

Distribution of Pathogenic Bacteria and Changes in Drug Resistance of Urinary Tract Infections in Children in Southwest China, 2020–2024

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Objective: Urinary tract infection (UTI) is a major health concern in pediatric populations. By analysing temporal changes in pathogen distribution and antimicrobial resistance among children with UTIs in Southwest China from 2020 to 2024, we aim to provide a robust scientific basis for the empirical antibiotic therapy in this region.

Methods: We retrospectively analyzed non-duplicate pathogens isolated from urine specimens and their antimicrobial susceptibility results in 6598 children (≤ 14 years old) diagnosed with UTIs in southwest China from 2020 to 2024. These results were interpreted according to the M100 guidelines of the American Clinical and Laboratory Standards Institute (CLSI) and analysed using WHONET 5.6 software.

Results: A total of 7831 strains of pathogenic bacteria were detected, of which 60.1% were gram-negative and 39.9% were gram-positive. The top five bacteria detected were *Escherichia coli* (37.8%), *Enterococcus faecium* (26.3%), *Enterococcus faecalis* (7.5%), *Klebsiella pneumoniae* (6.9%) and *Pseudomonas aeruginosa* (2.5%). *E. coli* showed less than 10% resistance to piperacillin/tazobactam, cefoperazone/sulbactam, amikacin and nitrofurantoin, with resistance to quinolones ranging from 31.3% to 51.5%. *K. pneumoniae* showed resistance rates of 13.1% and 16.8% to imipenem and meropenem, respectively, from 2020 to 2024. *E. faecium* showed significantly higher resistance rates to the tested drugs than *E. faecalis*, particularly to ampicillin (95.1–97.4% vs 4.9–8.0%). Methicillin-resistant *Staphylococcus aureus* (MRSA) was detected at a rate of 33.8%. MRSA showed a higher level of resistance to penicillin, rifampicin, levofloxacin, clindamycin and erythromycin than methicillin-sensitive strains.

Conclusion: Over the past five years, the main pathogenic bacteria responsible for pediatric UTIs in southwestern China were *E. coli*, *E. faecium* and *E. faecalis*. Resistance patterns among major uropathogens revealed diverse trends, and the emergence of multidrug-resistant organisms presents a serious therapeutic challenge that warrants close surveillance.

Keywords: urinary tract infection, drug resistance, children, China, surveillance of drug resistance

Introduction

Urinary tract infections (UTIs) are among the most common infections worldwide, affecting approximately 150 million people and causing around 13,000 deaths annually.^{1,2} Within the paediatric population, preterm and newborn infants are at higher risk of UTIs than full-term infants.³ Around 8.4% of girls and 1.7% of boys under the age of seven are diagnosed with UTIs,⁴ and 30% of children develop recurrent infections within six months.⁵ UTIs are one of the most common causes of fever and bacteraemia in infants and young children.⁶ Approximately 5% of girls and 20% of boys under 2 months of age with a fever are diagnosed with a UTI.⁷ The clinical presentation of UTIs varies by age. Short-term symptoms usually include fever, dysuria and low back pain.⁸ If not properly treated, these symptoms often progress to recurrent UTIs, decreased renal function, renal scarring and serious consequences in adulthood such as hypertension and chronic renal insufficiency.^{9,10} Children are more likely than adults to develop urinary tract infections due to their immature immune systems, anatomical differences and congenital urinary tract abnormalities.^{11,12} As the signs and symptoms of UTIs in children are non-specific, and as infants and young children cannot clearly express symptoms, diagnosis and treatment are often delayed. The severe morbidity and sequelae place a heavy burden on families and society.¹³

Although antibiotic therapy is key to UTI management, several recent studies have shown that antibiotic resistance in paediatric urinary tract infections continues to rise. The proportion of multidrug-resistant *E. coli* has increased significantly in childhood urinary tract infections in Ukraine over the past 10 years.¹⁴ A meta-analysis in the United Kingdom revealed a high prevalence of antibiotic resistance in childhood urinary tract infections, particularly in countries or regions outside the Organisation for Economic Co-operation and Development (OECD).¹⁵ Data from Poland also revealed a substantial rise in *E. coli* resistance to amoxicillin/clavulanic acid, gentamicin and ceftazidime.¹⁶ According to a Chinese report, the drug resistance rate of *Escherichia coli* to third- and fourth-generation cephalosporins (eg, cefaclor, ceftazidime) as well as ceftazidime-avibactam often exceeds 30%–50%, and is even higher in some regions.¹⁷ As the distribution and resistance of urinary tract infections vary geographically and over time, experiences from different countries and regions can only be used as a reference, and clinicians must adapt their regimens to the latest local resistance data. In China, studies have reported on the distribution and resistance rates of urinary tract infection pathogens in the Jiaying area (2020–2022), the Chongming area in eastern Shanghai (2018–2020) and the Sichuan province (2019–2023),^{18–20} but data specifically on paediatric UTI pathogen resistance remain scarce. Consequently, this study retrospectively analysed the distribution of pathogenic bacteria and drug sensitivity results of childhood urinary tract infections across 134 hospitals in southwestern China from 2020 to 2024, aiming to inform regional treatment strategies.

