58	52.61	15.51	4.50	5.99	21.39
a: Mean $\pm$ standard deviation										

1. *K. pneumoniae* **drug sensitivity results in various hospitals**

K. pneumoniae is the most sensitive to amikacin, with a resistance rate of 4.42%, resistance to carbapenem antibiotics and tigecycline less than 10%, and the average resistance rate to β -lactam- β -lactamase inhibitor combinations ranging from 9.95 to 16.92%. The resistance rate of cephalosporin, aztreonam, cefoxitin, ciprofloxacin, nitrofurantoin, and Sulfamethoxazole is 12.63–28.72%. Nitrofurantoin (36.18%) had the highest drug resistance rate in the Shaoxing people's hospital, and the other antibiotics had the highest drug resistance rate in the affiliated hospital of Shaoxing University. There are significant differences in the resistance rate between hospitals ($p<0.05$), as shown in Table 2.

Table 2
Comparison of the antibiotic resistance rate (%) of *K. pneumoniae* in various hospitals in Shaoxing city

Antibiotics	SPH	2ndH	SUH	TCM	7thH	SMCH	Mean	χ^2	<i>p</i>
Ampicillin	99.75	83.39	88.51	100.00	79.75	69.55	87.67	174.76	0.00
Cefazolin	30.13	33.91	ND	15.00	29.11	23.18	28.42	14.06	0.01
Ceftazidime	17.36	18.40	32.95	ND	ND	ND	20.45	30.88	0.00
Ceftriaxone	26.67	31.14	47.13	13.25	27.85	17.65	27.65	83.32	0.00
Cefepime	16.80	12.80	31.03	3.61	10.13	1.38	14.44	119.54	0.00
Amoxicillin / Clavulanic acid	18.80	33.33	ND	5.42	13.92	4.15	13.95	51.74	0.00
Piperacillin/Tazobactam	9.68	13.59	22.22	3.61	8.86	0.00	9.95	87.67	0.00
Cefoperazone/sulbactam	13.33	92.68	ND	ND	ND	ND	16.92	175.31	0.00
Aztreonam	22.70	26.99	40.23	8.43	20.25	9.69	22.36	97.07	0.00
Cefoxitin	15.71	16.67	ND	4.82	18.99	6.23	12.63	30.21	0.00
Amikacin	4.26	6.01	9.58	1.20	6.33	0.00	4.42	36.31	0.00
Gentamicin	15.50	15.22	28.74	6.02	8.86	14.88	16.24	46.63	0.00
Ciprofloxacin	24.05	33.56	47.89	15.06	27.85	21.45	28.72	77.27	0.00
Levofloxacin	18.89	17.30	37.16	9.04	18.99	9.69	18.90	83.81	0.00
Macroclantin	36.18	23.18	34.10	31.33	26.58	12.46	27.60	57.37	0.00
Sulfamethoxazole	24.42	30.21	30.27	10.98	25.32	23.53	24.83	25.32	0.00
Tobramycin	9.29	9.34	16.48	5.42	8.86	4.50	9.18	27.11	0.00
Ertapenem	7.76	17.36	23.37	1.23	0.00	0.69	9.42	129.43	0.00
Imipenem	7.02	16.61	21.46	1.83	8.86	0.00	8.97	113.26	0.00
Meropenem	6.83	ND	ND	ND	ND	ND	6.83	-	-
Tigecycline	8.65	16.67	ND	0.64	0.00	1.04	5.76	38.32	0.00
ND: not determined									

1. *K. pneumoniae* drug sensitivity results in different people groups

Among isolated strains in the ≤ 17 y group, no carbapenem-resistant strains were detected, and no strains resistant to amikacin, piperacillin/tazobactam, cefoperazone/sulbactam. The drug resistance rate of cefazolin in the ≤ 17 y group was 36.63%, which was significantly higher than that of other age groups ($\chi^2 = 23.67$, $p = 0.00$). For other antibiotics, the drug resistance rate of the ≥ 65 y group was the highest (Table 3). Except for cefoperazone and compound trimethoprim, the resistance rate of other commonly used antibiotics derived from male patients was significantly higher than that from female patients (Table 4).

