ORIGINAL ARTICLE

Frequency and Antimicrobial Susceptibility Patterns of ESBL-Producing Uropathogens in Culture-Confirmed Pediatric Urinary Tract Infections

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ABSTRACT

Objective: To determine the frequency of extended-spectrum beta-lactamase (ESBL) producing Enterobacteriaceae isolated from culture-confirmed pediatric urinary tract infections and to evaluate their antimicrobial susceptibility patterns according to age and sex.

Study Design: Analytical cross-sectional study employing consecutive sampling.

Place and Duration of Study: Holy Family Hospital, Department of Pediatrics from 1st April 2023 to 1st April 2024.

Materials and Methods: Children aged 1 month to 12 years with clinical features of urinary tract infection and a positive urine culture were recruited. Urine specimens were processed for bacterial identification, antimicrobial susceptibility testing and confirmation of ESBL production. Age, sex, isolated organism, ESBL status and antimicrobial susceptibility findings were recorded and analyzed.

Results: Among 384 children, 236 (61.5%) were female and 148 (38.5%) were male. *Escherichia Coli* was the most frequently isolated organism, accounting for 284 (74.0%) cases, followed by *Klebsiella Pneumoniae* in 62 (16.1%) cases. Of 346 *Enterobacteriaceae* isolates, 208 (60.1%) produced ESBL. ESBL production was detected in 162 (57.0%) *Escherichia coli* isolates and 46 (74.2%) *Klebsiella pneumoniae* isolates. Infections were more frequent among children aged 1 month to <5 years and among females. Resistance was highest to ampicillin, co-amoxiclav and ciprofloxacin, whereas meropenem and fosfomycin retained complete antimicrobial activity.

Conclusion: Extended-spectrum beta-lactamase producing *Enterobacteriaceae* were common among children with urinary tract infections, particularly in younger children and females. The high resistance to commonly prescribed antibiotics supports regular antimicrobial surveillance and culture guided treatment. Routine urine culture and antimicrobial susceptibility testing should be encouraged before initiation of definitive therapy to optimize antibiotic stewardship.

Key Words: *Antibiotic Resistance, Child, Enterobacteriaceae, Escherichia Coli, Klebsiella Pneumoniae, Urinary Tract Infection*.

Introduction

Recurrent urinary tract infection remains an important concern in children because repeated episodes may lead to additional investigations, prolonged treatment and increased antimicrobial exposure. Non antibiotic preventive measures have been evaluated, although the available evidence does not support the routine use of a single intervention for all children.[1] Antibiotic prophylaxis is still used in selected patients, however its benefit must be balanced against the increased likelihood of infection with resistant uropathogens.[2] Management is particularly complex in children with primary vesicoureteric reflux, for whom conservative and surgical approaches may be considered according to clinical severity.[3] Long term antibiotic prophylaxis may reduce recurrence in some children, but its overall benefit is modest and prolonged exposure may contribute to antimicrobial resistance.[4]

Escherichia Coli is the predominant organism isolated from pediatric urinary tract infections, while *Klebsiella pneumoniae* is also frequently identified, particularly among infections caused by extended-spectrum beta-lactamase (ESBL) producing organisms.[5] Studies conducted in different clinical settings have similarly shown *E. coli* to be the leading

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urinary pathogen and have documented substantial resistance to commonly prescribed antimicrobial agents.[6] ESBL production further complicates treatment because it reduces susceptibility to penicillins, extended spectrum cephalosporins and monobactams and may coexist with resistance to other antibiotic classes. A recent review highlighted the growing clinical and public health importance of ESBL producing uropathogens in children, including restricted treatment options, delayed effective therapy and the potential spread of multidrug resistant organisms. [7]

Antimicrobial resistance among urinary *E. coli* isolates in children has been associated with previous antibiotic exposure, emphasizing the need for careful empirical prescribing and timely culture based treatment.[8] Concerns regarding resistance have also encouraged investigation of non antibiotic approaches for preventing recurrent urinary tract infection, although their role in pediatric practice remains incompletely established.[1,9]

Limited data are available in Pakistan regarding Enterobacteriaceae causing urinary tract infections in the pediatric population and their antimicrobial susceptibility patterns. This study is particularly relevant in the context of UTIs, where inappropriate or excessive antibiotic use contributes to rising resistance rates. Given the limited local data on pediatric ESBL infections, the rationale of the study was to provide evidence based insights to help pediatricians select appropriate antibiotics, reduce resistance development and improve treatment outcomes in children under 12 years of age. Additionally, by identifying age and gender specific trends, the study can inform targeted infection control and preventive strategies, ultimately improving pediatric healthcare management in tertiary care settings. The objective of this study was to determine the frequency of ESBL-producing Enterobacteriaceae isolated from culture-confirmed pediatric urinary tract infections and to evaluate their antimicrobial susceptibility patterns according to age and sex.