Materials and Methods

Source of Bacterial Isolates

The diagnosis of a urinary tract infection (UTI) in children was based on a combination of clinical manifestations, laboratory tests, imaging findings and guidelines, as well as clinical practice. The inclusion criteria were as follows: (1) outpatients and inpatients aged 0–14 years; (2) patients diagnosed with a urinary tract infection based on clinical symptoms, routine urinalysis and other examination results, in accordance with the Asian Guidelines for Urinary Tract Infections in Children;²¹ (3) patients presenting with clinical symptoms such as fever, cough, vomiting and diarrhoea. The exclusion criteria were as follows: (1) children with negative urine cultures; (2) children with contaminated urine samples; (3) children who did not meet the criteria for routine urinalysis; (4) those with incomplete clinical information; (5) children with blood disorders, immune system dysfunction and other serious complications (eg, severe liver and kidney dysfunction).

From 2020 to 2024, a total of 6598 children were diagnosed with urinary tract infections in 134 hospitals located in southwestern China. For these children, drug sensitivity tests were performed on urine isolates according to the surveillance protocol. The initial strain of the pathogen from each patient was retained for the analysis, resulting in a total of 7831 strains being included in the study (multiple bacterial isolates were obtained from some patients). The ethical review of this retrospective study was approved by the Chinese Institutional Review Board of Sichuan Provincial People's Hospital and the University of Electronic Science and Technology (No. 2025788).

Bacterial Culture

All clinical samples were cultured following standardized microbiological procedures. Midstream urine specimens were collected in sterile containers and transported to the clinical microbiology laboratory for quantitative culture within 2 hours. A sterile inoculation loop (10 μ L) was used to streak the urine samples onto three types of agar plates, namely 5% sheep blood agar, MacConkey agar, and Chocolate agar plates. The inoculated plates were incubated aerobically at 35°C for 18–24 hours, during which colony morphology (size and shape) was closely observed. A urine culture was determined to be positive if the concentration of a single gram-negative bacterial species reached $\geq 10^5$ CFU/mL, or if that of a single gram-positive bacterial species reached $\geq 10^4$ CFU/mL.

Bacterial Identification and Susceptibility Testing

The identification of bacteria was conducted using the Vitek 2 automated system or the MALDI-TOF mass spectrometry system.

The drug susceptibility test was performed by the minimum inhibitory concentration (MIC) test and the Kirby-Bauer (K-B) method, which was conducted in accordance with the CLSI M100 34th edition guideline criteria.²² In this context, tigecycline was evaluated in alignment with the criteria stipulated by the US Food and Drug Administration (FDA).²³

Quality Control

According to CLSI guidelines, *Escherichia coli* (ATCC 25922), *Klebsiella pneumoniae* (ATCC 700603), *Staphylococcus aureus* (ATCC 25923), *Pseudomonas aeruginosa* (ATCC 27853), and *Enterococcus faecalis* (ATCC 29212) were used as QC strains, and weekly QC tests were performed.

Statistical Analysis

All data were analysed utilising WHONET5.6 data analysis software. The general steps of WHONET5.6 for statistical analysis of drug susceptibility result data are as follows: 1) the strain information, the antimicrobial drug name and the corresponding drug susceptibility test results must be entered into the software; 2) according to the statistical needs, the various types of analysis modes in the system must be selected, such as resistance analysis, sensitivity analysis and resistance spectrum analysis; 3) the analysis options must be set according to the data to be analysed. This involves selecting the source of strains, the types of strains, and the antimicrobial drugs of concern, among other considerations; 4) reports must be generated; 5) interpret the results; 6) export the data.

Results

Distribution of Pathogenic Bacteria in Urine Samples

A total of 7831 pathogenic isolates were detected in the 2020–2024 period, of which 4705 (60.1%) were gram-negative and 3126 (39.9%) were gram-positive. The top five detection rates were *E. coli* (37.8%), *E. faecium* (26.3%), *E. faecalis* (7.5%), *K. pneumoniae* (6.9%), *P. aeruginosa* (2.5%). The isolation rate of female patients (3636 strains, 55.1%) was found to be significantly higher than that of male patients (2962 strains, 44.9%). The highest isolation rate was identified in the age group of <28 days to ≤1 year (44.8%), and the lowest was identified in the age group of <1 year to ≤3 years (9.5%), as illustrated in Tables 1 and 2. The trend of detecting the top five bacteria causing urinary tract infections is demonstrated in Figure 1.

Table 1 Distribution of Bacterial Pathogens Isolated from Urine Specimens

Organism	Strain (n)	Percentage (%)
<i>Escherichia coli</i>	2958	37.8
<i>Enterococcus faecium</i>	2058	26.3
<i>Enterococcus faecalis</i>	591	7.5
<i>Klebsiella pneumoniae</i>	542	6.9
<i>Pseudomonas aeruginosa</i>	198	2.5
<i>Enterobacter cloacae</i>	184	2.3
<i>Proteus mirabilis</i>	164	2.1
<i>Klebsiella oxytoca</i>	123	1.6
<i>Enterococcus gallinarum</i>	87	1.1

(Continued)

Table 1 (Continued).

Organism	Strain (n)	Percentage (%)
<i>Staphylococcus aureus</i>	77	1.0
Others*	849	10.8
Total	7831	100.0

Note: *Bacteria other than the list.
Abbreviation: n, the number of strains.

Table 2 Characteristics of Strains Isolated in Different Sex and Age Groups

Characteristics	Strain (n)	Percentage (%)
Total	6598	100.0
Sex		
Male	2962	44.9
Female	3636	55.1
Age Groups		
≤28d	856	13.0
<28d~≤1y	2958	44.8
<1y~≤3y	629	9.5
<3y~≤14y	2155	32.7

Abbreviation: n, the number of strains.

