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Research Article

Resistance Patterns and Antimicrobial Susceptibility of Uropathogenic *E. coli* from UTI Patients in Rural Jamalpur, Bangladesh

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ABSTRACT

Urinary Tract Infections (UTIs) are common infections mainly caused by Escherichia coli, with rising antimicrobial resistance limiting treatment options in rural Bangladesh. This study assessed resistance patterns of uropathogenic E. coli from UTI patients in Jamalpur. Isolates were identified by standard methods, and susceptibility testing was performed using the Kirby-Bauer disk diffusion method following CLSI guidelines. Among the samples, 82 (20.7%) were culture-positive, and 47 (57%) yielded E. coli, with the highest prevalence in patients aged 18-40 years. High resistance was observed to β-lactams, cephalosporins, aztreonam, nalidixic acid, and chloramphenicol (100%). Aminoglycosides remained more effective, particularly netilmicin and amikacin. Carbapenems showed good activity, while trimethoprim-sulfamethoxazole and nitrofurantoin demonstrated moderate resistance. Uropathogenic E. coli (UPEC) isolates in rural Jamalpur exhibit substantial resistance to first-line antibiotics, highlighting the urgent need to update empirical treatment guidelines and strengthen AMR surveillance and antibiotic stewardship programs.

Keywords: Escherichia coli, urinary tract infection, antimicrobial resistance, multidrug resistance, rural Bangladesh

1. Introduction

Urinary tract infections (UTIs) are among the most common bacterial infections globally, affecting an estimated 150 million people each year and resulting in substantial clinical and economic burdens for both patients and healthcare systems. In high-income countries, UTIs account for nearly seven million outpatient visits and one million emergency department consultations annually, underscoring their pervasive impact on primary and acute care services (Dudzik *et al.*, 2025). Beyond localized urinary symptoms, UTIs are also a leading cause of sepsis among hospitalized patients, contributing to significant morbidity, mortality, and healthcare expenditure(Rahme *et al.*, 2025).

The lifetime risk of UTI is notably higher in women, with approximately 50-60% experiencing at least one episode, compared to 14% in men (Ahmed Al-Badr & Ghadeer Al-Shaikh, 2013). While a wide spectrum of pathogens can cause UTIs, including *Klebsiella pneumoniae*, *Proteus mirabilis*, *Enterococcus faecalis*, and *Staphylococcus saprophyticus*, *Escherichia coli* remains by far the most dominant etiological agent in both uncomplicated and complicated infections. The organism's unique virulence attributes, such as adhesins, biofilm formation, and resistance determinants, enable efficient colonization of the urinary tract and have positioned uropathogenic *E. coli* (UPEC) as a critical focus of global infectious disease research (Foxman, 2014; Rosero *et al.*, 2021).

A major challenge in UTI management today is the escalating burden of antimicrobial resistance (AMR). Widespread misuse and overuse of antibiotics, particularly fluoroquinolones, β-lactams, and cephalosporins, have driven the emergence of multidrug-resistant UPEC lineages worldwide. Since the early 2000s, resistance to fluoroquinolones has risen sharply, coinciding with the global dissemination of the high-risk, multidrug-resistant sequence type ST131. This clone has contributed significantly to therapeutic failures, increased hospitalization rates, and reliance on costlier reserve antibiotics such as carbapenems (Ruiz-Lievano *et al.*, 2024; Topa *et al.*, 2025).

The AMR crisis is even more pronounced in low- and middle-income countries (LMICs), where limited diagnostic capacity, over-the-counter antibiotic availability, economic constraints, and inadequate stewardship practices facilitate unregulated antimicrobial consumption. Bangladesh represents one such high-risk setting. The availability of inexpensive broad-spectrum antibiotics, coupled with frequent self-medication and insufficient surveillance mechanisms, has accelerated the selective pressure driving resistance (Babul Aktar *et al.*, 2022; Hanif *et al.*, 2025; Nobel *et al.*, 2021). Several reports from Bangladesh indicate rising resistance trends among UPEC isolates, including high levels of resistance to ampicillin, trimethoprim-sulfamethoxazole, third-generation cephalosporins, and fluoroquinolones. These trends severely compromise empirical treatment options and increase the risk of progression to pyelonephritis or systemic infection(Bishwajit Sutradhar *et al.*, n.d.; Sanjee *et al.*, 2017).