Table 3
Comparison of antibiotic resistance rates (%) of *K. pneumoniae* from different age groups

Antibiotics	≤ 17y	18-64y	≥ 65y	χ ²	p
Ampicillin	70.30	83.71	93.18	58.66	0.00
Cefazolin	36.63	20.95	33.65	23.67	0.00
Ceftazidime	12.50	13.43	24.86	26.90	0.00
Ceftriaxone	22.12	19.42	34.49	52.72	0.00
Cefepime	1.92	9.09	19.79	56.02	0.00
Amoxicillin / Clavulanic acid	8.82	8.47	19.31	33.73	0.00
Piperacillin/Tazobactam	0.00	5.36	14.46	54.08	0.00
Cefoperazone/sulbactam	0.00	12.68	19.78	8.87	0.01
Cefoxitin	11.76	9.83	15.12	8.20	0.02
Aztreonam	12.87	15.03	29.59	48.07	0.00
Amikacin	0.00	3.12	5.85	13.09	0.00
Gentamicin	17.82	13.39	18.35	6.39	0.04
Ciprofloxacin	26.73	21.90	34.54	27.28	0.00
Levofloxacin	11.54	13.82	23.54	31.86	0.00
Macroclantin	4.95	24.68	32.98	39.62	0.00
Sulfamethoxazole	25.00	22.75	26.42	3.27	0.20
Tobramycin	8.91	6.67	11.25	8.78	0.01
Ertapenem	0.00	6.07	12.96	36.32	0.00
Imipenem	0.00	5.49	12.54	38.44	0.00
Meropenem	0.00	5.20	7.91	1.45	0.48
Tigecycline	1.96	4.69	7.26	6.81	0.03

Table 4
Comparison of antibiotic resistance rates (%) of *K. pneumoniae* from different genders

Antibiotics	Male	Female	χ^2	<i>p</i>
Ampicillin	92.52	81.53	40.91	0.00
Cefazolin	32.76	23.63	11.37	0.00
Ceftazidime	22.09	17.23	4.59	0.03
Ceftriaxone	30.57	23.50	11.73	0.00
Cefepime	17.94	9.44	27.694	0.00
Amoxicillin / Clavulanic acid	18.36	8.05	30.18	0.00
Piperacillin/Tazobactam	12.23	6.71	16.07	0.00
Cefoperazone/sulbactam	18.27	13.93	2.59	0.11
Cefoxitin	15.06	9.40	9.90	0.00
Aztreonam	26.93	16.57	22.97	0.00
Amikacin	5.94	2.24	15.32	0.00
Gentamicin	19.06	12.67	10.97	0.00
Ciprofloxacin	32.07	24.47	10.44	0.00
Levofloxacin	21.10	15.78	8.74	0.00
Macroclantin	31.80	22.29	16.55	0.00
Sulfamethoxazole	24.96	24.66	0.02	0.88
Tobramycin	11.64	6.04	13.93	0.00
Ertapenem	12.18	5.53	24.16	0.00
Imipenem	11.69	5.09	25.22	0.00
Meropenem	8.52	3.36	4.20	0.04
Tigecycline	7.21	3.85	7.04	0.01

K. pneumoniae drug sensitivity results in different specimens

The resistance rates of *K. pneumoniae* isolated from blood to ertapenem, imipenem, piperacillin/tazobactam, aztreonam, and cefepime were 22.09%, 21.59%, 40.91%, 27.27%, respectively. It was higher than the *K. pneumoniae* isolated from other specimens ($p < 0.05$). The *K. pneumoniae* isolated from urine is significantly higher than the *K. pneumoniae* isolated from other specimens for levofloxacin, ciprofloxacin, cefoperazone/sulbactam, piperacillin/tazobactam, amikacin, and gentamicin ($p < 0.05$), as shown in Table 5.

