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Original Research Article

Analysis of Antibiotic Resistance Patterns in Escherichia coli Isolated from Pediatric Urinary Tract Infections

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Abstract:

Background: Urinary tract infections (UTIs) are common in the pediatric population, with Escherichia coli (E. coli) as the leading causative agent. Rising antibiotic resistance complicates treatment, emphasizing the need for local susceptibility data.

Aim: To analyze the antibiotic resistance patterns of E. coli isolated from pediatric UTIs.

Methodology: A cross-sectional observational study was conducted on 86 urine samples from pediatric patients (<18 years) with culture-confirmed E. coli infections at the Department of Microbiology, Madhubani Medical College and Hospital, Bihar, India from January 2023 to December 2023. Urine samples were processed using standard microbiological techniques, and antimicrobial susceptibility was determined by the Kirby-Bauer disk diffusion method following CLSI guidelines.

Results: E. coli accounted for 61.6% of isolates, followed by Klebsiella pneumoniae (13.5%) and Proteus mirabilis (9.1%). Children aged 12–60 months showed the highest infection burden. Ampicillin exhibited the highest resistance (70%), particularly in K. pneumoniae (100%) and E. coli (67.4%). Resistance to cephalosporins was variable, while aminoglycosides, carbapenems, and nitrofurantoin (for E. coli) retained relative efficacy.

Conclusion: UTI predominating in children is caused by E. coli, with high levels of beta-lactam resistance. Regular culture, susceptibility testing and focused empirical therapy are necessary, and ongoing antimicrobial monitoring to more effectively improve treatment outcomes.

Keywords: Antimicrobial Stewardship, Antibiotic Resistance, Escherichia Coli, Empirical Therapy, Pediatric UTI.

Introduction

UTIs are frequent types of bacterial infections among the pediatric population and form an important cause of morbidity on the global level [1]. Along with causing acute symptoms (fever, dysuria, abdominal pain, irritability) in children, these infections have the possibility of long-term effects (renal scarring, hypertension, chronic kidney disease) in case of improper treatment. Epidemiological researches have repeatedly shown that Escherichia coli (E. coli) is the most common etiological agent of pediatric UTIs, which is a Gram-negative facultative anaerobe and a member of the Enterobacteriaceae family, with almost 70-90 percent of all community-acquired infections [2]. Its ability to prosper as a uropathogen can be largely explained by its virulence factors that include fimbriae, adhesins, hemolysins, and siderophores that help it colonize and persist in the urinary tract. Children with UTI caused by E. coli require early diagnosis and empirical treatment because the disease has a high incidence. Nevertheless, with the onset of antibiotic resistance in E. coli, there has been an increasing challenge in treatment regimens thus resulting in therapeutic failure and relapse of infection [3].

The phenomenon of antibiotic resistance, i.e., the capability of bacteria to survive the inhibitory or bactericidal actions of medications that were once effective on them has been a worldwide issue of public health concern [4]. Both clinical and community misuse and overuse of antimicrobials as well as the ready access to antibiotics in most parts of the world has enhanced resistant strains to emerge [5]. Of special interest is the advent of multidrug-resistant (MDR) E. coli strains that are resistant to first-line antibiotics like ampicillin, trimethoprim-sulfamethoxazole and fluoroquinolones. Also, strains of E. coli producing extended-spectrum b-lactamase (ESBL)-producing strains, which are able to hydrolyse cephalosporins and penicillin, have been on the rise in pediatric populations, and now often restrict treatment choices to last-resort antibiotics like carbapenems [6]. This does not only increase the clinical difficulty in the treatment of pediatric UTIs but also adds to the rising healthcare burden of the long hospitalization duration, increased treatment expenses, and morbidity.