Despite the growing number of UTI cases and documented AMR concerns, data from rural regions of Bangladesh remain sparse. Most existing studies originate from tertiary hospitals in major cities such as Dhaka or Chattogram, leaving a critical knowledge gap regarding community-acquired UTIs in rural populations (Mahjabin *et al.*, 2025). Rural districts often face additional challenges such as limited diagnostic laboratories, fewer trained personnel, dependence on informal healthcare providers, and restricted access to second-line antimicrobials which may further exacerbate resistance dynamics (Mahmood *et al.*, 2024; Sanjee *et al.*, 2017). Understanding local susceptibility patterns is essential for guiding empirical therapy, developing evidence-based treatment guidelines, and informing public health interventions tailored to resource-limited settings.

Jamalpur, a predominantly rural district in northern Bangladesh, represents a typical example of such a vulnerable healthcare environment. The population relies heavily on primary care centers and informal providers, where empirical antibiotic use is common and often inconsistent with recommended guidelines (Bhowmick *et al.*, 2025). Yet, systematic data on the prevalence of UPEC and its resistance patterns within this community are lacking. Generating region-specific evidence is crucial, particularly as national AMR surveillance initiatives continue to expand and emphasize the need for decentralized, community-level data.

Given these gaps, this study was designed to characterize the antimicrobial susceptibility patterns of uropathogenic *E. coli* isolated from UTI patients in rural Jamalpur. By profiling resistance trends against commonly prescribed antibiotics including β-lactams, cephalosporins, fluoroquinolones, aminoglycosides, and nitrofurantoin, this work aims to provide practical insights for clinicians, public health professionals, and policymakers. Ultimately, strengthening empirical treatment decisions in rural healthcare settings is essential to slowing the progression of AMR, preserving the efficacy of existing antibiotics, and improving patient outcomes.

2. Materials and Methods

2.1 Study Design and Setting

A cross-sectional study was conducted from 01 August 2024 to 30 July 2025 to determine the antimicrobial susceptibility patterns of Escherichia coli isolated from urine samples of patients with suspected urinary tract infections (UTIs). Laboratory analyses were performed in the Department of Microbiology, Khwaja Yunus Ali University, and the Department of Microbiology, Zia Health Complex Ltd., Jamalpur.

2.2 Sample Collection and Culture Processing

A total of 397 midstream clean-catch urine samples were collected in sterile containers from patients presenting with UTI symptoms. Samples were transported to the laboratory within 1 hour of collection; delayed samples were stored at 4°C for a maximum of 6 hours. Each sample was inoculated onto CLED and MacConkey agar using a calibrated 0.001 mL loop and incubated aerobically at 35-37°C for 18-24 hours. Culture plates were examined for colony morphology and bacterial load. Significant bacteriuria was defined as $\geq 10^5$ CFU/mL; symptomatic patients with lower colony counts were also included following updated diagnostic criteria.

2.3 Identification of E. coli

Among the 82 growth-positive samples, presumptive *E. coli* isolates were identified by observing lactose-fermenting pink colonies on MacConkey agar, followed by Gram staining, which confirmed Gram-negative rods. Biochemical characterization included positive indole reaction, negative citrate and urease tests, an A/A reaction with gas production on TSI agar, and motility. Only confirmed *E. coli* isolates (n = 47) were included for antimicrobial susceptibility analysis.