Resistance of Main Gram-Negative Bacteria

From 2020 to 2024, *E. coli* demonstrated high susceptibility to piperacillin/tazobactam, cefoperazone/sulbactam, amikacin, and nitrofurantoin, with a resistance rate of less than 10%. The resistance rate to ceftriaxone and cefotaxime

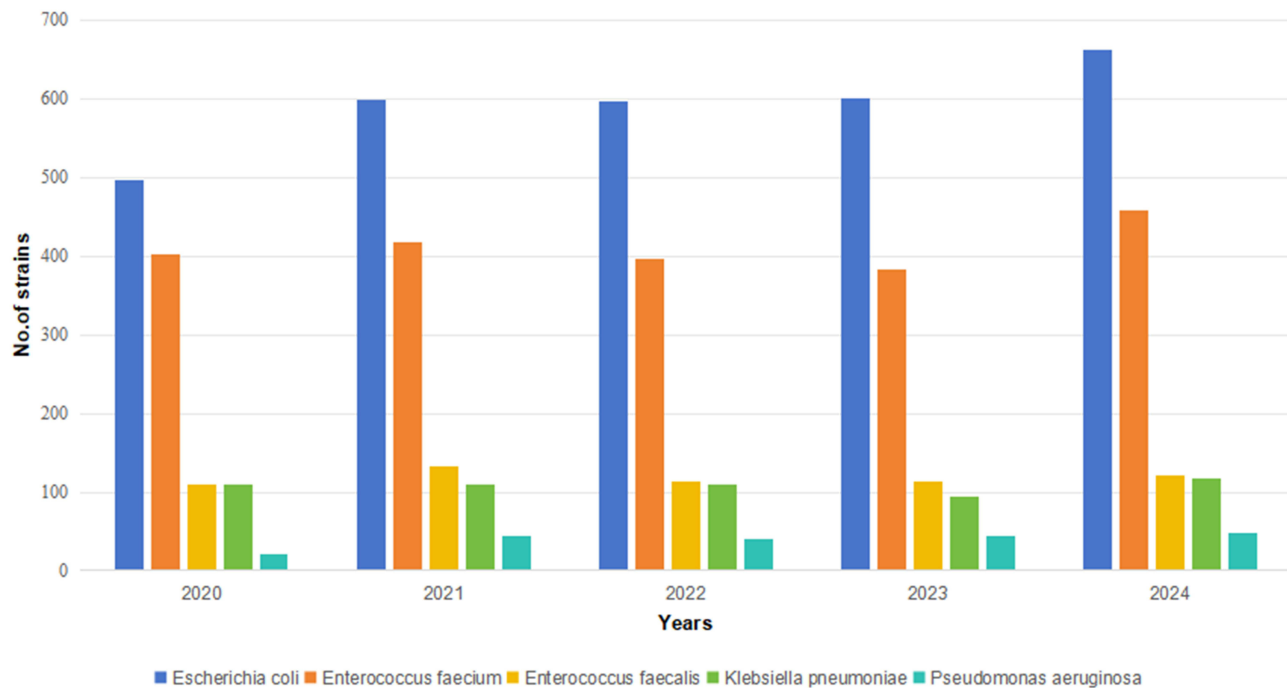


Figure 1 Detection trends of the top 5 bacterial pathogens causing UTIs.

ranged from 57.4% to 67.3%, and to quinolones from 31.3% to 51.5%. There were insignificant changes in trends over the 5-year period, as illustrated in Table 3. The resistance rates of *K. pneumoniae* to ceftriaxone and cefotaxime ranged from 59.1% to 67.3%. The resistance rates to nitrofurantoin (18.6% to 24.7%) were considerably higher than those of *E. coli* (0.8% to 2.0%). As demonstrated in Table 4, the resistance rates of *K. pneumoniae* to imipenem and meropenem decreased from 16.7% and 24.2% in 2020 to 13.1% and 16.8% in 2024, respectively. This indicates a slight downward trend; however, it remains significantly higher than the resistance rates of *E. coli* to carbapenems (0.3–1.6%). Furthermore, the data demonstrates that the resistance rate of *Enterobacter cloacae* to aminoglycosides was less than 8.4%, to levofloxacin 4.1%, and to amikacin with a sensitivity of 100%. The resistance rate of *Proteus mirabilis* to ciprofloxacin and levofloxacin was 30.7% and 22.8%, respectively. *P. aeruginosa* demonstrated a resistance rate of less than 6.1% to each of the tested drugs and exhibited high activity, as shown in Table 5.

Drug Resistance in Main Gram-Positive Bacteria

A total of 2058 strains of *E. faecium* (26.3%) and 591 strains of *E. faecalis* (7.5%) were detected. *E. faecium* demonstrated a substantially higher degree of resistance to the drugs in question than *E. faecalis*, particularly with regard to ampicillin (95.1–97.4% VS 4.9–8.0%), resistance to ciprofloxacin and levofloxacin (greater than 53.4%), and a decline in resistance to nitrofurantoin from 11.4% in 2020 to 5.5% in 2024. *E. faecalis* demonstrated a high rate of resistance to rifampicin, ranging from 38.5% to 52.9%, and a susceptibility rate of >94.0% to linezolid and teicoplanin, with no vancomycin-resistant strains detected, as shown in Table 6.