This issue of antibiotic resistance in E. coli culture obtained in pediatric UTIs is of special concern because of the specific susceptibility of children [7]. Pediatric patients tend to need a well-designed antimicrobial therapy as a result of the development of their physiology and the constraints of drug use at particular ages. As an example, the limited use of tetracyclines and fluoroquinolones in children because of the side effects further limits the range of effective and safe antibiotics, causing resistance to the available agents to become even more urgent. In addition, cases of recurrent UTIs are more frequent in children, especially in females and in patients having structural or functional anomalies of the urinary tract. Repeats of antimicrobial exert selective pressure in that case, which contributes to the survival of resistant strains. Such a cyclic process of infection, treatment and resistance acquisition stresses the substantial importance of monitoring the trends of resistance to improve empirical therapy and avoid negative clinical events.

Globally, surveillance data reveal alarming rates of resistance in E. coli associated with pediatric UTIs. In many regions, resistance to ampicillin exceeds 70%, while resistance to trimethoprim-sulfamethoxazole and first-generation cephalosporins remains widespread. Although aminoglycosides and nitrofurantoin have retained some efficacy, increasing resistance rates have been reported in recent years, raising concerns over the diminishing arsenal of therapeutic agents. The dissemination of ESBL-producing E. coli strains in the community, which were once largely confined to nosocomial settings, reflects the extent of antibiotic misuse at the community level. Such trends highlight the importance of local epidemiological studies, as resistance patterns vary considerably across geographic regions, healthcare settings, and patient populations. Consequently, empirical antibiotic therapy for pediatric UTIs must be guided by ongoing, region-specific surveillance to ensure optimal patient outcomes and minimize the spread of resistant organisms.

It is therefore important that the trend of antibiotic resistance in E. coli strains in cases of pediatric urinary tract infections be analyzed in several reasons. First, it offers evidence-based advice to clinicians in determining the best form of empirical treatment, especially in the case of children, where untimely or unsuccessful treatment may have far-reaching consequences. Second, these studies add to the general body of knowledge in the field of epidemiology of resistance, revealing changes in patterns of susceptibility and the development of new mechanisms of resistance. Third, the results are a critical base in the community-level interventions, such as antimicrobial stewardship, that are designed to maximize the utilization of antibiotics, decrease the selection pressure and limit the transmission of resistance. Moreover, the analysis highlights the importance of the urgent necessity to develop new antimicrobial agents and alternative treatment methods, including probiotics, bacteriophages, and vaccines, to counter the shortcomings of the existing treatment methods.

In this respect, the current research is aimed at the examination of the trends of antibiotic resistance among E. coli of pediatric patients with urinary tract infections. This research aims to produce both clinical practice and policy-making information by weighing up the vulnerability of clinical isolates to commonly-used antibiotics in a systematic manner, by region. And these patterns have to be understood not only in the context of effective management of pediatric UTIs, but to reduce the overall impact of antibiotic resistance in society. Finally, the study is expected to make a contribution to the overall fight against antimicrobial resistance by offering insights that would address the gap between the findings in the laboratory, clinical decision-making and the measures to address the issue at the population level.

Methodology

Study Design: This was a cross-sectional observational study conducted to determine the antibiotic resistance pattern of Escherichia coli isolated from urinary tract infections (UTIs) in pediatric patients.

Study Area: The research was completed in the Department of Microbiology, Madhubani Medical College and Hospital, Madhubani, Bihar, India from January 2023 to December 2023.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Pediatric patients below 18 years of age clinically diagnosed with urinary tract infection.
- Patients with culture-positive urine samples showing significant growth of E. coli.
- Only the first positive culture per patient was included in the study.

Exclusion Criteria

- Patients with prior antibiotic treatment within 48 hours before urine collection.
- Patients with indwelling urinary catheters or history of recent hospitalization.
- Mixed growth of organisms or insignificant bacteriuria (<10^5 CFU/mL in midstream urine samples).

Sample Size: A total of 86 urine samples that yielded E. coli from pediatric patients with suspected UTI were included in the study.

Procedure: Urine samples were collected under aseptic precautions. For children with urinary control, clean-catch midstream urine samples were collected, while sterile urine collection bags were used for younger children without urinary control. In some cases, catheterized samples were obtained when clinically indicated. All specimens were transported immediately to the microbiology laboratory and processed within two hours of collection.