2.4 Antimicrobial Susceptibility Testing

Susceptibility testing was performed using the Kirby-Bauer disc diffusion method on Mueller-Hinton agar following CLSI 2023 guidelines. For inoculum preparation, three to five colonies from an 18-24-hour culture were suspended in sterile saline and adjusted to a 0.5 McFarland standard ($\approx 1.5 \times 10^8$ CFU/mL). The standardized suspension was lawn-inoculated onto Mueller-Hinton agar using a sterile swab, and antibiotic discs were placed at least 24 mm apart to avoid overlapping inhibition zones. Plates were incubated aerobically at 35-37 °C for 16-18 hours. The antibiotic panel included β-lactams (AMC 10 µg, CAZ 30 µg, CXM 30 µg, CRO 30 µg, CTX 30 µg, MEC 10 µg), aminoglycosides (AK 30 µg, CN 10 µg, NET 30 µg), fluoroquinolones (CIP 5 µg, LEV 5 µg, MXF 5 µg, NA 30 µg), tetracyclines (TET 30 µg, DO 30 µg), other agents (SXT 25 µg, F 30 µg, ATM 30 µg), and carbapenems (IPM 10 µg, MEM 10 µg). After incubation, inhibition zone diameters were measured in millimeters, and isolates were categorized as susceptible, intermediate, or resistant based on CLSI 2023 interpretive breakpoints.

2.5 Data Analysis

Data was recorded in Microsoft Excel and analyzed using R (v2025.09.2 Build 418). Descriptive statistics summarized patient characteristics and antimicrobial susceptibility patterns. Results were expressed as frequencies and percentages.

2.6 Ethical Considerations

Ethical approval was obtained from the Ethical Review Committee of Khwaja Yunus Ali University (Approval No. Ref.: KYAU/DEAN/SBS/2023/012). All patient information was anonymized using coded identifiers**.**

3. Results

3.1 Demographic properties of E. coli UTI Cases

A total of 397 urine samples were processed during the study period, extending from 01 August 2024 to 30 July 2025. Samples were cultured and analyzed using standard microbiological techniques in the Department of Microbiology at Khwaja Yunus Ali University and the Department of Microbiology at Zia Health Complex Ltd., Jamalpur. Of the total specimens, 82 (20.7%) yielded significant bacterial growth, whereas 315 (79.3%) showed no growth and were classified as negative cases (Figure 1). This indicates that approximately one in five clinically suspected urinary tract infection (UTI) cases was microbiologically confirmed. The disproportionately high proportion of culture-negative samples may reflect prior antibiotic intake, non-bacterial etiologies of urinary symptoms, or limitations of routine culture in detecting fastidious organisms.

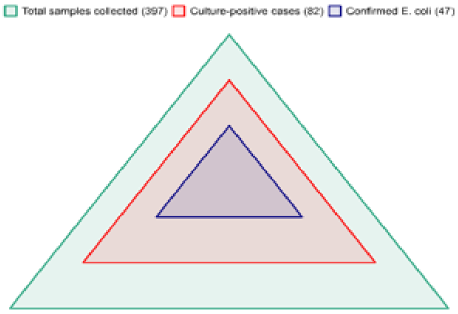

Figure 1. Progressive filtering of urine samples through culture and species-level identification steps. A total of 397 urine samples were analyzed, of which 82 (20.7%) showed significant positive bacterial growth. Among the culture-positive isolates, 47 isolates (11.8% of total samples and 57% of the culture-positive cases) were confirmed as Escherichia coli.

Among the 82 culture-positive cases, a marked sex disparity was observed. Females accounted for 58 cases (70.7%), while males contributed 24 cases (29.3%). This two-fold higher occurrence among females follows well-established epidemiological patterns attributable to anatomical and physiological factors, including shorter urethral length, hormonal influences, and greater susceptibility to peri-urethral colonization. These findings emphasize the need for targeted preventive strategies and community-level awareness for UTI risk among women. Analysis of age distribution among confirmed *E. coli* cases revealed no significant difference between males and females. Ridge density plots demonstrated similar age trends across sexes, and statistical comparison using the Wilcoxon rank-sum test confirmed no significant sex-based disparity (W = 264.5, p = 0.719) (Figure 2).

