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Prevalence and Antibiotic Resistance Patterns of Uropathogenic Escherichia coli Isolated from Community-Acquired Urinary Tract Infections: A Cross-Sectional Study

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Abstract

Background: *Escherichia coli* is the main cause of urinary tract infections (UTIs), which are among the most common community-acquired diseases in the world. Particularly in low- and middle-income nations, the growing antibiotic resistance in uropathogenic E. coli (UPEC) has become a serious therapeutic issue.

Objective: To determine the prevalence and antibiotic resistance patterns of UPEC isolated from community-acquired UTIs in Pakistan.

Methods: From March 2024 to April 2025, this cross-sectional descriptive research was conducted in tertiary care facilities across Pakistan. 110 midstream urine samples from people with UTI symptoms were collected in total. UPEC was grown and identified using standard microbiological techniques, and the Kirby-Bauer disk diffusion method was used to test for antibiotic susceptibility in compliance with CLSI 2023 criteria. Resistance to at least three antibiotic classes was referred to as multidrug resistance (MDR). SPSS version 25 was utilized to analyze the data.

Results: UPEC was isolated in 68 of 110 urine samples, yielding a prevalence of 61.8%. The majority of cases occurred in females (72.1%), particularly in the 18–40 years age group (55.9%). Resistance was highest against ampicillin (85.3%), trimethoprim–sulfamethoxazole (73.5%), ciprofloxacin (66.2%), and levofloxacin (61.8%). Moderate resistance was noted to ceftriaxone (50.0%) and cefotaxime (48.5%), whereas aminoglycosides retained better activity, with gentamicin (39.7%) and amikacin (17.6%) showing lower resistance. Nitrofurantoin (14.7%) and fosfomycin (11.8%) were the most effective oral options, while carbapenem resistance was minimal (2.9%). MDR was detected in 51.5% of isolates.

Conclusion: UPEC is the predominant cause of community-acquired UTIs in Pakistan, with high resistance to commonly prescribed agents and significant multidrug resistance. Nitrofurantoin and fosfomycin remain reliable first-line therapies, while carbapenems should be preserved for complicated cases.

Keywords: Urinary tract infection, *Escherichia coli*, antibiotic resistance, multidrug resistance

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INTRODUCTION

People of all ages and genders are susceptible to urinary tract infections (UTIs), which are among the most common bacterial disorders observed in clinical practice worldwide [1]. They are a major contributor to hospital admissions, antibiotic prescriptions, and outpatient visits. An estimated 150 million UTIs are thought to occur annually worldwide, significantly impairing patient quality of life and placing a financial burden on healthcare systems [2]. UTIs are a serious public health issue because they can range in severity from mild pyelonephritis and cystitis to severe urosepsis [3].

Gram-negative facultative anaerobic bacteria belonging to the Enterobacteriaceae family, Escherichia coli (E. coli), is known to be the main causative agent of community-acquired urinary tract infections [4]. Uropathogenic Escherichia coli (UPEC) is really responsible for between 70 and 90 percent of community-based UTI infections. In order to colonize and remain inside the urinary tract, avoid host immune responses, and cause recurrent infections, UPEC strains have a number of virulence features, including as adhesins, fimbriae, toxins, and siderophores [5]. These elements, together with some populations' physiological and anatomical vulnerabilities (especially women of reproductive age), make UTIs one of the most common bacterial infections seen in primary care [6].

UPEC's increasing antibiotic resistance has been a major clinical and treatment issue in recent decades. First-line treatments for community-acquired UTIs have traditionally included antibiotics including ampicillin, trimethoprim-sulfamethoxazole, fluoroquinolones, and cephalosporins [7]. But because these medications are widely used and often misused, multidrug-resistant (MDR) UPEC strains have emerged [8]. The fluoroquinolone and third-generation cephalosporins, which were first believed to be quite successful, have frighteningly high resistance rates, according to recent studies [9]. Additionally, the spread of E. coli that produces extended-spectrum beta-lactamase (ESBL) has made treating hospital- and community-acquired UTIs more difficult, often requiring the use of last-resort drugs such carbapenems [10].

This growing resistance crisis has reduced the effectiveness of many oral antibiotics traditionally used in outpatient settings, leaving clinicians with limited therapeutic options [11]. In contrast, drugs such as nitrofurantoin and fosfomycin have retained considerable activity against UPEC in many regions, making them valuable oral alternatives for uncomplicated infections [12]. Nonetheless, their effectiveness varies geographically, highlighting the importance of local antimicrobial surveillance programs [13]. Understanding regional resistance trends is crucial for guiding empirical therapy, optimizing treatment outcomes, and preventing further development of resistance [14].