Table 3 Antibiotic Resistance of *Escherichia coli*

Antimicrobial Agent	2020		2021		2022		2023		2024	
	n=497		n=600		n=597		n=602		n=662	
	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%
Ampicillin	87.8	11.8	85.2	14.4	83.2	16.1	86.3	12.9	89.0	10.0
Amoxicillin/clavulanate	11.2	70.9	10.6	75.4	13.4	73.9	8.2	73.7	12.1	73.0
Piperacillin/tazobactam	1.6	95.3	2.0	95.6	2.5	95.2	1.5	95.7	3.4	94.5
Ceftazidime	27.6	66.9	26.2	69.7	23.5	71.5	26.3	68.5	26.9	68.4
Ceftriaxone	62.0	38.0	59.1	40.6	57.5	42.1	60.8	39.2	64.9	35.1
Cefotaxime	67.3	32.7	66.1	32.2	57.4	42.6	66.0	33.6	66.6	32.5
Cefepime	22.7	66.7	20.5	71.1	19.3	74.9	25.2	68.0	27.7	63.6
Cefoperazone/Sulbactam	4.7	76.9	3.5	82.9	4.9	80.5	6.9	74.8	7.4	78.1
Cefotetan	1.5	97.9	2.5	97.3	1.2	97.8	1.5	97.7	2.6	97.0
Cefoxitin	14.3	84.1	6.6	92.5	6.5	90.2	8.4	89.2	6.0	94.0
Aztreonam	39.9	58.6	38.3	60.2	37.0	61.5	39.7	58.6	38.8	58.4
Ertapenem	0.3	99.7	0.6	99.4	0.2	99.8	0.4	99.6	1.4	98.4
Imipenem	1.0	98.6	1.1	98.7	0.4	99.5	0.5	99.3	1.6	98.2
Meropenem	0.3	99.7	0.9	99.1	0.2	99.6	0.4	99.3	1.3	98.7
Amikacin	1.6	98.4	1.0	98.9	2.0	81.1	2.4	78.1	1.5	98.3
Gentamicin	35.2	63.5	31.2	68.3	31.0	67.6	26.5	73.3	25.4	72.7
Tobramycin	13.5	64.1	9.7	67.6	8.6	67.6	7.1	73.3	9.2	72.0
Ciprofloxacin	42.6	45.2	41.0	43.4	43.6	44.2	43.7	41.2	42.4	46.6
Levofloxacin	37.1	24.9	34.9	31.3	38.1	34.0	39.2	32.8	35.8	42.4
Trimethoprim/sulfamethoxazole	58.8	41.2	56.6	43.4	56.4	43.6	48.5	51.5	53.2	46.8
Nitrofurantoin	2.0	91.8	0.9	94.6	1.2	94.1	0.8	96.3	2.0	95.4
Chloramphenicol	17.2	72.4	20.4	73.5	29.4	70.6	23.1	74.4	15.8	81.6
Tetracycline	68.8	31.2	68.7	31.3	65.7	33.9	61.0	39.0	68.8	31.2
Tigecycline	0.0	100.0	0.0	100.0	0.0	100.0	0.0	99.7	0.0	99.8

Abbreviations: n, number of strains; R, drug resistance rate; S, drug susceptibility rate.

Table 4 Antibiotic Resistance of *Klebsiella pneumoniae*

Antimicrobial Agent	2020		2021		2022		2023		2024	
	n=110		n=110		n=110		n=95		n=117	
	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%
Amoxicillin/clavulanic acid	57.1	28.6	40.4	42.3	19.6	63.0	25.0	57.5	21.8	54.5
Piperacillin/tazobactam	24.3	72.9	21.7	70.4	19.3	74.5	15.9	78.0	23.8	71.4
Ceftazidime	45.0	51.4	39.4	56.9	31.5	65.7	35.8	58.9	41.0	55.6
Ceftriaxone	64.8	35.2	55.5	44.5	44.3	54.7	48.4	50.5	61.3	38.7
Cefotaxime	51.5	48.5	58.3	37.5	50.0	47.9	48.8	48.8	64.6	35.4
Cefepime	33.7	58.2	29.9	64.5	21.0	75.0	27.3	68.2	35.2	58.1
Cefoperazone/sulbactam	46.4	42.9	22.8	63.2	13.8	70.7	13.5	76.9	28.8	57.6
Cefotetan	10.2	87.4	14.3	82.1	6.2	92.2	8.5	91.5	11.8	88.2
Cefoxitin	35.7	64.3	27.8	72.2	26.7	73.3	25.8	74.2	27.8	72.2
Aztreonam	52.4	45.6	42.7	55.5	36.4	61.7	42.7	56.2	44.3	53.9
Ertapenem	7.6	92.4	7.6	92.4	4.8	94.0	4.3	95.7	6.7	92.1
Imipenem	16.7	81.5	13.0	86.1	15.6	83.5	10.2	89.8	13.1	86.9
Meropenem	24.2	75.8	14.6	85.4	14.8	84.0	13.7	86.3	16.8	83.2
Amikacin	1.8	85.3	1.7	87.0	3.7	95.4	3.4	77.5	5.6	94.4
Gentamycin	19.6	79.4	15.3	80.2	20.8	77.4	18.9	81.1	24.3	69.9
Tobramycin	5.1	77.8	6.5	79.6	10.8	74.5	13.3	77.1	11.8	75.3
Ciprofloxacin	33.0	56.8	30.6	55.9	35.6	53.8	35.7	48.8	44.1	48.4
Levofloxacin	15.6	57.5	17.1	52.3	19.4	49.5	19.3	50.0	28.4	48.3
Trimethoprim/sulfamethoxazole	38.5	61.5	38.6	61.4	34.9	65.1	29.0	71.0	40.4	59.6
Nitrofurantoin	23.5	24.7	24.7	20.2	22.2	24.7	18.6	35.7	22.6	21.4
Chloramphenicol	22.9	77.1	33.3	66.7	25.0	75.0	27.5	72.5	28.6	71.4
Tetracycline	53.3	46.7	38.3	61.7	46.2	53.8	46.7	51.1	42.9	57.1
Tigecycline	0.0	96.8	3.7	96.3	1.7	98.3	0.0	100.0	0.0	98.6

Abbreviations: n, number of strains; R, drug resistance rate; S, drug susceptibility rate.