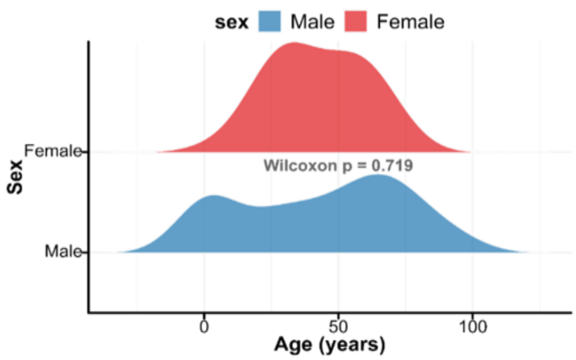

Figure 2. Age distribution of confirmed Escherichia coli UTI cases by sex. This plot showing the age distribution of patients with confirmed E. coli urinary tract infections, stratified by sex. The Wilcoxon rank-sum test indicates no significant difference in age distribution between sexes (p = 0.719).

Further stratification into epidemiological age groups like 0-5 (child), 6-17 (adolescent), 18-40 (young adult), 41-60 (middle-aged), >60 (elderly) exposed a non-uniform distribution of UTI burden. A Chi-square goodness-of-fit test showed significant variation across categories (χ^2 = 20.13, p = 0.00047), with the 18-40-year group comprising the largest proportion of cases, followed by the 41-60-year group. Children aged 0-5 years exhibited the lowest incidence. Age distribution also differed significantly by sex (χ^2 = 13.44, p = 0.0093), indicating that the relative proportions of male and female cases varied across age strata (Figure 3).

3.2 Antimicrobial Susceptibility Patterns of E. coli

The antimicrobial resistance profile of the 47 *E. coli* isolates revealed a substantial burden of resistance across multiple antibiotic classes. β-lactams showed the highest resistance rates. Amoxicillin–clavulanic acid (68.1% resistance), cefotaxime (74.5%), ceftazidime (68.1%), cefuroxime (85.1%), and ceftriaxone (91.5%) performed poorly, suggesting widespread extended-spectrum β-lactamase (ESBL) activity among community isolates. Aztreonam resistance was also high (63.8%). These findings underscore the declining utility of third-generation cephalosporins and β-lactam/β-lactamase inhibitor combinations for empirical UTI therapy.

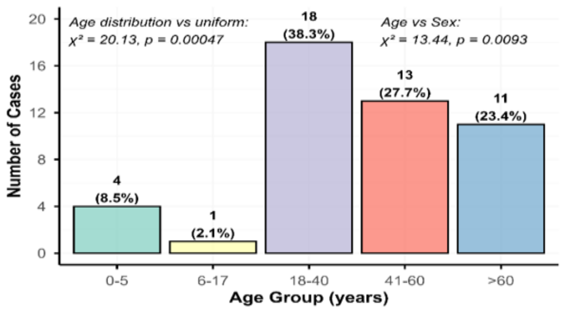

Figure 3. Age-group distribution of confirmed *E. coli* UTI cases. This plot shows the number and percentage of cases in each epidemiological age group. The overall age distribution differs significantly from uniform across age groups (χ^2 = 20.13, df = 4, p = 0.00047), and age patterns differ by sex (χ^2 = 13.44, df = 4, p = 0.0093).

Aminoglycosides demonstrated comparatively better activity. Amikacin exhibited 72.3% sensitivity, while netilmicin showed excellent susceptibility (97.9%) with only 2.1% resistance. Gentamicin showed variable effectiveness. These results position aminoglycosides as viable therapeutic options when guided by susceptibility data. Carbapenems displayed divergent performance: meropenem was highly effective (97.9% sensitivity), while imipenem resistance reached 51.1%, raising early concerns regarding carbapenemase-producing *E. coli* in the community. Fluoroquinolones exhibited mixed performance. Ciprofloxacin showed 68.1% sensitivity, indicating moderate effectiveness. Nalidixic acid, an older quinolone, showed poor activity with 89.4% resistance. Trimethoprim-sulfamethoxazole demonstrated 59.6% sensitivity, consistent with global resistance patterns among urinary *E. coli* isolates. Nitrofurantoin remained a reliable oral option for uncomplicated UTIs, with 68.1% susceptibility. Chloramphenicol demonstrated complete resistance (100%), eliminating its usefulness in treating community-acquired UTIs (Figure 4).