Table 5
Comparison of antibiotic resistance rate (%) of *K. pneumoniae* in different specimens

Antibiotics	Respiratory tract samples	Urine	Blood	Sterile body fluids	Non-sterile body fluids	χ^2	<i>p</i>
Ampicillin	91.88	86.07	93.85	94.63	73.17	77.48	0.00
Cefazolin	26.65	43.09	47.73	32.74	16.54	47.09	0.00
Ceftazidime	15.86	33.76	32.05	20.98	14.13	44.68	0.00
Ceftriaxone	23.49	43.71	40.23	33.91	17.16	75.73	0.00
Cefepime	12.17	24.75	27.27	19.05	4.61	69.86	0.00
Amoxicillin / Clavulanic acid	13.68	21.59	20.83	21.19	3.32	39.80	0.00
Piperacillin/Tazobactam	8.87	18.21	20.45	10.87	1.64	58.81	0.00
Cefoperazone/sulbactam	12.88	32.77	21.43	18.12	17.14	28.52	0.00
Cefoxitin	10.94	24.43	18.75	20.53	3.32	53.31	0.00
Aztreonam	20.29	35.92	40.91	25.66	10.34	65.95	0.00
Amikacin	3.22	10.37	6.82	5.63	0.99	39.02	0.00
Gentamicin	14.21	24.59	20.00	18.12	12.54	18.70	0.001
Ciprofloxacin	25.99	42.45	39.39	29.14	21.538	36.25	0.00
Levofloxacin	15.11	32.34	27.27	25.54	10.86	68.85	0.00
Macroclant	28.09	32.38	40.00	34.23	16.03	30.39	0.00
Sulfamethoxazole	19.82	36.88	24.14	32.17	24.34	43.79	0.00
Tobramycin	8.49	16.33	18.18	9.93	2.43	37.71	0.00
Ertapenem	7.97	17.45	22.09	16.38	2.64	70.24	0.00
Imipenem	8.38	14.52	22.73	12.82	2.40	56.45	0.00
Meropenem	4.81	13.79	12.50	9.52	6.38	7.59	0.11
Tigecycline	4.13	10.40	8.51	14.47	1.65	40.06	0.00

Detection rate of ESBL-producing and carbapenem-resistant *K. pneumoniae*

Among the 1954 strains of *K. pneumoniae*, the detection rate of CRKP was 10.18%, and the detection rate of ESBL production was 20.97% (Fig. 1). The detection rate of ESBL in TCM hospitals was 11.80%, the lowest among all hospitals. The detection rate of CRKP in SMCH is the lowest among all hospitals, only 0.69%. Among all hospitals, the detection rates of ESBL and CRKP in SUH were the highest, which were 33.33% and 23.37% respectively. There were significant differences in the detection rates of ESBL and CRKP among all hospitals (ESBL: $\chi^2 = 30.04$, $p = 0.00$, CRKP: $\chi^2 = 106.26$, $p = 0.00$), as shown in Fig. 1a. The detection rate of ESBLs in the ≤ 17 y group was 23.08%, and no CRKP strain was detected. ESBLs and CRKP in the ≥ 65 y group were 25.47%

and 13.94%, respectively, and the detection rate was the highest among the three groups. ESBLs were the lowest in the 18-64y group, which was 15.25%. With the increase of age, the detection rate of CRKP increased significantly (≤ 17 y group:0, 18-64y group:6.60%, ≥ 65 y group: 13.94%), as shown in Fig. 1b. The detection rate of CRKP isolated from males was 13.75%, which was significantly higher than that isolated from females (7.58%) ($\chi^2 = 18.13$, $p = 0.00$), as shown in Fig. 1c. The ESBLs rates of respiratory tract specimens, urine, blood, sterile specimens, and non-sterile specimens were 17.50%, 32.42%, 25.71%, 37.37%, and 16.95%, respectively. The CRKP rates were 8.85%, 18.48%, 23.86%, 17.09%, and 2.63%, respectively. as shown in Fig. 1d.

Discussions

K. pneumoniae is an opportunistic pathogen that causes a wide range of infections, including pneumonia, urinary tract infection, bacteremia, cholecystitis, and meningitis, especially in immunocompromised individuals. CHINET shows that both the *K. pneumoniae* isolation rate and drug resistance rate are steadily increasing [2]. Data from 66 hospitals in Shanghai show that the separation rate of ESBLs-KP derived from sputum, blood, and urine increased year by year from 2015 to 2017 [9]. The change in antibiotic resistance rates over 17 years (2000–2016) from EARSNet was becoming more and more serious, and that the resistance rates to third-generation cephalosporins, fluoroquinolones, and aminoglycosides showed a significant upward trend, and the analysis was related to ambient temperature [10].