Table 5 Antibiotic Resistance of *Enterobacter cloacae*, *Proteus mirabilis* and *Pseudomonas aeruginosa*

Antimicrobial Agent	<i>E. cloacae</i> (n=184)		<i>P. mirabilis</i> (n=164)		<i>P. aeruginosa</i> (n=198)	
	R%	S%	R%	S%	R%	S%
Cefoperazone/sulbactam	24.1	54.0	0.0	98.2	—	—
Piperacillin/tazobactam	26.3	59.1	0.0	98.8	3.2	93.7
Cefuroxime	64.5	21.8	35.1	62.9	—	—
Ceftazidime	43.1	55.8	8.0	89.0	4.5	94.4
Ceftriaxone	48.6	49.7	26.4	71.7	—	—
Cefotaxime	59.8	37.8	39.7	60.3	—	—
Cefepime	12.0	81.0	5.6	86.9	1.5	95.9
Aztreonam	43.2	56.2	3.2	95.5	6.1	84.7
Ertapenem	8.4	87.0	0.0	99.3	—	—
Imipenem	6.9	88.5	11.1	63.9	2.1	95.8
Meropenem	8.3	91.0	0.0	100.0	1.2	98.8
Amikacin	0.0	100.0	1.3	97.4	0.7	99.3
Gentamicin	8.4	91.6	18.4	60.8	1.2	96.3
Tobramycin	4.2	91.1	12.8	61.5	0.5	98.4
Ciprofloxacin	10.3	76.4	30.7	64.1	1.1	95.7

(Continued)

Table 5 (Continued).

Antimicrobial Agent	<i>E. cloacae</i> (n=184)		<i>P. mirabilis</i> (n=164)		<i>P. aeruginosa</i> (n=198)	
	R%	S%	R%	S%	R%	S%
Levofloxacin	4.1	76.2	22.8	66.7	4.2	94.2
Moxifloxacin	22.5	72.5	54.3	43.2	—	—
Trimethoprim/sulfamethoxazole	12.5	87.5	50.6	49.4	—	—
Tetracycline	12.8	86.0	—	—	—	—
Tigecycline	0.0	100.0	—	—	—	—

Abbreviations: n, number of strains; R, drug resistance rate; s, drug susceptibility rate; "—", Not detected.

A total of 77 *S. aureus* strains were isolated from urine, and the detection rate of methicillin-resistant *S. aureus* was 33.8% (26/77). The resistance rate of MRSA to penicillin, rifampicin, levofloxacin, clindamycin and erythromycin was higher than that of methicillin-susceptible strains; MSSA exhibited a higher resistance rate to trimethoprim/sulfamethoxazole than MRSA (18.0% vs 4.3%) No strains resistant to vancomycin, linezolid, teicoplanin, and nitrofurantoin were detected, as shown in [Table 7](#).

Multidrug-Resistant Bacteria Changes

Among the multi-drug resistant bacteria detected in the period 2020–2024, carbapenem-resistant *E. coli* (CR-ECO) and vancomycin-resistant *Enterococci* (VRE) remained at a low level, carbapenem-resistant *K. pneumoniae* (CR-KPN) showed a jagged distribution, and methicillin-resistant *S. aureus* (MRSA) showed a significant decrease in 2024, as shown in [Figure 2](#).

Discussion

The present study revealed that a total of 6598 children were diagnosed with urinary tract infections, and 7831 pathogenic bacteria were isolated from 134 hospitals in Southwest China from 2020 to 2024. The top five detection rates were *E. coli* (37.8%), *E. faecium* (26.3%), *E. faecalis* (7.5%), *K. pneumoniae* (6.9%) and *P. aeruginosa* (2.5%). A plethora of studies from different regions have demonstrated discrepancies in the distribution of pathogens associated with urinary tract infections in children. For instance, in Chongqing, China, *E. coli* (40.5%), *E. faecium* (15.0%) and *K. pneumoniae* (8.9%) were predominantly detected,²⁴ in Brazil, *E. coli* (56.9%), *K. pneumoniae* (18.5%) and *E. faecalis* (7.7%) were predominantly present,²⁵ and in Nepal, the most prevalent pathogens were *E. coli* (53.0%), followed by *E. faecalis* (22.0%) and *K. pneumoniae* (7.0%).²⁶ Conversely, in the Middle East, *E. coli* accounted for 88.6% of the total, with the remaining common pathogens comprising *K. pneumoniae* (10.3%) and *P. mirabilis* (4.7%).²⁷ This finding indicates that the distribution of pathogens across different regions may be influenced by a variety of factors, including the local environment, medical conditions, and antibiotic use habits. In this study, the prevalence of urinary tract infections was highest (44.8%) in the infant group (<28d to ≤1y), which may be related to anatomical structure (eg, bladder neck position, shorter urethra) and immature immune system in infancy.