Materials and Methods

An analytical cross-sectional study employing non probability consecutive sampling was conducted in the Holy Family Hospital Department of Pediatrics, Rawalpindi from 1st April 2023 to 1st April 2024. Children aged 1 month to 12 years presenting with clinically suspected urinary tract infection and culture confirmed urinary tract infection were enrolled. Ethical approval was obtained from the Institutional Research and Ethics Forum of Rawalpindi Medical University through Letter No. 307/IREF/RMU/2022, dated 12 February 2022. Written informed consent was obtained from the parent of each child before enrolment.

The sample size was calculated using OpenEpi version 3.01, assuming a 95% confidence level, 5% absolute precision, and an anticipated prevalence of 49.3% for ESBL-producing uropathogens among children hospitalized with urinary tract infection, as reported by Koçak et al., yielding a calculated sample size of 384 participants.[10]

Clinically suspected urinary tract infection was defined by the presence of fever without an identifiable alternative focus or at least one age-appropriate urinary symptom. In infants and younger children, relevant features included fever, poor feeding, vomiting, irritability or failure to thrive. In older children, clinical features included dysuria, increased urinary frequency, urgency, suprapubic or abdominal pain, flank pain or new onset urinary incontinence. Children were included when they had compatible clinical features and a culture confirmed urinary tract infection. Children who had received antibiotics during the preceding two weeks, had contaminated or insignificant urine cultures or had urine collected using a collection bag were excluded. Urine specimens were obtained according to the child's age, toilet training status and clinical condition through midstream clean catch collection or urethral catheterization.

Specimens were transported to the microbiology laboratory within one hour of collection. In the laboratory, each urine specimen was mixed thoroughly and a 2-µL aliquot was inoculated onto cystine lactose electrolyte deficient (CLED) agar using a sterile calibrated 2-µL inoculating loop. The inoculated plates were incubated aerobically at 35–37°C for 18–24 hours. Following incubation, colonies were counted and multiplied by 500 to express the bacterial concentration as colony forming units per millilitre (CFU/mL). Colony growth and colony morphology were also assessed. Significant bacterial growth was defined as the

isolation of a single uropathogen at a concentration of at least 10^5 CFU/mL in a midstream clean catch specimen or at least 10^4 CFU/mL in a catheter obtained specimen. Following confirmation of significant bacterial growth, representative pure colonies were subjected to preliminary identification based on colony morphology and Gram staining.

Enterobacterales isolates were identified using the API 20E identification system, whereas non fermenting Gram negative isolates were identified using the API 20NE identification system, according to the manufacturer's instructions. Antimicrobial susceptibility testing of the identified isolates was performed using the Kirby–Bauer disk-diffusion method on Mueller–Hinton agar in accordance with Clinical and Laboratory Standards Institute disk diffusion procedures. Inhibition-zone diameters were measured and interpreted according to the Clinical and Laboratory Standards Institute Performance Standards for Antimicrobial Susceptibility Testing, 33rd edition (CLSI M100, 2023). ESBL production in *Escherichia coli* and *Klebsiella pneumoniae* isolates was assessed using the combination disk method. Ceftazidime and cefotaxime disks were tested alone and in combination with clavulanic acid. An increase of at least 5 mm in the inhibition zone diameter around either antimicrobial disk combined with clavulanic acid, compared with the corresponding disk without clavulanic acid was interpreted as confirmation of ESBL production.[11]

Clinical information was obtained from the patient's history and medical record. Following completion of urine culture, bacterial identification and antimicrobial susceptibility testing, the principal investigator manually entered the clinical and microbiological findings into a structured data collection proforma. Recorded variables included age, sex, presenting clinical features, method of urine collection, isolated organism, ESBL status and antimicrobial susceptibility results.