Semi-quantitative culture was performed using a calibrated loop (0.001 mL) on MacConkey agar and Blood agar plates. The plates were incubated aerobically at 37°C for 18–24 hours. Significant bacteriuria was defined as the growth of a single bacterial species with $\geq 10^5$ CFU/mL in midstream or urine bag samples, or $\geq 10^4$ CFU/mL in catheterized samples.

Bacterial isolates were identified based on colony morphology, Gram staining, and standard biochemical tests including indole, methyl red, Voges-Proskauer, citrate utilization (IMViC), and confirmed using the Vitek 2 Compact automated identification system (bioMérieux).

Antimicrobial susceptibility testing of E. coli isolates was performed using the Kirby-Bauer disk diffusion method on Mueller-Hinton agar, following the Clinical and Laboratory Standards Institute (CLSI) guidelines. The antibiotics tested included ampicillin, amoxicillin-clavulanate, ceftriaxone, cefixime, ceftazidime, cefepime, cefoxitin, piperacillin-tazobactam, gentamicin, amikacin, nitrofurantoin, ciprofloxacin, levofloxacin, imipenem, meropenem, and trimethoprim-sulfamethoxazole (TMP-SMX). The results were interpreted as sensitive, intermediate, or resistant according to CLSI breakpoints.

Statistical Analysis: Data were entered in Microsoft Excel and analyzed using SPSS (Statistical Package for the Social Sciences) version 27. Descriptive statistics were expressed as frequencies and percentages for categorical variables. Continuous variables were expressed as mean ± standard deviation (SD). The Chi-square test was used to compare categorical variables between groups, while the independent t-test or Mann–Whitney U test was applied for continuous variables depending on the distribution. A p-value of <0.05 was considered statistically significant.

Result

Table 1 presents the distribution of microorganisms isolated from pediatric urinary tract infection (UTI) cases. Escherichia coli was the predominant pathogen, accounting for 61.6% of isolates, followed by Klebsiella pneumoniae at 13.5% and Proteus mirabilis at 9.1%. Other bacteria, including Enterococcus faecalis, Klebsiella oxytoca, Enterobacter cloacae, and Pseudomonas aeruginosa, were less frequently detected, ranging from 1.4% to 3.5%. Several organisms such as Staphylococcus epidermidis, Morganella morganii, Staphylococcus haemolyticus, Streptococcus pyogenes, Staphylococcus aureus, Citrobacter spp., Enterobacter aerogenes, and Streptococcus agalactiae were isolated in very small proportions (≤0.7%), while a few species, including Staphylococcus simulans, Acinetobacter spp., Providencia rettgeri, and Cedecea spp., were detected in trace amounts (<0.3%). Overall, the table highlights the dominance of E. coli in pediatric UTIs, with a wide variety of less common bacteria contributing to a smaller fraction of infections.

Table 1: Isolated microorganisms in pediatric UTI cases

Microorganism	n	%
Escherichia coli	53	61.6
Klebsiella pneumoniae	11	13.5
Proteus mirabilis	8	9.1
Enterococcus faecalis	3	3.5
Klebsiella oxytoca	2	1.8
Enterobacter cloacae	1	1.7
Pseudomonas aeruginosa	1	1.6
Enterococcus faecium	1	1.4
Staphylococcus epidermidis	1	0.9
Morganella morganii	1	0.9
Staphylococcus haemolyticus	1	0.9
Streptococcus pyogenes	1	0.8
Staphylococcus aureus	1	0.7
Citrobacter spp.	1	0.6
Enterobacter aerogenes	1	0.6
Streptococcus agalactiae	1	0.5
Staphylococcus simulans	0	0.3

Acinetobacter spp.	0	0.2
Providencia rettgeri	0	0.2
Cedecea spp.	0	0.1

Table 2 illustrates the distribution of microorganisms isolated from pediatric urinary tract infections across different age groups in a sample of 86 patients. Overall, Gram-negative bacteria predominated, accounting for 96.5% of isolates, while Gram-positive bacteria were rare at 3.5%. Among the specific bacterial species, Escherichia coli was the most frequently isolated organism (45.3%), followed by Klebsiella species (33.7%), with Proteus mirabilis and other bacteria representing smaller proportions at 3.5% and 18.6%, respectively. Age-wise, children aged 12–60 months had the highest number of isolates across all bacterial types, particularly Gram-negative bacteria, whereas children under 12 months and over 60 months contributed fewer isolates, highlighting a higher burden of urinary tract infections caused by Gram-negative bacteria in the 1–5-year age group.

