

Original Article

Urinary tract infections among children under age 3: distribution of pathogens, evolution of antimicrobial resistance, and clinical implications

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Abstract: Objective: To investigate the distribution of pathogens causing urinary tract infections (UTIs) in children aged 3 years and younger, the changes in antimicrobial resistance, and the clinical significance of these findings. Methods: A retrospective analysis was conducted on 727 pediatric patients aged 3 years and younger who were admitted to the Guangxi Zhuang Autonomous Region Maternal and Child Health Hospital for UTIs between January 2021 and December 2023. The distribution of causative pathogens and trends in antimicrobial resistance patterns were investigated. Results: Among the 727 pediatric patients, 408 (56.12%) presented with fever, 23 (3.16%) exhibited irritative urinary tract symptoms, and 31 (4.26%) presented with atypical symptoms. Imaging studies revealed abnormalities in 130 children (17.88%). Urine culture isolated 220 Gram-positive bacterial strains (30.26%), 409 Gram-negative bacterial strains (56.26%), and 98 fungal strains (13.48%). In particular, resistance of *Enterococcus faecalis* to ampicillin, ciprofloxacin, and levofloxacin, as well as resistance of *Klebsiella pneumoniae* to ticarcillin/clavulanic acid, showed decreasing trends. Conclusion: The primary clinical symptom of UTIs in children aged 3 years and younger is fever, and the main causative pathogens are Gram-negative bacteria. Multidrug-resistant strains are primarily *Enterobacteriaceae* that produce extended-spectrum β -lactamases.

Keywords: Infants and young children, urinary tract infection, clinical characteristics, pathogenic bacteria, antimicrobial susceptibility testing, evolution of antimicrobial resistance

Introduction

Urinary tract infection (UTI) is one of the most common infectious diseases of the urinary tract in young children. UTI is defined as inflammation of the urinary tract due to abnormal proliferation of pathogens accompanied by invasion of the urinary tract mucosa or tissue [1]. Infants and young children do not usually exhibit typical urinary symptoms such as dysuria or frequency. Symptoms from other systems or systemic manifestations frequently occur, leading to misdiagnosis or delayed diagnosis. If not treated early, an infection can damage the renal parenchyma, which might lead to renal failure or urosepsis [2]. Therefore, early and precise diagnosis is crucial for providing effective antimicrobial treatment for pediatric UTI patients. Due to the absence of

usual clinical signs and symptoms of UTIs in infants and young children, diagnosis is usually laboratory-based [3]. The gold standard for the diagnosis of UTI is urine culture and the main clinical approach is antimicrobial therapy [4]. However, antibiotic abuse currently results in gradual pathogen resistance, which makes treatment increasingly difficult [5]. Consequently, investigating the distribution and drug resistance of pathogens in UTIs among infants and young children is of considerable value for guiding treatment. Research on UTIs in children aged 3 years and below is limited. Accordingly, this study analyzed the distribution of pathogens and changes in antimicrobial resistance among pediatric patients with positive urine cultures at the Guangxi Zhuang Autonomous Region Maternal and Child Health Hospital from 2021 to 2023, and examined their clinical sig-

nificance, with the aim of providing data to inform the development of clinical treatment.

Materials and methods

Baseline information

We conducted a retrospective analysis of 727 children aged 3 years and below with positive urine cultures at the Maternal and Child Health Care Hospital of Guangxi Zhuang Autonomous Region from January 2021 to December 2023 was conducted. Among them, 419 were male and 308 were female, with a mean age of 1.73 ± 0.11 years and a mean body mass index of 16.42 ± 0.43 kg/m². This study was approved by the Medical Ethics Committee of the Maternal and Child Health Care Hospital of Guangxi Zhuang Autonomous Region [No. (2025) 6-3]. The families of all pediatric patients signed informed consent forms. Inclusion criteria: ① Age ≤ 3 years; ② Presence of fever and/or urinary tract irritation symptoms (e.g., crying or resistance during urination, urinary frequency and urgency, interrupted urination); ③ Presence of atypical symptoms (e.g., restlessness, refusal to eat, vomiting, or other abnormal behaviors) in the absence of typical symptoms; ④ No use of immunosuppressants or glucocorticoids within the past 2 weeks. Exclusion criteria: Presence of ① malignant tumors; ② congenital diseases such as congenital heart disease or congenital adrenal hyperplasia; ③ immunodeficiency disorders; or ④ simultaneous isolation of multiple bacterial strains (indicating a high risk of contamination).