Data were analyzed using SPSS version 26. Continuous variables were presented as mean and standard deviation or median and interquartile range, as appropriate. Categorical variables were summarized as frequencies and percentages. The overall distribution of cultured organisms was compared between females and males using Pearson's Chi-square test. Age group distributions were compared between sexes separately for *Escherichia coli* and *Klebsiella pneumoniae* isolates. ESBL-production was compared between the two bacterial species. Pearson's Chi-square test was used when its assumptions were satisfied, while Fisher's exact test or the Fisher–Freeman–Halton exact test was used when expected cell frequencies were inadequate. All statistical tests were two sided. A p value of <0.05 was considered statistically significant. These analyses were unadjusted bivariate comparisons, and no multivariable regression model was fitted

Results

Our study enrolled a total of 384 children with culture confirmed urinary tract infections. Of these, 236 (61.5%) were female and 148 (38.5%) were male. The mean age was 6.4±5.3 years, with participants ranging from 1 month to 12 years. Because ESBL testing and organism-specific antimicrobial resistance analyses focused on *Escherichia coli* and *Klebsiella pneumoniae,* these analyses included 346 isolates.

Escherichia coli was the predominant cultured organism, accounting for 284 (74.0%) isolates, followed by *Klebsiella pneumoniae* with 62 (16.1%) isolates. The remaining 38 (9.9%) were other Gram-negative isolates. The overall distribution of organism categories differed between females and males (p=0.028). (Table I)

Resistance to commonly prescribed antimicrobial agents was high in both major bacterial species. Among *E. coli* isolates, resistance was highest against ampicillin (253/284, 89%), co-amoxiclav (239/284, 84%), and ciprofloxacin (230/284, 81%). The corresponding resistant counts among *K. pneumoniae* isolates were 59/62 (95%), 56/62 (91%), and 52/62 (84%), respectively. No resistance to meropenem or fosfomycin was recorded in either organism (Table II).

Among the 346 *Escherichia coli* and *Klebsiella pneumoniae* isolates, 181 (52.3%) were recovered from children aged 1 month to <5 years, 86 (24.9%) from children aged 5 to <9 years, and 79 (22.8%) from children aged 9 to 12 years.

The age distribution of *Escherichia coli* isolates differed between females and males (p = 0.006). No difference in the age distribution of *Klebsiella*

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pneumoniae isolates was observed between the sexes (p = 0.609). When both bacterial species were considered together, their distribution across age categories differed according to sex (p = 0.016). (Table III).

Overall, 208 of the 346 isolates (60.1%) were ESBL-positive. ESBL production was detected in 162 of 284 (57.0%) *Escherichia coli* isolates and 46 of 62 (74.2%) *Klebsiella pneumoniae* isolates. The proportion of ESBL-positive isolates differed significantly between the two bacterial species (p = 0.012; Table IV).

Table I: Distribution Of Cultured Uropathogens According To Sex (n=384)

Organism	Females: n(%) (n=236)	Males:n(%) (n=148)	Total :n(%)	*P* value
Escherichia coli	183 (77.5)	101 (68.2)	284(74)	
Klebsiella pneumoniae	37 (15.6)	25 (16.8)	62(16.1)	
Other Gram-negative organisms	16(6.8)	22(14.9)	38(9.9)	
Total	236(100)	148(100)	384(100)	0.028

Pearson's chi-square test was used to compare the overall distribution of cultured organism categories between females and males. The reported P value represents the overall three category comparison

Table II: Antibiotic Resistance Patterns Of *Escherichia Coli* And *Klebsiella Pneumoniae* Isolates

Antibiotic	*Escherichia coli Resistance*: n(%), (n=284)	*Klebsiella pneumoniae* Resistance: n(%), (n=62)
Amikacin	26 (9)	7 (11)
Ampicillin	253 (89)	59 (95)
Cefixime	111 (39)	17 (27)
Ceftazidime	162 (57)	46 (74)
Ceftriaxone	88 (31)	33 (53)
Ciprofloxacin	230 (81)	52 (84)
Co-Amoxiclav	239 (84)	56 (91)
Co-Trimoxazole	196 (69)	54 (87)
Fosfomycin	0 (0)	0 (0)
Gentamicin	102 (36)	25 (41)
Meropenem	0 (0)	0 (0)
Nitrofurantoin	82 (29)	43 (69)
Piperacillin–Tazobactam	31 (11)	19 (31)