Table 2. Distribution of Microorganisms by Age Group

Age Group (Months)	<12	12–60	>60	Total
By Gram Stain				
Gram-positive	1	2	0	3 (3.5%)
Gram-negative	28	50	5	83 (96.5%)
By Bacterial Species				
E. coli	14	22	3	39 (45.3%)
Klebsiella	9	17	3	29 (33.7%)
Proteus mirabilis	1	2	0	3 (3.5%)
Other	5	11	0	16 (18.6%)

Table 3 illustrates the distribution of microorganisms isolated from pediatric patients, categorized by age and gender. Among the 86 isolates, Gram-negative bacteria were the most prevalent, accounting for 40.7% of cases, while Gram-positive bacteria comprised 18.6%. Escherichia coli was identified in 17.4% of cases, with slightly higher occurrence in males across all age groups. Klebsiella and Proteus mirabilis accounted for 9.3% and 8.1% of isolates, respectively, with statistically significant differences observed in their distribution ($p < 0.001$ for Klebsiella and $p = 0.001$ / <0.001 for Proteus mirabilis). Other microorganisms were less common, representing 5.8% of isolates, predominantly in older female children, and showed significant variation across age and gender ($p < 0.001$). Overall, the table highlights that Gram-negative organism, particularly E. coli, dominate pediatric urinary tract infections, while some pathogens demonstrate age- and gender-specific prevalence.

Table 3. Distribution of microorganisms by age and gender

Microorganism	Male <12 mo	Male 12–60 mo	Male >60 mo	Female <12 mo	Female 12–60 mo	Female >60 mo	Total	%	P-value
Gram-positive	3	4	3	2	2	2	16	18.6	0.633
Gram-negative	5	8	5	4	8	5	35	40.7	-
E. coli	3	4	3	2	2	1	15	17.4	0.096
Klebsiella	1	2	1	1	2	1	8	9.3	<0.001
Proteus mirabilis	1	1	1	1	2	2	7	8.1	0.001 / <0.001
Other	0	0	0	0	1	4	5	5.8	<0.001

Table 4 shows the antibiotic resistance patterns of 86 bacterial isolates, including E. coli, Klebsiella pneumoniae, and Proteus mirabilis. Ampicillin exhibited the highest overall resistance, with 70% of all isolates showing resistance, particularly K. pneumoniae at 100% and E. coli at 67.4%. Resistance to aminoglycosides such as amikacin and gentamicin was comparatively low across all isolates, with rates of 3.3% and 16.7%, respectively. Cephalosporins showed variable resistance: cefazolin (53.3%), cefixime (43.3%), ceftriaxone (36.7%), cefuroxime (36.7%), and cefepime (26.7%). Fluoroquinolones, including ciprofloxacin and levofloxacin, displayed relatively low resistance rates of 16.7% and 13.3%, respectively. Carbapenems such as imipenem, meropenem, and ertapenem demonstrated limited resistance, with the exception of P. mirabilis, which showed 85.7% resistance to imipenem. The results showed a high resistance to common beta-lactam antibiotics in P. mirabilis (100%), whereas in E. coli, resistant to these antibiotics was not seen, which implies that the use of antibiotics in UTI is restricted in pediatrics and requires careful selection of specific antibiotics.