Clinical indicators

(1) UTI in infants and young children: UTI was diagnosed according to the diagnostic criteria outlined in the Evidence-Based Guidelines for Diagnosis and Treatment of UTI (2016) [6].

(2) Imaging examination: The Hitachi Aloka Hl-VISION Preirus color Doppler ultrasound system was used for ultrasound examination of the urinary system. Before the test, families were instructed to have the child withhold urine 2 hours prior to the examination. In addition, they were instructed to drink sufficient water to ensure bladder filling. For infants incapable

of deferring urination for two hours, bladder filling was assessed by monitoring urination intervals. Urine is usually formed 45 minutes post-feeding, and ultrasound can be performed at this time. Throughout the examination, the patient's position was changed depending on their condition, space availability, and clinical needs. To reduce bowel gas artifacts, the operator applied slight pressure on the probe while making circular counterclockwise or clockwise movements over the target area. The bladder, ureters, and kidneys were examined in a multi-angle, multi-dimensional, and multi-planar manner. Any abnormal findings encountered on the images were recorded.

(3) Pathogen identification and antimicrobial resistance analysis: Before the initiation of therapy, a midstream fresh urine specimen (10 mL) was collected from each pediatric patient. Collection was typically performed catheterization with parental consent. When consent was not given, micturition was induced by gently tapping the lower abdomen or massaging the lumbosacral area, discarding the first stream and collecting the midstream portion. Specimens were submitted immediately for urine culture. If contamination was suspected, the results were re-evaluated, and collection of a repeat midstream urine sample was considered to reduce contamination rates. Pathogen identification and antimicrobial susceptibility testing were performed according to the National Clinical Laboratory Operating Procedures [7]. Interpretation of susceptibility results followed the CLSI M100 Ed31 guidelines [8]. Automated readings were supplemented by manual review to minimize errors. The Clinical Laboratory Center of the Ministry of Health provided quality control strains of *E. coli*, *P. aeruginosa*, and *S. aureus*, namely *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, and *Staphylococcus aureus* ATCC 29213.

Statistical analysis

SPSS 27.0 statistical software was used. Categorical variables were expressed as [n (%)]. Intergroup comparisons were performed using the chi-square test or Fisher's exact test. $P < 0.05$ was considered statistically significant.

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Table 1. Abnormal imaging findings

Imaging Finding	Cases	%
Right hydronephrosis	10	7.69
Right ureteral dilatation with hydronephrosis	5	3.85
Right ectopic kidney with hypoplasia, right ureteral abnormality	1	0.77
Left ureteral dilatation with hydronephrosis of the left kidney	18	13.85
Separation of the right renal pelvis	7	5.38
Separation of both renal pelvises	5	3.85
Separation of the left renal pelvis	22	16.92
Dilatation of the upper segment of the left ureter	9	6.92
J-tube attached to bladder wall	2	1.54
Left kidney enlargement	1	0.77
Right duplicated kidney	3	2.31
Left duplicated kidney	5	3.85
Bilateral ureteral dilatation throughout their entire length, bilateral hydronephrosis	2	1.54
Cyst at the left ureteric orifice	1	0.77
Mild hydronephrosis and dilatation of both renal pelvises and calyces	1	0.77
Hydronephrosis of the left kidney	3	2.31
Separate dilatation of the left renal pelvis and calyces	3	2.31
Polycystic kidney disease on the left side	1	0.77
Enlargement of both kidneys	1	0.77
Chronic kidney disease sonographic findings in both kidneys	2	1.54
Severe bilateral hydronephrosis	2	1.54
Vesicoureteral reflux	2	1.54
Left ureteral agenesis	1	0.77
Bilateral ureteral dilatation throughout their entire length	5	3.85
Mild hydronephrosis in both kidneys	9	6.92
Bladder diverticulum	1	0.77
Separation of the collecting system in the left kidney	5	3.85
Enlargement of both kidneys with increased parenchymal echogenicity	1	0.77
Cyst in the left kidney	1	0.77
Separation of the calyces in the right kidney	1	0.77
Total	130	100.00