Discussion

This study demonstrated a high burden of ESBL production and resistance to commonly prescribed antibiotics among pediatric uropathogens. Although

Table III :*Escherichia coli* and *Klebsiella pneumoniae* distribution by age group and sex (n = 346)

Organism	Female: 1 month to <5 years, n (%)	Female: 5 to <9 years, n (%)	Female: 9 to 12 years, n (%)	Male: 1 month to <5 years, n (%)	Male: 5 to <9 years, n (%)	Male: 9 to 12 years, n (%)	p-value
Escherichia coli	82 (44.8)	45 (24.6)	56 (30.6)	64 (63.4)	21 (20.8)	16 (15.8)	0.006
Klebsiella pneumoniae	21 (56.8)	13 (35.1)	3 (8.1)	14 (56.0)	7 (28.0)	4 (16.0)	0.609
Both organisms	**103 (46.8)**	**58 (26.4)**	**59 (26.8)**	**78 (61.9)**	**28 (22.2)**	**20 (15.9)**	**0.016**

Percentages were calculated across age categories within each organism-and-sex group. Pearson's chi-square test was used for the E. coli and combined comparisons. The Fisher-Freeman-Halton exact test was used for K. pneumoniae because of small expected cell frequencies. All p-values are two-sided

Table IV: ESBL production in *Escherichia coli and Klebsiella pneumoniae* isolates (n = 346)

Organism	Total Isolated Organisms	ESBL-positive n (%)	Non-ESBL n (%)	P value
Escherichia coli	284	162 (57%)	122 (43%)	
Klebsiella pneumoniae	62	46 (74%)	16 (26%)	
Total	346	208 (60%)	138 (40%)	**0.012**

Footnote:Other gram-negative isolates (n = 38) such as *Pseudomonas spp*. were excluded from ESBL analysis. *Pearson's chi-square test was used to compare the proportion of ESBL-positive isolates between Escherichia coli and Klebsiella pneumoniae. ESBL: Extended spectrum beta-lactamase.*

E. coli remained the predominant organism, ESBL production was proportionally more frequent in *K. pneumoniae*. The marked resistance to commonly used oral agents highlights the importance of local antimicrobial surveillance and culture-directed treatment.

The female predominance observed in the current study is consistent with the established pattern of pediatric urinary tract infection beyond early infancy. Tamas et al. described a similar shift towards female predominance after infancy, while also identifying *E. coli* as the principal pediatric uropathogens.[12] A recent research from Karachi reported that 80% of culture positive children were female and that *E. coli* accounted for 73.9% of isolates, which is almost identical to the 74.0% observed in the present study.

However, *Klebsiella species* constituted only 6.5% of isolates in that study compared with 16.1% in the present series.[13] A nationwide study by Shkalim Zemer et al. also identified *E. coli* as the dominant organism, although its proportion of 82.1% was higher than ours.[14] These differences may reflect variation in referral patterns, participant age, urine collection methods and the proportion of children with complicated or recurrent infections. Lin et al. reported a male predominance among hospitalized children with *E. coli* urinary tract infection, but their patients had a median age of seven months.[15] The contrasting sex distribution may therefore be explained partly by their concentration on infants, among whom urinary tract infection is more frequently recognized in boys, whereas the present study included children up to 12 years of age.

Children aged 1 month to <5 years contributed more than half of the *E. coli* and *K. pneumoniae* isolates in the present study. This finding is compatible with the young age profile reported by Lin et al., whose participants had a median age of seven months.[15] Heshmat et al. similarly studied a predominantly young hospitalized population with a median age of 12 months.[16] Nevertheless, direct comparison requires caution because those investigators included febrile hospitalized children, whereas the present study included culture confirmed urinary tract infections across a broader pediatric age range.