The results of this study show that, except for SMCH, mainly from middle-aged and elderly patients, and with increasing age, the detection rate of *K. pneumoniae* gradually increases; the detection rate of *K. pneumoniae* isolated from men is higher than that of women, and *K. pneumoniae* isolated from males is more resistant to antibiotics than females. These findings suggest that elderly men are facing a more severe situation of *K. pneumoniae* resistance. Population-based surveillance is essential for monitoring the emergence and trends of antimicrobial resistance and guiding the development of rational antibiotic treatment recommendations[11].

Compared with the meta-analysis results of multiple studies in Asia, the overall resistance rates of amikacin, aztreonam, and meropenem were 40.8%, 73.3%, and 62.7%, respectively[12], the drug resistance rate in this study area is generally low. In our study, the resistance rate of amikacin was the lowest at 4.42%, followed by tigecycline, meropenem, imipenem, ertapenem, piperacillin/tazobactam, and the resistance rates were 5.76%, 6.83%, 9.42%, 9.02%, 9.95%, respectively. The resistance rate of the remaining antibiotics is greater than 10%, and the highest resistance rate is ciprofloxacin, with a resistance rate of 28.72%, which was generally lower than the CHINET average[13]. The high resistance rate of ciprofloxacin mainly comes from the urinary tract. The resistance rates of *K. pneumoniae* isolated from urine in this study to ciprofloxacin and levofloxacin were 42.45% and 32.34%, respectively, which were much higher than those of *K. pneumoniae* isolated from other specimens. This may be because fluoroquinolones are the first-line treatment of empirical medication in urinary tract infections[14, 15].

The production of ESBLs is one of the main resistance mechanisms of *K. pneumoniae*. ESBLs genes are mostly mediated by plasmids, which can spread between bacteria, including TEM, OXA, CTX-M, and SHV, etc, among which CTX-M is the main type contribution of the epidemiologic evolution of human ESBL infections[16]. An epidemiological survey in Zhejiang Province shows that the ESBLs rate is slightly higher than 20% in recent

years[17]. The results in 2019 in the Shaoxing region are consistent with it. However, the ESBLs rate of each hospital is different. Among them, the ESBLs rate of TCM Hospital is the lowest, at only 11.80%. Whether it is related to the different disease composition of the patients admitted to this hospital or maybe because Chinese medicine is mainly used and antibiotics are used less is unknown, which is limited study on epidemiology and mechanism in TCM hospitals. A retrospective surveillance study in a TCM hospital in Hangzhou, Zhejiang Province, showed that 11.2% of hospital-acquired bloodstream infections were caused by *K. pneumoniae*, and 57.1% strains produced ESBLs, which is significantly higher than the average level of ESBLs in this study[18]. In our study, SUH has the highest ESBLs rate, which was converted from an infectious disease hospital to a general hospital in July 2018. The patients are mainly immunosuppressed people such as liver disease and HIV. The long hospital stay and repeated hospitalization history of these patients may be the main reasons.

K. pneumoniae may have become one of the important pathogens of childhood infections, and also is one of the vital cause of mortality[19]. A systematic review suggests that *K. pneumoniae* is the most frequent etiology of community-acquired pneumonia among children in China[20]. In our study, the detection rate of *K. pneumoniae* in the ≤ 17 y group was 5.32%, much lower than previous reports[21]. Previous study has shown that children with bloodstream infections have the highest isolation rate and are mainly isolated from the ICU[22]. The *K. pneumoniae* isolated from the SMCH has the lowest resistance rate to carbapenems, β -lactam- β -lactamase inhibitor combinations, fourth-generation cephalosporins, amikacin, tobramycin, and sulfamethoxazole. However, the detection rate of ESBL strains in ≤ 17 y group is 23.08%. Among them, up to 83.33% (20/24) of the strains were isolated from the neonatal ICU of the hospital (data not shown), which was higher than the adult group in this study. Children infected with ESBLs strains had a significantly longer length of hospital stays and required more ICU care days than those without such infection. At the same time, it increases the risk of further acquisition and transmission with resistant bacteria[23]. But the separation rate of ESBL is lower than that of large tertiary children's hospitals in our country[24]. And fortunately, no carbapenem resistance strain was found in ≤ 17 y group in this study.