Note: Percentages are calculated based on the total number of children with abnormal imaging findings (n=130). Double-J stent: a ureteral stent used to maintain patency of the ureter.

Results

UTIs in pediatric patients

Among the 727 pediatric patients, 408 (56.12%) presented with fever, 23 (3.16%) exhibited urinary tract irritation symptoms, and 31 (4.26%) demonstrated atypical symptoms.

Abnormal imaging findings in pediatric patients

Abnormal ultrasound findings in 727 pediatric patients are shown in **Table 1**. A total of 130

cases (17.88%) exhibited abnormalities, with the top three findings being left renal pelvic separation in 22 cases (16.92%), left ureteral dilatation with left hydronephrosis in 18 cases (13.85%), and right hydronephrosis in 10 cases (7.69%).

Distribution of pathogens

Among 727 pediatric patients with UTI, 220 Gram-positive bacteria (30.26%), 409 Gram-negative bacteria (56.26%), and 98 fungi (13.48%) were isolated. From 2021 to 2023, the numbers of isolates of *Enterococcus faeci-*

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Table 2. Distribution of pathogens by year [n (%)]

Pathogen	2021	2022	2023	Total
Gram-positive bacteria				220 (30.26)
<i>Enterococcus faecalis</i>	61 (36.75)	54 (32.53)	51 (30.72)	166 (22.83)
<i>Enterococcus faecium</i>	15 (35.71)	14 (33.33)	13 (30.95)	42 (5.78)
Others	5 (41.67)	5 (41.67)	2 (16.67)	12 (1.65)
Gram-negative bacteria				409 (56.26)
<i>Escherichia coli</i>	76 (34.86)	65 (29.82)	77 (35.32)	218 (29.99)
<i>Acinetobacter baumannii</i>	3 (18.75)	5 (31.25)	8 (50.00)	16 (2.20)
<i>Klebsiella pneumoniae</i>	21 (33.33)	16 (25.40)	26 (41.27)	63 (8.67)
<i>Pseudomonas aeruginosa</i>	10 (32.26)	8 (25.81)	13 (41.94)	31 (4.26)
<i>Enterobacter cloacae</i>	6 (35.29)	7 (41.18)	4 (23.53)	17 (2.34)
Others	21 (32.81)	22 (34.38)	21 (32.81)	64 (8.80)
Fungi				98 (13.48)
<i>Candida tropicalis</i>	5 (45.45)	2 (18.18)	4 (36.36)	11 (1.51)
<i>Candida albicans</i>	16 (27.12)	17 (28.81)	26 (44.07)	59 (8.12)
Others	6 (21.43)	7 (25.00)	15 (53.57)	28 (3.85)
Total	245 (33.70)	222 (30.54)	260 (35.76)	727 (100.00)

Note: n, number of cases; %, percentage of the total within each category or overall total. Percentages in each cell represent the proportion of isolates for that pathogen/year relative to the total isolates of that pathogen across all years. The "Others" category includes less common pathogens not listed individually.