The overall ESBL frequency of 60.1% was considerably higher than most recently published pediatric estimates. Among *E. coli* isolates, our ESBL proportion of 57.0% was close to the 53.6% reported by Lin et al. in hospitalized children with community acquired urinary tract infection.[15] In contrast, Abdelgalil et al. identified ESBL production in 20.7% of pediatric *E. coli* urinary isolates in Saudi Arabia.[17] Heshmat et al. reported ESBL production in 5.8% of *E. coli* and *K. pneumoniae* isolates,[16] while Rizik et al. found ESBL producing Enterobacterales in 9.8% of children with community acquired urinary tract infection.[18] Further pediatric studies reported frequencies of 14.1% in Taiwan and 19.0% among *E. coli* isolates in Romania.[19,20]

The higher frequency in the present study may reflect differences in local antibiotic pressure, tertiary care referral, prior healthcare exposure, underlying urinary abnormalities and regional circulation of resistant strains. Study definitions and laboratory methods may also influence the reported frequency. Children exposed to antibiotics more than two weeks before enrolment were not excluded from the present study and such earlier exposure was not analyzed separately. In addition, the research did not record recurrent infection, previous hospitalization or structural urinary tract disease, all of which may influence the likelihood of an ESBL producing infection. The significantly greater ESBL proportion in *K. pneumoniae* than in *E. coli* may also reflect species related resistance patterns or local hospital ecology. However, the smaller number of *K. pneumoniae* isolates and absence of molecular typing prevent conclusions regarding clonal transmission or a particular resistance mechanism.

Resistance to ampicillin and co-amoxiclav was high in both principal organisms. This pattern was consistent with the Karachi study, in which amoxicillin-clavulanate was the least active tested agent, although that study reported substantially greater ciprofloxacin susceptibility than the present study.[13] Pakistani data reported by Iqbal et al. also demonstrated extensive resistance among pediatric uropathogens, including resistance of 61% to amoxicillin-clavulanate, 94% to co-trimoxazole and 37% to gentamicin.[21] The gentamicin result was close to the 36% resistance in *E. coli* and 41% in *K. pneumoniae* observed in the present study, whereas the differences for the other agents indicate considerable variation even between centres within the same country.

Among ESBL producing *E. coli* isolates, Abdelgalil et al. reported resistance of 56% to quinolones and 64% to Trimethoprim-Sulfamethoxazole.[17] These values were lower than our ciprofloxacin resistance of 81% but close to the 69% co-trimoxazole resistance among *E. coli*. Their nitrofurantoin resistance of 8% was also lower than the 29% found in the present study. Rizik et al. reported resistance of 62.5% to amoxicillin-clavulanate, 58.9% to trimethoprim-sulfamethoxazole and 33.9% to ciprofloxacin among ESBL producing Enterobacterales, all lower than the corresponding findings in our population. Their piperacillin-tazobactam resistance of 26.8% was, however between the rates observed for *E. coli* and *K. pneumoniae* in the present study.[18]

The difference in nitrofurantoin resistance between

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E. coli and *K. pneumoniae* was substantial in the present study. Heshmat et al. reported a comparable organism specific pattern, with nitrofurantoin resistance of 15.7% in *E. coli* and 73.3% in *K. pneumoniae*.[16] Their *K. pneumoniae* finding was close to our rate of 69%, supporting the need to interpret nitrofurantoin susceptibility according to the isolated organism rather than treating all urinary Enterobacterales as a single group.

No resistance to meropenem or fosfomycin was observed in the present study. Abdelgalil et al. similarly reported no meropenem resistance among their pediatric ESBL producing *E. coli* isolates.[17] Păcurar et al. found complete susceptibility to fosfomycin and high susceptibility to carbapenems and amikacin among ESBL producing *E. coli*.[20] These findings are reassuring, but the preserved activity of these agents should not justify unrestricted empirical use. The absence of resistant isolates in a single centre sample does not exclude their presence in the wider population.

Previous antibiotic exposure and contact with urological services have been identified as independent risk factors for community acquired pediatric ESBL producing *E. coli* urinary tract infection.[22] These unmeasured factors may partly explain the high ESBL frequency in the present study. Choi et al. also documented a progressive increase in resistance among pediatric urinary isolates over a ten-year period, including a rise in ciprofloxacin resistance.[23] Their findings reinforce the importance of updating hospital antibiograms rather than depending on resistance estimates from other centres or earlier periods.

The high resistance to commonly prescribed oral agents in the present study makes empirical selection difficult. Culture and susceptibility testing should therefore guide definitive therapy whenever possible. Piperacillin-tazobactam retained greater activity than ampicillin, co-amoxiclav and ciprofloxacin, particularly against *E. coli*. Recent pediatric evidence suggests that it may have a role as a carbapenem sparing option in selected hospitalized children, although treatment must be individualised according to age, illness severity, infection site and susceptibility results.[24] Carbapenems should remain reserved for patients with severe infection or isolates for which narrower effective alternatives are unavailable.