Pathogenic bacterial resistance testing is an important reference for guiding the rational use of clinical medications. Local resistance patterns can be used as supportive data to optimise the treatment regimen of empirical medications used in the region. This can reduce the mortality rate and healthcare costs of patients. The results of this surveillance study revealed that the resistance rate of *Escherichia coli* to piperacillin/tazobactam, cefoperazone/sulbactam, amikacin, and cefotetan was less than 10.0%. This finding indicates a high level of sensitivity, which is comparable to the 2019–2023 situation in this region reported by Zhong Min and the national data for 2015–2021.^{20,28} The resistance rate of *Escherichia coli* to nitrofurantoin ranged from 0.8% to 2.0%, and the drug continues to be used empirically since it has been demonstrated to inhibit bacteria in the urine significantly more than in the bloodstream in the treatment of

Table 6 Resistance Rates of *Enterococcus faecium* and *Enterococcus faecalis* to Antimicrobial Agents

Antimicrobial Agent	2020				2021				2022				2023				2024			
	EFM (n=401)		EFA (n=107)		EFM (n=427)		EFA (n=135)		EFM (n=394)		EFA (n=114)		EFM (n=381)		EFA (n=113)		EFM (n=455)		EFA (n=122)	
	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%	R%	S%
Ampicillin	95.2	4.8	6.4	93.6	97.4	2.6	6.0	94.0	95.1	4.9	6.2	93.8	96.6	3.4	8.0	92.0	95.9	4.1	4.9	95.1
Gentamicin-high (120µg)	38.1	61.9	33.7	66.3	42.1	57.9	31.7	68.3	44.2	55.8	38.9	61.1	47.3	52.7	41.9	58.1	41.3	58.7	32.5	67.5
Rifampicin	86.0	7.0	45.0	35.0	72.4	13.8	50.0	45.0	83.8	5.4	41.7	33.3	75.0	11.8	52.9	35.3	75.3	8.6	38.5	30.8
Ciprofloxacin	69.0	4.4	15.8	82.1	65.0	3.0	15.7	81.0	58.6	4.5	17.0	76.6	62.2	3.3	18.7	73.6	61.6	8.7	30.6	63.5
Levofloxacin	56.3	21.7	14.9	82.2	54.8	20.5	12.4	84.5	53.4	29.8	16.0	82.0	54.4	29.8	14.7	82.4	57.9	29.2	24.1	70.4
Nitrofurantoin	11.4	23.6	1.3	91.1	8.4	24.4	0.0	93.5	6.2	30.8	2.5	91.4	7.6	32.9	0.0	93.5	5.5	42.3	2.7	94.6
Linezolid	0.5	99.2	0.0	100.0	0.0	98.6	2.3	95.4	0.8	98.4	0.0	100.0	0.0	98.6	3.8	94.2	0.0	99.6	0.9	99.1
Vancomycin	0.2	99.8	0.0	100.0	0.0	99.8	0.0	99.3	0.3	99.7	0.0	100.0	1.3	98.7	0.0	100.0	0.2	99.8	0.0	100.0
Teicoplanin	0.0	97.3	0.0	100.0	0.0	98.6	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0

Abbreviations: n, number of strains; R, drug resistance rate; S, drug susceptibility rate.

Table 7 Resistance Rates of *Staphylococcus aureus* to Antimicrobial Agents

Antimicrobial Agent	MRSA		MSSA	
	n=26		n=51	
	R%	S%	R%	S%
Penicillin G	100.0	0.0	95.5	4.5
Gentamicin	4.2	95.8	14.0	86.0
Rifampin	4.5	90.9	2.2	97.8
Levofloxacin	9.1	90.9	5.3	92.1
Trimethoprim/sulfamethoxazole	4.3	95.7	18.0	82.0
Clindamycin	47.6	52.4	26.0	72.0
Erythromycin	57.1	42.9	46.9	53.1
Linezolid	0.0	100.0	0.0	100.0
Vancomycin	0.0	100.0	0.0	100.0
Teicoplanin	0.0	100.0	0.0	100.0
Nitrofurantoin	0.0	100.0	0.0	100.0

Abbreviations: n, number of strains; R, drug resistance rate; S, drug susceptibility rate.

urinary tract infections. However, in India, the resistance rate of *Escherichia coli* to nitrofurantoin was reported to be 78.7%,²⁹ suggesting that antibiotic resistance patterns vary considerably between regions and countries.

The carbapenem resistance rate of *E. coli* was found to be less than 1.6%, with high activity and resistance to ceftriaxone and cefotaxime >57.4%, and quinolone resistance in the range of 31.3%–51.5%. *K. pneumoniae* demonstrated a resistance rate to ceftriaxone and cefotaxime in the range of 59.1%–67.3%, and quinolone resistance in the range of >15.6%. This