Table 3. Annual resistance profiles of *Enterococcus faecium* [n (%)]

Antibiotic	Total (n=166)	2021 (n=61)	2022 (n=54)	2023 (n=51)	χ^2	P
Ampicillin	152 (91.57)	60 (98.36) ^a	46 (85.19) ^b	46 (90.20) ^{ab}	-	0.025*
Ciprofloxacin	112 (67.47)	51 (83.61) ^a	32 (60.38) ^b	29 (56.86) ^b	11.510	0.003
Erythromycin	1 (0.60)	0	1 (1.85)	0	-	0.633*
Linezolid	0	0	0	0	-	-
Levofloxacin	69 (41.57)	32 (52.46) ^a	23 (43.40) ^{ab}	14 (27.45) ^b	7.187	0.028
Minocycline	8 (4.82)	0	5 (9.26)	3 (5.88)	-	0.034*
Nitrofurantoin	34 (20.48)	17 (27.87)	10 (18.87)	7 (13.73)	3.601	0.165
Penicillin	164 (98.8)	61 (100.00)	53 (98.15)	50 (98.04)	-	0.532*
Rifampicin	138 (83.13)	48 (78.69)	46 (85.19)	44 (86.27)	1.380	0.501
Tetracycline	59 (35.54)	21 (34.43)	25 (47.17)	13 (25.49)	5.008	0.082
Vancomycin	0	0	0	0	-	-

Note: n, number of isolates; %, percentage of resistant isolates within each year/total; χ^2 , chi-square value; P, p-value; * indicates Fisher's exact test was used. Different superscript letters (a, b) within the same row indicate significant differences between groups (P < 0.05). The dash (-) indicates that the chi-square test was not applicable due to low expected frequencies.

um, *Enterococcus faecalis*, *Escherichia coli*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Candida tropicalis*, and *Candida albicans* were 166 (22.83%), 42 (5.78%), 218 (29.99%), 16 (2.20%), 63 (8.67%), 31 (4.26%), 17 (2.34%), 11 (1.51%), and 59 (8.12%), respectively. The distribution of pathogens by year is shown in **Table 2**.

Key gram-positive bacteria antimicrobial resistance testing results

Antibiotic susceptibility testing revealed that the top three antibiotics to which *Enterococcus faecium* exhibited resistance were penicillin, ampicillin, and rifampicin. Among these, resistance to penicillin and rifampicin showed no significant difference between 2021 and

Table 4. Annual antimicrobial resistance profiles of *Enterococcus faecalis* [n (%)]

Antibiotic	Total (n=42)	2021 (n=15)	2022 (n=14)	2023 (n=13)	χ^2	P
Ampicillin	3 (7.14)	1 (6.67)	2 (14.29)	0	-	0.634*
Ciprofloxacin	4 (9.52)	0	2 (14.29)	2 (16.67)	-	0.366*
Erythromycin	1 (2.38)	0	0	1 (7.69)	-	0.310*
Linezolid	0	0	0	0	-	-
Levofloxacin	4 (9.52)	0	2 (14.29)	2 (16.67)	-	0.366*
Minocycline	11 (26.19)	5 (33.33)	2 (14.29)	4 (30.77)	-	0.461*
Nitrofurantoin	1 (2.38)	0	1 (7.14)	0	-	0.643*
Penicillin	3 (7.14)	0	3 (21.43)	0	-	0.057*
Rifampicin	20 (47.62)	6 (40.00)	6 (42.86)	8 (61.54)	1.486	0.476
Tetracycline	34 (80.95)	13 (92.86)	12 (85.71)	9 (75.00)	-	0.546*
Vancomycin	0	0	0	0	-	-

Note: n, number of isolates; %, percentage of resistant isolates within each year/total; χ^2 , chi-square value; P, p-value; * indicates Fisher's exact test was used. The dash (-) indicates that the chi-square test was not applicable due to low expected frequencies.