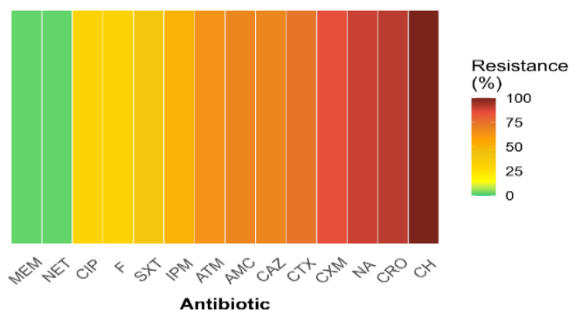

Figure 4. Antibiotic Resistance Profile of Community-Acquired *E. coli* Isolates. Heatmap illustrates the proportion of *E. coli* isolates resistant to each antibiotic tested. Colors range from light yellow (minimal resistance) to dark red (maximum resistance), visualizing comparison of resistance burdens across agents.

The resistance landscape of community-acquired *E. coli* isolates showed a pronounced and uneven distribution across antibiotic classes. Our study reveals consistently high resistance to multiple β-lactams, with amoxicillin-clavulanate, cefuroxime, cefotaxime, and ceftazidime all demonstrating resistance levels exceeding 60-80%. Several agents exhibited near-complete loss of activity, including chloramphenicol, which showed 100% resistance. In contrast, aminoglycosides retained comparatively better activity, reflected by substantially lower resistance percentages. Overall, the result highlights a critical resistance burden in *E. coli*, particularly toward frontline β-lactam therapies and an emerging MDR threat within the community, emphasizing the urgent need for strengthened antimicrobial stewardship and routine surveillance in community settings.

4. Discussion

This study provides important insights into the etiological agents and antimicrobial resistance profiles associated with community-acquired urinary tract infections (UTIs) in a mixed rural-peri-urban population in Jamalpur, Bangladesh. Of the 397 urine samples analyzed, 20.7% demonstrated significant bacterial growth. This positivity rate is comparable to earlier reports from Bangladesh, where culture positivity typically ranges from 18% to 25% at the community and district levels. The high prevalence of culture-negative samples may reflect prior antibiotic exposure, non-bacterial etiologies of urinary symptoms, or infections caused by fastidious organisms that are not readily detectable by routine culture techniques(Dudzik *et al.*, 2025). Consistent with national and global findings, Escherichia coli was the predominant causative agent, representing 57.3% of all culture-positive isolates. Studies conducted in Dhaka, Chattogram, Rajshahi, and Mymensingh similarly show *E. coli* as the leading pathogen in 55-70% of community-acquired UTI cases (Sanjee *et al.*, 2017; Smr *et al.*, 2018). Comparable results have been documented in South Asian countries such as India and Nepal, reinforcing the organism's dominance in UTI etiology across diverse population groups (Rosero *et al.*, 2021).