The study has several strengths, including a relatively large sample of culture confirmed pediatric infections, organism specific resistance reporting and standard phenotypic assessment of ESBL production. However, its single centre design limits generalisability. Molecular characterisation of ESBL genes was not performed, and multivariable analysis was not undertaken. Information regarding antibiotic exposure occurring more than two weeks before enrolment was not collected; therefore, the possible association between earlier antimicrobial exposure and ESBL production could not be evaluated. Despite these limitations, the study demonstrates a substantial local burden of ESBL producing pediatric uropathogens and provides clinically relevant data for antimicrobial surveillance and culture directed treatment.

Conclusion

Extended-spectrum beta-lactamase producing Enterobacteriaceae were common among children with urinary tract infections, particularly in younger children and females. The high resistance to commonly prescribed antibiotics supports regular antimicrobial surveillance and culture guided treatment. Routine urine culture and antimicrobial susceptibility testing should be encouraged before initiation of definitive therapy to optimize antibiotic stewardship.

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REFERENCES

1. Meena J, Thomas CC, Kumar J, Raut S, Hari P. Non-antibiotic interventions for prevention of urinary tract infections in children: a systematic review and meta-analysis of randomized controlled trials. Eur J Pediatr. 2021;180(12): 3535-45. doi:10.1007/s00431-021-04091-2.
2. Selekman RE, Shapiro DJ, Boscardin WJ, Williams GJ, Craig JC, Brandström P, et al. Uropathogen resistance and antibiotic prophylaxis: a meta-analysis. Pediatrics. 2018;142(1):e20180119. doi:10.1542/peds.2018-0119.
3. Williams G, Hodson EM, Craig JC. Interventions for primary vesicoureteric reflux. Cochrane Database Syst Rev. 2019;2:CD001532. doi:10.1002/14651858.CD001532.pub5.
4. Williams G, Craig JC. Long-term antibiotics for preventing