2023 ($P > 0.05$); however, in 2022, *Enterococcus faecium* resistance to ampicillin was significantly lower than in 2021 ($P < 0.05$), but showed no significant difference compared to 2023 ($P > 0.05$). Additionally, *Enterococcus faecium* resistance to ciprofloxacin decreased annually, being significantly higher in 2021 than in 2022 or 2023 ($P < 0.05$). Resistance to levofloxacin also decreased annually, being significantly lower in 2023 than in 2021 ($P < 0.05$). The top three antibiotics for resistance in *Enterococcus faecalis* were tetracycline, rifampicin, and minocycline, with no significant differences in resistance rates across years ($P > 0.05$) (Tables 3, 4).

Gram-negative bacteria antimicrobial resistance test results

Antibiotic susceptibility testing revealed that the top three antibiotics for which *Escherichia coli* exhibited resistance were ampicillin, cotrimoxazole, and cefuroxime. However, no significant differences in *Escherichia coli* resistance patterns were observed between 2021 and 2023 ($P > 0.05$). For *Klebsiella pneumoniae*, the top three antibiotics with resistance were cefuroxime, ampicillin/sulbactam, and co-trimoxazole. Additionally, *Klebsiella pneumoniae* resistance to ticarcillin/clavulanic acid showed a decreasing trend from 2021 to 2023, with 2023 resistance rates significantly lower than 2021 ($P < 0.05$). Resistance to ampicillin alone was detected in only 15 cases in 2021, with no cases identified in 2022 or 2023, indi-

cating a significant intergroup difference ($P < 0.05$) (Tables 5, 6).

Fungal resistance testing results

Antimicrobial susceptibility testing revealed that the top three drugs to which *Candida albicans* exhibited resistance were itraconazole, voriconazole, and fluconazole; however, there were no significant differences in resistance patterns between 2021 and 2023 ($P > 0.05$) (Table 7).

Detection of multidrug-resistant strains

From 2021 to 2023, a total of 116 multidrug-resistant strains were detected. Among these, the highest detection rate was observed for *Enterobacteriaceae* strains producing extended-spectrum β -lactamases (ESBLs) at 90.52%. The detection rate showed an upward trend over time, with the 2023 rate significantly higher than that of 2021 ($P < 0.05$) (Table 8).

Discussion

UTI is a bacterial infection causing inflammation of the urinary system. Urine culture is often used for the diagnosis of UTI, but urine collection from infants and children can be challenging [9]. Also, their clinical signs can often be atypical, making diagnosis difficult [10]. For effective guidance of clinical diagnosis and treatment, it is important to know the clinical characteristics of UTIs in infants and young

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Table 5. Annual antimicrobial resistance profiles of *Escherichia coli* [n (%)]

Antibiotic	Total (n=218)	2021 (n=76)	2022 (n=65)	2023 (n=77)	χ^2	P
Amikacin	2 (0.92)	0	0	2 (2.67)	-	0.332*
Ampicillin	184 (84.4)	65 (85.53)	54 (83.08)	65 (86.67)	0.160	0.972
Aztreonam	0	0	0	0	-	-
Ceftazidime	51 (23.39)	18 (23.68)	15 (23.08)	18 (24.00)	0.007	0.996
Chloramphenicol	0	0	0	0	-	-
Ciprofloxacin	66 (30.28)	22 (28.95)	18 (27.69)	26 (34.67)	0.713	0.700
Ceftriaxone	99 (45.41)	32 (42.11)	31 (47.69)	36 (48.00)	0.527	0.768
Cefoperazone/Sulbactam	11 (5.05)	4 (5.26)	5 (7.69)	2 (2.67)	-	0.370*
Cefuroxime	102 (46.79)	32 (42.11)	32 (49.23)	38 (50.67)	1.028	0.598
Cefazolin	0	0	0	0	-	-
Cefepime	64 (29.36)	19 (27.14)	21 (35.00)	24 (36.92)	1.090	0.580
Cefoxitin	17 (7.80)	6 (7.89)	5 (7.69)	6 (8.00)	0.002	0.999
Gentamicin	54 (24.77)	16 (21.05)	18 (27.69)	20 (26.67)	0.921	0.631
Imipenem	3 (1.38)	2 (2.63)	1 (1.54)	0	-	0.406*
Levofloxacin	55 (25.23)	14 (18.42)	17 (26.15)	24 (32.00)	3.337	0.189
Meropenem	3 (1.38)	2 (2.63)	1 (1.54)	0	-	0.406*
Minocycline	6 (2.75)	3 (3.95)	1 (1.54)	2 (2.67)	-	0.778*
Nitrofurantoin	2 (0.92)	0	0	2 (2.67)	-	0.332*
Norfloxacin	0	0	0	0	-	-
Piperacillin	0	0	0	0	-	-
Polymyxin B	0	0	0	0	-	-
Ampicillin/Sulbactam	63 (28.90)	21 (27.63)	24 (36.92)	18 (24.00)	3.239	0.198
Sulfamethoxazole/Trimethoprim	127 (58.26)	44 (57.89)	41 (63.08)	42 (56.00)	1.061	0.588
Ticarcillin/Clavulanate	31 (14.22)	10 (13.16)	13 (20.00)	9 (12.00)	2.160	0.340
Tobramycin	0	0	0	0	-	-
Piperacillin/Tazobactam	9 (4.13)	3 (3.95)	2 (3.08)	4 (5.33)	-	0.913*