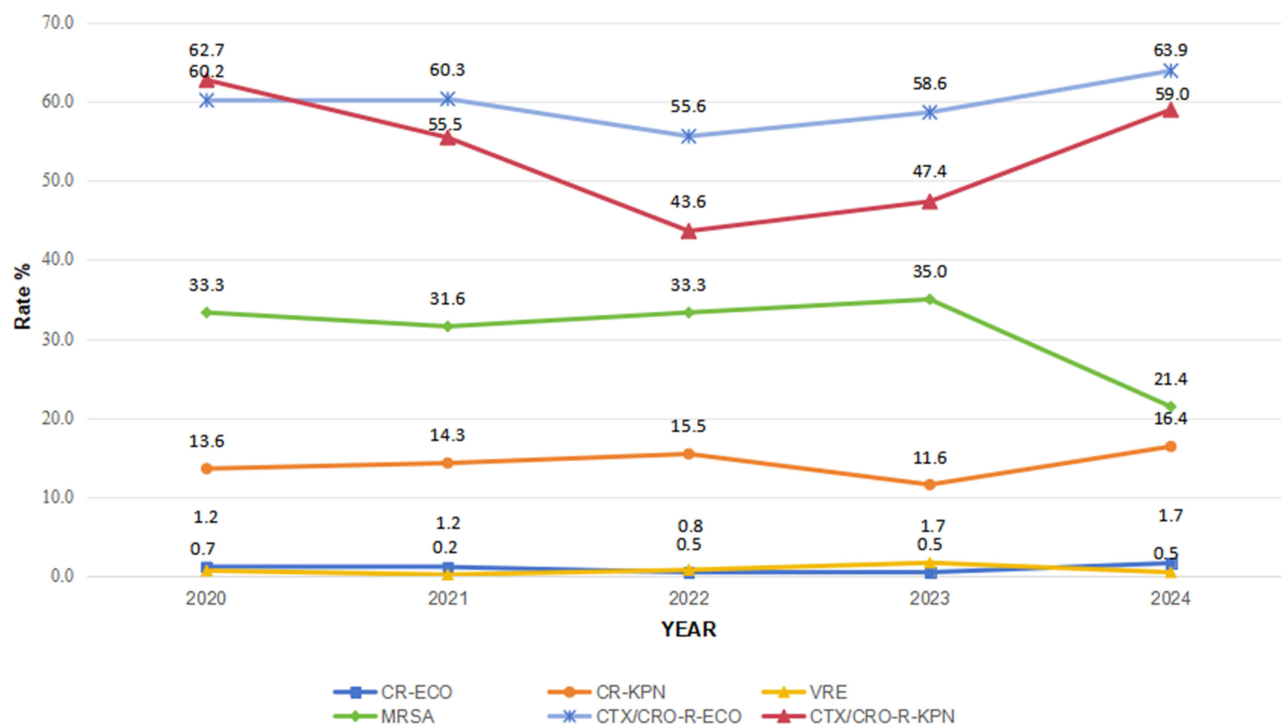


Figure 2 Distribution of multi-drug resistant strains in 2020–2024.

Abbreviations: CR-ECO, Carbapenem-resistant *Escherichia coli*; CR-KPN, Carbapenem-resistant *Klebsiella pneumoniae*; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, Vancomycin-resistant *Enterococcus*; CTX/CRO-R-ECO, cefotaxime/ceftriaxone-resistant *Escherichia coli*; CTX/CRO-R-KPN, cefotaxime/ceftriaxone-resistant *Klebsiella pneumoniae*.

result was consistent with the data reported by Niu et al in the Jiaxing region, where they found that the resistance rates of *E. coli* to ceftriaxone and quinolones exceeded 50.0%, while the resistance rates to carbapenems (1.0%), nitrofurantoin (1.8%), and piperacillin/tazobactam (0.7%) were relatively low.¹⁹ The utilisation of quinolones is proscribed for individuals under the age of 18 years in China, and the emergence of quinolone-resistant strains may be attributable to the extensive utilisation of such pharmaceuticals in adults to induce bacterial resistance, which is then transmitted through the bacterial plasmid, resulting in hospitalised paediatric pathogens also becoming resistant to them.

In the period 2020–2024, the detection rates for CTX/CRO-R-ECO remained high (55.6–63.9%) and the detection rates for CTX/CRO-R-KPN ranged from 43.6% to 60.2%. This rate was higher than the national average (49.2%) reported by the China Antimicrobial Surveillance Network (CHINET) in 2024,³⁰ and far higher than the 12.9% reported in the United States.³¹ This was due to the emergence of strains resistant to third-generation cephalosporins (3GC) as a result of the production of ultrabroad-spectrum β -lactamases (ESBLs) or AmpC enzymes. This phenomenon has been widely exacerbated by the widespread use of third-generation cephalosporins.³² In the Bacterial Priority Pathogens List 2024 (BPPL-2024) published by the World Health Organization (WHO),³³ 3GCRE have been individually categorized as a key priority, there by adding to the burden of low- and middle-income countries and vulnerable populations due to their high rate of therapeutic failures and increased healthcare costs. Studies have demonstrated that significant discrepancies exist in the treatment regimens for urinary tract infections (UTIs) across different regions worldwide, indicating that therapeutic strategies should be formulated based on local antimicrobial resistance profiles.³⁴ The data of the present study were collected from 134 hospitals in Southwest China, which are representative of the bacterial resistance patterns in this region. Our findings suggest that third-generation cephalosporins may no longer be suitable for the treatment of pediatric UTIs in this area. Given that antibiotic-resistant UTIs are associated with prolonged hospital stays and extended treatment courses,³⁵ Therefore, it is imperative for clinical practice to promptly establish antibiotic administration and feedback mechanisms, implement a prescription review system, and intervene in irrational antibiotic use. Meanwhile, patients infected with drug-resistant bacteria should be isolated, and disinfection of ward environments should be strengthened to prevent the transmission of such pathogens.