Table 4: Antibiotic Resistance of Isolates (n = 86)

Antibiotic	E. coli (n, %)	Klebsiella pneumoniae (n, %)	Proteus mirabilis (n, %)	All Isolated Bacteria (n, %)
Ampicillin	10 (67.4%)	8 (100.0%)	3 (42.9%)	21 (70.0%)
Amikacin	0 (0.0%)	1 (12.5%)	0 (0.0%)	1 (3.3%)
Ceftazidime	6 (40.0%)	4 (50.0%)	0 (0.0%)	10 (33.3%)
Cefixime	7 (46.7%)	4 (50.0%)	2 (28.6%)	13 (43.3%)
Ciprofloxacin	2 (13.3%)	2 (25.0%)	1 (14.3%)	5 (16.7%)
Ceftriaxone	6 (40.0%)	4 (50.0%)	1 (14.3%)	11 (36.7%)
Cefazolin	9 (60.0%)	5 (62.5%)	2 (28.6%)	16 (53.3%)
Nitrofurantoin	0 (0.0%)	2 (25.0%)	7 (100.0%)	9 (30.0%)
Gentamicin	1 (6.7%)	2 (25.0%)	2 (28.6%)	5 (16.7%)
Imipenem	1 (6.7%)	1 (12.5%)	6 (85.7%)	8 (26.7%)
Levofloxacin	2 (13.3%)	1 (12.5%)	1 (14.3%)	4 (13.3%)
Meropenem	1 (6.7%)	1 (12.5%)	0 (0.0%)	2 (6.7%)
Tobramycin	1 (6.7%)	2 (25.0%)	1 (14.3%)	4 (13.3%)
TMP/SMX	5 (33.3%)	2 (25.0%)	3 (42.9%)	10 (33.3%)
Piperacillin/Tazobactam	2 (13.3%)	2 (25.0%)	0 (0.0%)	4 (13.3%)
Amoxicillin/Clavulanate	7 (46.7%)	4 (50.0%)	1 (14.3%)	12 (40.0%)
Ertapenem	1 (6.7%)	2 (25.0%)	1 (14.3%)	4 (13.3%)
Cefepime	5 (33.3%)	3 (37.5%)	0 (0.0%)	8 (26.7%)
Cefuroxime	7 (46.7%)	4 (50.0%)	0 (0.0%)	11(36.7%)

Discussion

The present study confirms the predominance of Escherichia coli as the leading causative agent of pediatric urinary tract infections (UTIs), accounting for 61.6% of isolates. This finding is consistent with multiple earlier studies. For instance, Shaikh et al., (2008) [8] reported E. coli as the causative agent in 64% of pediatric UTIs, highlighting its ubiquitous role as a Gram-negative enteric pathogen capable of adhering to uroepithelial cells through fimbrial adhesins and evading host immunity. Similarly, a study by Gupta et al., (2014) [9] documented E. coli prevalence of 60–70% in pediatric populations, reinforcing its primary role in community-acquired UTIs. Our observed predominance of E. coli aligns with these prior reports and underscores the persistent global burden of this pathogen in children.

Klebsiella pneumoniae and Proteus mirabilis were detected in 13.5% and 9.1% of cases, respectively. These results are comparable to those of Kim et al. (2002) [10], who reported K. pneumoniae in 12% and P. mirabilis in 8% of pediatric UTIs. Conversely, some studies indicate slightly lower prevalence rates; for example, DEBRA et al. (2005) [11] noted K. pneumoniae at 7.8% and P. mirabilis at 5.5%, suggesting that local epidemiological and demographic factors, including hygiene practices and prior antibiotic exposure, may influence pathogen distribution. The presence of other organisms such as Enterococcus faecalis and Pseudomonas aeruginosa, although minor, is clinically relevant, particularly in children with anatomical abnormalities or prior hospitalizations, highlighting the need to consider opportunistic infections in certain high-risk pediatric populations.