Note: n, number of isolates; %, percentage of resistant isolates within each year/total; χ^2 , chi-square value; P, p-value; * indicates Fisher's exact test was used. The dash (-) indicates that the chi-square test was not applicable due to low expected frequencies.

children and the distribution of bacteria. A study shows that fever alone is typically seen in infants and young children with UTI [11]. Our results are consistent with this observation, as 408 out of 727 pediatric patients (56.12%) presented with fever. A urinary system ultrasound is a non-invasive imaging examination commonly used to visualize the anatomical status and abnormalities of the urinary system such as stones, tumors, and malformations [12]. The results of this study show that among children with UTIs, 130 had urinary tract malformations, with the most common being left-sided ureteral dilatation with left-sided hydronephrosis and left-sided renal pelvis separation. Hydronephrosis affects the renal parenchyma, immune cell function, and blood circulation in infants and children. This ulti-

mately weakens the child's ability to clear pathogens from the kidneys [13]. Left hydronephrosis is obstructive fluid accumulation in the kidney that impedes urinary flow. Such conditions can cause infection of the renal pelvis, ureter, and bladder, with pyelonephritis being the most common [14]. The reduced muscular tone and peristalsis of dilated ureters fail to clear pathogens from the urinary tract, increasing the likelihood of UTI [15]. Urinary retention promotes ascending bacterial infection, which can lead to pyelonephritis. The complication of obstruction during ureteral dilatation leads to mucosal edema, which promotes bacterial colonization followed by ureteritis [16, 17]. Left-sided hydronephrosis typically occurs due to obstruction of the left urinary tract, causing urine drainage blockage and accumulation in

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Table 6. Annual resistance patterns of *Klebsiella pneumoniae* [n (%)]