recurrent urinary tract infection in children. Cochrane Database Syst Rev. 2019;4:CD001534. doi:10.1002/14651858.CD001534.pub4.
5. Balasubramanian S, Kuppuswamy D, Padmanabhan S, Chandramohan V, Amperayani S. Extended-spectrum beta-lactamase-producing community-acquired urinary tract infections in children: chart review of risk factors. J Glob Infect Dis. 2018;10(4):222-5. doi:10.4103/0974-777X.246391.
6. Alanazi MQ, Alqahtani FY, Aleanizy FS. An evaluation of *Escherichia coli* in urinary tract infection in the emergency department at KAMC in Riyadh, Saudi Arabia: a retrospective study. Ann Clin Microbiol Antimicrob. 2018;17(1):3. doi:10.1186/s12941-018-0255-z.
7. Ekpunobi NF, Ugwu MC, Agu KC, Chukwunwejim CR, Oghonyon EI, Ogunmola T, et al. Extended-spectrum beta-lactamase-producing uropathogens in pediatric urinary tract infections: molecular characteristics, clinical impact and public health consequences. J Adv Biol Biotechnol. 2025;28(9):691-709. doi:10.9734/jabb/2025/v28i92918.
8. Bryce A, Costelloe C, Wootton M, Butler CC, Hay AD. Comparison of risk factors for, and prevalence of, antibiotic resistance in contaminating and pathogenic urinary *Escherichia coli* in children in primary care: prospective cohort study. J Antimicrob Chemother. 2018;73(5):1359-67. doi:10.1093/jac/dkx525.
9. Sihra N, Goodman A, Zakri R, Sahai A, Malde S. Nonantibiotic prevention and management of recurrent urinary tract infection. Nat Rev Urol. 2018;15(12):750-76. doi:10.1038/s41585-018-0106-x.
10. Koçak M, Büyükkaragöz B, Çelebi Tayfur A, Çaltik A, Köksoy AY, Çizmeci Z, et al. Causative pathogens and antibiotic resistance in children hospitalized for urinary tract infection. Pediatr Int. 2016;58(6):467-71. doi:10.1111/ped.12842.
11. Clinical and Laboratory Standards Institute. *Performance standards for antimicrobial susceptibility testing*. 33rd ed. CLSI supplement M100. Wayne (PA): Clinical and Laboratory Standards Institute; 2023.
12. Tamas V, Ulloa ER, Kumaraswamy M, Dahesh S, Zurich R, Nizet V, et al. Extended-spectrum β-lactamase-producing *Escherichia coli* and pediatric urinary tract infections: a review of the literature and selected experimental observations. Antibiotics (Basel). 2025;14(12):1284. doi:10.3390/antibiotics14121284.
13. Khan MA, Shakeel N. Pediatric uropathogens and their antimicrobial susceptibility pattern: experience from an impoverished district of Karachi, Pakistan. Clin Med Insights Pediatr. 2024;18:11795565241254321. doi:10.1177/11795565241254321.
14. Shkalim Zemer V, Ashkenazi S, Levinsky Y, Richenberg Y, Jacobson E, Nathanson S, et al. Pathogens causing pediatric community-acquired urinary tract infections and their increasing antimicrobial resistance: a nationwide study. Pathogens. 2024;13(3):201. doi:10.3390/pathogens13030201.
15. Lin Y, Peng Q, Li W, Chen B. Analysis of antibiotic resistance and risk factors of extended-spectrum beta-lactamase-producing *Escherichia coli* in hospitalized children with community-acquired urinary tract infections. Int Urol Nephrol. 2025;57(7):2271-8. doi:10.1007/s11255-025-04417-1.
16. Heshmat H, Meheissen M, Farid A, Hamza E. Bacteremia and antimicrobial resistance pattern of uropathogens causing febrile urinary tract infection in a pediatric university hospital. Germs. 2023;13(3):210-20. doi:10.18683/germs.2023.1387.
17. Abdelgalil A, Saeedi F, Metwalli E, Almutairi F, Felemban M, Albaradei H, et al. Prevalence, risk factors and antibiotic resistance of extended-spectrum beta-lactamase-producing *Escherichia coli* in children hospitalized with urinary tract infection at King Abdulaziz University Hospital, Jeddah, Saudi Arabia. Children (Basel). 2024;11(11):1332. doi:10.3390/children11111332.
18. Rizik S, Kassis I, Nasrallah E, Makhoul N, Dabaja-Younis H. Prevalence, predictors, and cross-resistance of community-acquired extended-spectrum beta-lactamase-producing *Enterobacterales* in pediatric urinary tract infections in Israel. Clin Pediatr (Phila). 2024;63(12):1727-33. doi:10.1177/00099228241241932.
19. He XT, Chang CN, Yu CH, Wang CC. The risk factors, antimicrobial resistance patterns, and outcomes associated with extended-spectrum β-lactamase-producing pathogens in pediatric urinary tract infection. Pediatr Neonatol. 2024;65(3):242-8. doi:10.1016/j.pedneo.2023.04.021.
20. Păcurar D, Dinulescu A, Totu AV, Dijmărescu I, Pavelescu ML. *Escherichia coli* urinary tract infections from a Romanian pediatric hospital: antimicrobial resistance trends, ESBL prevalence, and empirical treatment implications. Antibiotics (Basel). 2025;14(9):855. doi:10.3390/antibiotics14090855.
21. Iqbal Z, Sheikh AS, Basheer A, Hafsa HT, Ahmed M, Sabri AN, et al. Antibiotic drug resistance pattern of uropathogens in pediatric patients in Pakistani population. Antibiotics (Basel). 2023;12(2):395. doi:10.3390/antibiotics12020395.
22. Collingwood JD, Wang L, Aban IB, Yarbrough AH, Boppana SB, Dangle PP. Risk factors for community-acquired pediatric urinary tract infection with extended-spectrum β-lactamase-producing *Escherichia coli*: a case-control study. J Pediatr Urol. 2023;19(1):129.e1-129.e7. doi:10.1016/j.jpurol.2022.10.020.
23. Choi U, Kim E, Lyu DH, Kim KS, Park BH, Chung H, et al. The change of antibiotic susceptibility in febrile urinary tract infection in childhood and adolescence during the last decade. Investig Clin Urol. 2022;63(1):99-106. doi:10.4111/icu.20210350.
24. Han KH, Oh MS, Ahn J, Lee J, Kim YW, Yoon YM, et al. Piperacillin-tazobactam versus cefotaxime as empiric treatment for febrile urinary tract infection in hospitalized children. Infect Chemother. 2024;56(2):266-75. doi:10.3947/ic.2024.0020.

CONFLICT OF INTEREST

Authors declared no conflicts of Interest.

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DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.