The current study also observed a marked female predominance (70.7%) among culture-positive cases. This trend aligns with well-established epidemiological patterns and can be attributed to anatomical characteristics, hormonal influences, and behavioral factors that increase susceptibility in females (Flores-Mireles *et al.*, 2015). Age distribution analysis revealed the highest burden of *E. coli* UTIs among individuals aged 18–40 years, followed by those aged 41-60 years. These findings reflect patterns observed across Bangladesh and other low- and middle-income countries, where sexually active young adults and middle-aged individuals constitute major risk groups (Mahmood *et al.*, 2024; Sanjee *et al.*, 2017). Particularly, although infection proportions varied across age categories, the distribution did not differ significantly between males and females, suggesting similar age-related vulnerability regardless of sex. A critical observation of this study is the substantial antimicrobial resistance (AMR) burden among *E. coli* isolates. High resistance levels were detected against multiple β-lactam antibiotics, including amoxicillin-clavulanate (68.1%), cefotaxime (74.5%), ceftazidime (68.1%), and cefuroxime (85.1%). These resistance levels mirror findings from recent Bangladeshi surveillance studies and highlight the widespread dissemination of extended-spectrum β-lactamase (ESBL)-producing strains in the community. Similar resistance trends have been noted across South Asia and parts of sub-Saharan Africa, highlighting the global expansion of ESBL-mediated resistance in resource-constrained settings (Akter *et al.*, 2020; Bishwajit Sutradhar *et al.*, n.d.).

Carbapenem susceptibility demonstrated notable variation. Meropenem retained excellent activity, showing 97.9% sensitivity, whereas imipenem exhibited moderate resistance (51.1%). Emerging reports from Bangladesh have documented rising rates of carbapenemase - producing Enterobacteriaceae, particularly NDM-type enzymes, which may explain the unexpected resistance to imipenem observed in this study (Anu Sahaya Supria K & Julliyan Dilleban A, 2023; Mahmood *et al.*, 2024; Sanjee *et al.*, 2017). Such trends are alarming, given carbapenems' role as last-line agents for multidrug-resistant infections. Aminoglycosides, in contrast, showed more favorable susceptibility profiles. Netilmicin displayed the highest sensitivity (97.9%), followed by amikacin (72.3%). These findings support the continued therapeutic relevance of aminoglycosides for complicated UTIs or parenteral treatment in settings where resistance to β-lactams is widespread. Nitrofurantoin also demonstrated moderate activity (68.1% sensitivity), consistent with global recommendations endorsing it as a first-line treatment for uncomplicated UTIs. In comparison, chloramphenicol (100% resistance) and nalidixic acid (89.4% resistance) were entirely or largely ineffective, consistent with their declining clinical utility due to extensive historical use and established resistance mechanisms (Malekzadegan *et al.*, 2024; Smr *et al.*, 2018). These analytical representations highlight the severe compromise of β-lactam efficacy while highlighting aminoglycosides and nitrofurantoin as relatively preserved options. Collectively, the resistance patterns observed emphasize the urgent need to revise empirical treatment protocols for UTIs in Bangladesh. Current widespread community use of cephalosporins and amoxicillin–clavulanate is no longer justified given the resistance levels reported.

This study has several limitations. First, antimicrobial susceptibility analysis was restricted primarily to *E. coli*, and other isolated pathogens were not evaluated in detail. Molecular characterization of resistance mechanisms such as ESBL, AmpC, or carbapenemase genes was not performed, limiting insight into the genetic drivers of resistance. Future research should incorporate molecular diagnostic tools to identify specific resistance genes and enhance understanding of emerging AMR threats. Expanding surveillance to multiple regions of Bangladesh would provide a more representative national resistance profile. Longitudinal studies examining treatment outcomes, recurrence, and patient risk factors are also needed. Finally, integrating data on antibiotic consumption and evaluating rapid diagnostic approaches may help optimize empirical therapy and support more effective antimicrobial stewardship programs.

5. Conclusion

This study confirms *Escherichia coli* as the predominant cause of community-acquired UTIs and reveals a notable burden of antimicrobial resistance among circulating isolates. High resistance to first-line agents particularly β-lactams and fluoroquinolones indicate that commonly used empirical therapies are rapidly losing effectiveness. In contrast, the preserved susceptibility to nitrofurantoin and carbapenems highlights their continued clinical value for uncomplicated and severe infections. These findings emphasize the urgent need for updated treatment guidelines informed by local resistance patterns, strengthened antibiotic stewardship, and routine surveillance to prevent further escalation of AMR. Overall, the study provides essential evidence for optimizing UTI management in the community and supports broader public health efforts to mitigate resistance in uropathogenic *E. coli*.

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