Antibiotic	Total (n=63)	2021 (n=21)	2022 (n=16)	2023 (n=26)	χ^2	P
Amikacin	1 (1.59)	1 (4.76)	0	0	-	0.587*
Ampicillin	15 (23.81)	15 (71.43)	0	0	39.375	0.001
Aztreonam	0	0	0	0	-	-
Ceftazidime	24 (38.10)	11 (52.38)	7 (43.75)	6 (23.08)	4.521	0.104
Chloramphenicol	0	0	0	0	-	-
Ciprofloxacin	10 (15.87)	3 (14.29)	2 (12.50)	5 (19.23)	-	0.829*
Ceftriaxone	27 (42.86)	12 (57.14)	7 (43.75)	8 (30.77)	3.306	0.191
Cefoperazone/Sulbactam	13 (20.63)	6 (28.57)	2 (12.50)	5 (19.23)	-	0.491*
Cefuroxime	33 (52.38)	13 (61.9)	8 (50.00)	12 (46.15)	1.204	0.548
Cefazolin	1 (1.59)	1 (4.76)	0	0	-	0.587*
Cefepime	19 (30.16)	9 (42.86)	6 (37.50)	4 (15.38)	-	0.089*
Cefoxitin	15 (23.81)	5 (23.81)	4 (25.00)	6 (23.08)	-	1.000*
Gentamicin	8 (12.70)	3 (14.29)	1 (6.25)	5 (19.23)	-	0.534*
Imipenem	2 (3.17)	1 (4.76)	1 (6.25)	0	-	0.507*
Levofloxacin	9 (14.29)	3 (14.29)	2 (12.50)	4 (15.38)	-	1.000*
Meropenem	2 (3.17)	1 (4.76)	1 (6.25)	0	-	0.507*
Minocycline	4 (6.35)	2 (9.52)	1 (6.25)	1 (3.85)	-	0.817*
Nitrofurantoin	8 (12.70)	1 (4.76)	2 (12.50)	5 (19.23)	-	0.345*
Norfloxacin	0	0	0	0	-	-
Piperacillin	0	0	0	0	-	-
Polymyxin B	2 (3.17)	0	2 (12.50)	0	-	0.061*
Ampicillin/Sulbactam	30 (47.62)	13 (61.90)	8 (50.00)	9 (34.62)	3.517	0.172
Sulfamethoxazole/Trimethoprim	29 (46.03)	13 (61.90)	6 (37.50)	10 (38.46)	3.198	0.202
Ticarillin/Clavulanate	26 (41.27)	13 (61.90) ^a	7 (43.75) ^{a,b}	6 (23.08) ^b	7.280	0.026
Tobramycin	0	0	0	0	-	-
Piperacillin/Tazobactam	10 (15.87)	3 (14.29)	4 (25.00)	3 (11.54)	-	0.519*

Note: n, number of isolates; %, percentage of resistant isolates within each year/total; χ^2 , chi-square value; P, p-value; * indicates Fisher's exact test was used. The dash (-) indicates that the chi-square test was not applicable due to low expected frequencies. Different superscript letters (a, b) within the same row indicate significant differences between groups (P < 0.05).

Table 7. Annual antifungal resistance profiles of *Candida albicans* [n (%)]

Antimicrobial Agent	Total (n=65)	2021 (n=14)	2022 (n=27)	2023 (n=24)	P
Amphotericin B	0	0	0	0	-
Flucytosine	4 (6.15)	0	2 (7.41)	2 (8.33)	0.672
Fluconazole	16 (24.62)	4 (28.57)	6 (22.22)	6 (25.00)	0.933
Itraconazole	26 (40.00)	5 (35.71)	12 (44.44)	9 (37.50)	0.848
Voriconazole	19 (29.23)	5 (35.71)	7 (25.93)	7 (29.17)	0.833

Note: Fisher's exact test was used for all comparisons. The dash (-) indicates that the p-value was not calculated due to zero resistance across all years. P values represent comparisons of resistance rates across the three years.

the renal pelvis. This could lead to pyelonephritis and increased UTI risk [18].

Research suggests that the distribution of pathogens causing pediatric UTI varies by region, with significant differences in commonly used antibiotics and antimicrobial resistance

patterns [19]. Out of 727 isolated pathogens, the most abundant were Gram-negative bacteria (predominantly *Escherichia coli*) followed by Gram-positive bacteria (*Enterococcus faecalis*). Ascending infection, through which *E. coli* enters the urethra and bladder through the urethral opening, causes UTI [20, 21]. Due

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Table 8. Detection rates of multidrug-resistant strains by year [n (%)]

	Total (n=116)	2021 (n=41)	2022 (n=36)	2023 (n=39)	P
CRE	8 (6.90)	5 (12.20)	3 (8.33)	0	0.075
ESBLs	105 (90.52)	34 (82.92) ^a	32 (88.89) ^{a,b}	39 (100.00) ^b	0.017
MRSA	3 (2.58)	2 (4.88)	1 (2.77)	0	0.527