Studies have demonstrated that carbapenems may serve as effective alternatives. However, it should be noted that the detection rate of carbapenem-resistant *K. pneumoniae* (CRKPN) among isolates increased from 13.6% in 2020 to 16.4% in 2024, which is slightly lower than the CHINET 2015–2021 surveillance results,³⁶ and the detection rate of carbapenem-resistant *E. coli* (CRECO) fluctuated between 0.5% and 1.7%. In China, the drug resistance of carbapenem-resistant Enterobacterales (CRE) is mainly driven by the plasmid-mediated transmission of KPC-2/ST11 and NDM-5/ST48 clones, which is distinct from that in Western countries (eg, the KPC-2/ST258 clone prevalent in the United States).^{37–39} This dual feature of high pathogenicity plus high drug resistance renders the clinical treatment extremely challenging. Although in vitro drug sensitivity tests have demonstrated the presence of good antimicrobial activity of tigecycline against CRE, it is not recommended for the treatment of urinary tract infections caused by CRE because it does not reach effective therapeutic concentrations in urine. The Infectious Diseases Society of America (IDSA) has issued guidelines recommending the utilisation of ciprofloxacin, levofloxacin, and TMP/SMX as preferred treatment options for uncomplicated bladder infections caused by CRE. For cases of pyelonephritis or complicated urinary tract infections caused by CRE, the aforementioned three drugs are recommended if they are susceptible to sensitization tests; otherwise, ceftazidime-avibactam, meropenem-vaborbactam, imipenem-relebactam, and cefdinir are preferred.⁴⁰ Given the contraindication of quinolones in paediatric patients, ceftazidime/avibactam represents the sole antibiotic currently available in China for treatment of CRE infections in children, thereby significantly restricting the range of therapeutic options. However, the most recent study demonstrated that New Delhi metallo- β -lactamase (NDM) accounted for as many as 68.0% of carbapenem-resistant *Klebsiella pneumoniae* (CRKP) infections in neonates. Since the metalloenzyme NDM is capable of hydrolyzing ceftazidime/avibactam, the role of the latter in the treatment of CRKP infections has been drastically limited.⁴¹ Consequently, there is a necessity for heightened vigilance with regard to CRE infections in the paediatric population. Moreover, there is a requirement for the continuous promotion and implementation of prevention and control initiatives for multidrug-resistant bacterial infections, including rectal swab screening of key populations, environmental disinfection, and the management of family visitors. It is encouraging that phage therapy has demonstrated positive outcomes in the treatment of CRKP-induced urinary tract infections, thus providing a more extensive range of clinical treatment options.⁴²

Of the enterococci that cause urinary tract infections, *E. faecium* (2058 strains, 26.3%) and *E. faecalis* (591 strains, 7.5%) predominate. Surveillance in this region revealed that *E. faecium* exhibited higher resistance rates to most of the drugs tested than *E. faecalis*, especially ampicillin (95.1–97.4% vs 4.9–8.0%). Furthermore, *E. faecalis* demonstrated a sensitivity rate of >91.0% to nitrofurantoin and a sensitivity rate of 100.0% to teicoplanin. A low prevalence of *Enterococci* was observed to demonstrate resistance to vancomycin (<1.3%) and linezolid (<3.8%), a figure that was marginally higher than the national average.²⁸ In China, the drug resistance of vancomycin-resistant *Enterococcus* (VRE) is mainly attributed to the horizontal transfer of the *vanA* gene carried by enterococci via plasmids, accompanied by the expansion of the ST78 clone.⁴³ Consequently, enterococcal urinary tract infections in children can be treated with scientifically empirical antimicrobial therapy based on this large resistance monitoring data.

The present study was subject to certain limitations. Firstly, it is important to note that antibiotic exposure has the capacity to affect the positivity rate and microbiologic profile of urine cultures, due to the retrospective nature of the analysis, it was not possible to ascertain whether the patients had previously used antibiotics. Secondly, the contamination of infant faeces is a matter that requires resolution, given its direct impact on the detection of pathogenic bacteria in urine cultures. Furthermore, it should be noted that not all hospitals employ precisely the same testing methods (due to a lack of personnel, equipment, facilities, and/or methodology), which may have an impact on the results.

Conclusion

In the contemporary context of Southwest China, the epidemiology of paediatric urinary tract infections is characterised by a predominance of *Escherichia coli*, followed by *Enterococcus faecium* and *Enterococcus faecalis*. There is an observed rise in infections with multidrug-resistant organisms, underscoring the necessity for a focused investigation of CRE and VRE. Clinicians are advised to send urine specimens for microbial culture as early as possible, develop treatment strategies based on the drug sensitivity results, and isolate patients with isolation of multidrug-resistant bacteria to prevent the spread of MDR within the hospital. In order to facilitate a more profound comprehension of the molecular epidemiological characteristics of multidrug-resistant bacteria in the region, it is recommended that the changes of drug-resistant gene profiles be monitored, thus enabling the tracking of clone/plasmid transmission in real time and the implementation of targeted interventions.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of Sichuan Provincial People's Hospital, University of Electronic Science and Technology of China, Chengdu, China (No. 2025788). The ethics committee waived the need for written informed consent provided by participants due to the retrospective nature of this study. Patients' anonymous information was provided from the microbiology hospital laboratory, which isolated the strains. The study completely followed the principles outlined in the Declaration of Helsinki.

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Disclosure

The authors report no conflicts of interest in this work.

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