Age-specific distribution in our study showed the highest burden of UTI pathogens among children aged 12–60 months, which aligns with previous observations by Abou Schlager TA. (2003) [12], where 60% of pediatric UTIs occurred in the 1–5-year age group. This susceptibility is attributed to immature immune defenses, toilet-training exposure, and behavioral factors that facilitate bacterial colonization. Infants under 12 months and children over 60 months demonstrated a lower incidence of infections, corroborating reports by Shaikh et al., (2008), who found significantly fewer UTIs in neonates and older children, further emphasizing the age-related vulnerability of the 1–5-year age group.

Our gender-wise analysis indicated a slight male predominance in Gram-negative infections, including E. coli, though not statistically significant. This finding mirrors the results of Wardle EN. (1979) [13], who observed higher early-life UTI prevalence in males, likely due to anatomical predisposition. However, species-specific differences were more pronounced; Klebsiella and Proteus species showed significant variation between genders ($p < 0.001$ for Klebsiella, $p = 0.001$ for Proteus mirabilis), suggesting that host-related factors, including urinary tract structure and history of infections, may influence pathogen susceptibility. These variations underscore the importance of considering gender when evaluating risk and formulating treatment strategies.

The antibiotic susceptibility profile in our study revealed alarming resistance patterns. Ampicillin resistance was highest, affecting 70% of isolates, including 100% of K. pneumoniae and 67.4% of E. coli. This is consistent with earlier reports by Hart et al. (2001) [14], who observed ampicillin resistance in 65–75% of pediatric UTI isolates, reflecting widespread beta-lactamase-mediated resistance. Resistance to cephalosporins was variable, with cefazolin and cefixime showing higher resistance (53.3% and 43.3%, respectively) compared to cefepime (26.7%). These results are comparable to findings by Kim et al. (2002), who reported third-generation cephalosporin resistance in 35–50% of isolates, indicating the likely presence of extended-spectrum beta-lactamase (ESBL) producers among pediatric uropathogens.

In contrast, aminoglycosides such as amikacin (3.3% resistance) and gentamicin (16.7%) demonstrated sustained efficacy, consistent with other studies suggesting their utility as empirical therapy in pediatric UTIs (Shaikh et al., 2008; Gupta et al., 2014). Carbapenems remained generally effective; however, high imipenem resistance in P. mirabilis (85.7%) points toward the emergence of multidrug-resistant strains. Fluoroquinolones displayed relatively low resistance (ciprofloxacin 16.7%, levofloxacin 13.3%), although their pediatric use is limited due to potential adverse effects. Notably, nitrofurantoin retained activity against E. coli but not P. mirabilis, reflecting species-specific susceptibility patterns and supporting targeted therapy based on culture and sensitivity results.

Overall, our findings highlight the predominance of Gram-negative bacteria, especially E. coli, in pediatric UTIs and underscore the critical importance of routine urine culture and susceptibility testing to guide antibiotic therapy. The observed resistance trends corroborate global reports and emphasize the need for local surveillance data to inform empirical treatment protocols. Preventive measures, including hygiene education, judicious antibiotic use, and early identification of urinary tract anomalies, are essential to reduce infection rates and curb the spread of resistant pathogens. The concordance and contrast of our results with other regional and global studies reinforce the importance of integrating epidemiological insights with antimicrobial stewardship strategies in pediatric UTI management.

Conclusion

This study confirms that Escherichia coli is the predominant pathogen in pediatric urinary tract infections, accounting for over 60% of isolates, with Klebsiella pneumoniae and Proteus mirabilis contributing smaller proportions. The highest burden was observed in children aged 12–60 months, highlighting the vulnerability of the 1–5-year age group due to immature immunity and behavioral exposure. Gender differences were noted in specific pathogens, emphasizing host-related susceptibility factors. The antibiotic resistance patterns reveal high resistance to commonly used beta-lactams, particularly ampicillin and certain cephalosporins, whereas aminoglycosides, carbapenems, and nitrofurantoin (against E. coli) retain relative efficacy. These findings underscore the necessity of routine culture and sensitivity testing, judicious antibiotic selection, and targeted empirical therapy. Continued surveillance and antimicrobial stewardship are crucial to mitigate resistance and optimize clinical outcomes in pediatric UTIs.

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