Note: Fisher's exact test was used in all cases. Different superscript letters (a, b) within the same row indicate significant differences between groups ($P < 0.05$). n, number of multidrug-resistant strains; %, percentage within each year/total; CRE, Carbapenem-resistant Enterobacteriaceae; ESBLs, Extended-spectrum β -lactamases; MRSA, Methicillin-resistant *Staphylococcus aureus*.

to insufficient immune function in infants and young children, the balance of *Enterococcus faecalis* can be disrupted, allowing it to invade other tissues and cause UTI [22]. Fungi may cross the mucosal barrier of the urinary tract during immunosuppression, leading to UTI. The study showed that among Gram-positive bacteria, *Enterococcus faecalis* was sensitive to erythromycin, linezolid, and vancomycin, and *Enterococcus faecium* was sensitive to erythromycin, linezolid, nitrofurantoin, and vancomycin. Among Gram-negative bacteria, *Escherichia coli* exhibited sensitivity to amikacin, chloramphenicol, cefazolin, norfloxacin, piperacillin, polymyxin B, and tobramycin, while *Klebsiella pneumoniae* showed sensitivity to amikacin, chloramphenicol, norfloxacin, piperacillin, and tobramycin. Among fungi, *Candida albicans* and *Candida parapsilosis* are both susceptible to amphotericin B, while *Candida parapsilosis* also exhibits susceptibility to flucytosine. These findings may help clinicians select appropriate therapeutic agents based on the etiology and imaging features of UTI in children.

This study examined the antimicrobial resistance patterns of *Enterococcus faecalis* and *Klebsiella pneumoniae*. In 2022, *Enterococcus faecalis* was significantly less resistant to ampicillin than in 2021 ($P < 0.05$). Resistance of *Enterococcus faecalis* to ciprofloxacin declined annually, with significantly higher resistance in 2021 than in 2022 and 2023 ($P < 0.05$). Annual resistance to levofloxacin also decreased, with lower levels in 2023 than in 2021 ($P < 0.05$). The resistance of *Klebsiella pneumoniae* to ticarcillin/clavulanic acid decreased between 2021 and 2023, with 2023 resistance significantly lower than 2021 ($P < 0.05$). Nevertheless, resistance to ampicillin monotherapy was detected in only 15 cases in

2021, with none detected in 2022 or 2023. Furthermore, this study identified ESBL-producing *Enterobacteriaceae* as the most common multidrug-resistant strain in pediatric UTI. ESBL-producing strains are resistant variants derived from normal flora. Illnesses cause a decline in host immunity, which disrupts the intestinal microbiota and leads to endogenous infections [23].

The most common clinical sign of UTI in children under 3 years old is fever. The most likely causative pathogens are gram-negative bacteria. One frequently involved pathogen, *Escherichia coli*, exhibits high resistance to ampicillin, co-trimoxazole, and cefuroxime. Most multidrug-resistant strains belong to ESBL-producing *Enterobacteriaceae*. Clinicians should make a prompt diagnosis based on the child's clinical symptoms and imaging findings, and select early appropriate antimicrobial therapy based on pathogen identification and susceptibility testing to improve outcomes. This study was conducted at a single center, which may have limited how applicable the results are to other settings. Additionally, the study did not examine how factors like age and gender affect infection rates or pathogen distribution; it also did not identify the specific strains of ESBL-producing *Enterobacteriaceae* or test the resistance genotypes of these strains. As a result, the analysis of resistance mechanisms was not detailed enough. Future research should improve the study design to enable a more comprehensive investigation.

Conclusion

In children under 3 years of age, fever is the most common clinical presentation of UTI. The main causative pathogens are Gram-negative bacteria, mainly *Escherichia coli*. The main mul-

tidrug-resistant strains are ESBL-producing Enterobacteriaceae.

Disclosure of conflict of interest

None.

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