CHINET surveillance showed that the national average CRKP isolation rate in 2019 was 27.6%[13]. The 2014–2018 survey in Zhejiang Province indicated that the CRKP prevalence rate in Shaoxing was 9.72%, the detection rate by our study is slightly higher than that, which is far lower than the national average level[17]. However, the hospitals covered by the above-mentioned research studies are completely different, and there are also certain differences from the six hospitals covered by this research.

The detection rate of CRKP in different specimen sources is varied. In our study, the detection rate in non-sterile body fluids is the lowest at 2.63%, and except for cefoperazone/sulbactam and Sulfamethoxazole, *K. pneumoniae* isolated from non-sterile body fluids has the lowest resistance rate to antibiotics, while the detection rate of CRKP in the blood group is the highest at 23.86%. In our study, the resistance rate of *K. pneumoniae* isolated from blood to imipenem, cefepime, piperacillin/tazobactam is higher than that of strains isolated from other specimen sources. Previous research of bloodstream infections by Yang et al. found that *K. pneumoniae* was the second most infectious pathogen, and both adults and children showed an increasing trend between 2012 and 2017, and resistance to carbapenems and amikacin was on the rise [25]. Bloodstream infections are often combined with infections of other sites, and the most common sites are the respiratory tract and urinary tract[26]. There is also a study that intra-abdominal infection is an important source[27]. Carbapenems have been considered to be the last line of defense against *K. pneumoniae* infection. With increasing drug resistance makes

clinical anti-infective treatment has become a more difficult problem. Especially carbapenem-resistant *K. pneumoniae* bloodstream infections are accompanied by higher mortality[10].

Conclusions

In brief, the drug resistance situation of *K. pneumoniae* is becoming more and more serious. In different hospitals in the same area and different specimen sources, the clinical distribution and drug resistance of *K. pneumoniae* are very different. Surveillance systems are vital to monitor the emergence and trends in antimicrobial resistance. They are helpful for the development of rational and effective empirical therapy recommendations and policies for limiting the spread of drug-resistant *K. pneumoniae*. When treating infections caused by *K. pneumoniae*, clinicians should give full consideration to factors such as gender, age, source of specimens, and cross-hospital visits to patients, to rationally use antibiotics. Besides, it is necessary for us to further study the mechanism of *K. pneumoniae* resistance in this region to lay the foundation for better prevention and control.

Abbreviations

MDR: Multidrug resistance ; CRE: Carbapenem-resistant Enterobacteriaceae; CRKP: Carbapenem-resistant *K. pneumoniae* ; CHINET: China antimicrobial surveillance network; CRPA: Carbapenem-resistant *P. aeruginosa* ; ESBLs: Extended-spectrum β -lactamases; CLSI: Clinical and Laboratory Standards Institute; ATCC: American Type Culture Collection.

Declarations

Authors' contributions

GFM conceived and designed the study. XJZ, QLH, QHY, SLW, FXJ, SD, XQL, and LL performed the susceptibility testing and collected data. YCR and MHL analyzed the data. MCL wrote the manuscript. YQZ critically reviewed and edited the manuscript. All coauthors have read, commented, and approved the final version of the article to be published.

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Availability of data and materials

The data and materials used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Ethical approval was approved by the Institutional Review Board of Shaoxing People's Hospital, who waived the need for informed consent. The study is conducted on already available data. All inpatients data were anonymized before analysis. Acquisition of participating hospital data was approved by the scientific research department of the hospital.

Consent for publication

Not applicable.

Conflicts of interest

The authors declare that they have no conflict of interest.

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Figures

Figure 1

ESBL-KP and CR-KP distribution ESBL rate (gray) and CR rate (black) of all strains. Among them, Fig.1a shows the ESBL rate and CR rate of strains isolated from different hospitals; Fig.1b shows the ESBL rate and CR rate of strains from patients with different age groups; Fig.1c shows the ESBL rate and CR rate of strains from different genders; and Fig.1d shows the ESBL rate and CR rate of strains from different specimens.