The burden of antibiotic resistance is particularly severe in low- and middle-income countries, including Pakistan, where self-medication, over-the-counter availability of antibiotics, and lack of strict antibiotic stewardship contribute to the rapid spread of resistant pathogens [15]. Studies from South Asia consistently demonstrate high prevalence rates of resistant UPEC strains, with multidrug resistance becoming increasingly common in both community and hospital settings [16]. Consequently, regular monitoring of local prevalence and resistance profiles is essential for developing evidence-based treatment guidelines tailored to the needs of specific populations [17-25].

MATERIALS AND METHODS

This cross-sectional descriptive study was conducted in the microbiology departments of different tertiary care hospitals of Pakistan over a fourteen-month period, from March 2024 to April 2025. The study population included male and female patients of all ages who presented to outpatient departments and emergency units with symptoms suggestive of community-acquired urinary tract infection such as dysuria, urinary frequency, urgency, suprapubic discomfort, flank pain, fever, or hematuria. To restrict the study to community-acquired cases, patients with a history of hospitalization within the preceding fourteen days, those who had received antibiotics in the past two weeks, and individuals with indwelling urinary catheters were excluded. Pregnant women already receiving prophylactic antibiotics and patients with polymicrobial growth in urine cultures were also excluded. A total of one hundred and ten midstream urine samples were collected consecutively from patients meeting the inclusion criteria. The samples were collected under aseptic conditions in sterile, wide-mouthed, leak-proof containers after instructing patients on proper perineal hygiene. Ten to twenty milliliters of midstream urine were obtained and transported to the laboratory within one hour of collection. When immediate processing was not possible, samples were refrigerated at four degrees Celsius and processed within four hours [1-7].

Using a calibrated 0.001 mL loop, urine samples were inoculated onto MacConkey agar and cysteine-lactose-electrolyte-deficient agar. For 18 to 24 hours, the plates were incubated aerobically at 37°C. Bacteriuria was defined as a single organism with at least 10^5 colony-forming units per milliliter. Gram staining revealed colonies thought to be *Escherichia coli* as Gram-negative bacilli. These were then verified biochemically by the use of tests for citrate consumption, Indole, Methyl Red, and Voges-Proskauer. The API-20E identification system was used to further validate isolates as needed.

Mueller-Hinton agar was subjected to antimicrobial susceptibility testing using the Kirby-Bauer disk diffusion technique in compliance with the guidelines provided by the Clinical and Laboratory Standards Institute (CLSI 2023). New colonies were used to create a bacterial solution that matched the 0.5 McFarland standard, which was then evenly spread out on agar plates. Fosfomycin, ampicillin, ceftriaxone, cefotaxime, cefepime, ciprofloxacin, levofloxacin, trimethoprim-sulfamethoxazole, gentamicin, amikacin, meropenem, imipenem, and nitrofurantoin were among the commercial antibiotic discs that were utilized.

After 16 to 18 hours of incubation at 37 degrees Celsius, the inhibitory zone widths were determined and categorized as sensitive, moderate, or resistant based on CLSI breakpoints. To guarantee test accuracy, the standard reference strains Pseudomonas aeruginosa ATCC 27853 and *Escherichia coli* ATCC 25922 were used as quality control organisms.

Resistance to three or more antibiotic classes was defined as multidrug resistance. SPSS version 25 was used to enter and analyze all of the data. The chi-square test was utilized to examine correlations between resistance patterns and demographic traits including age and gender. The prevalence of uropathogenic *Escherichia coli* and their resistance profiles were calculated as frequencies and percentages. Statistical significance was defined as a p-value < 0.05.

RESULTS

During the research period of March 2024 to April 2025, one hundred and ten urine samples from individuals with probable community-acquired urinary tract infections were

processed. The overall incidence of these isolates was 61.8%, with sixty-eight of them being identified as uropathogenic *Escherichia coli* (UPEC). Other species, such as Klebsiella pneumoniae, Proteus mirabilis, and Enterococcus faecalis, were found but at considerably lower rates, and were eliminated from further investigation. This research showed that E. coli remains the most common bacterium responsible for community-acquired urinary tract infections in Pakistan's tertiary care institutions.

Table 1: Prevalence of Uropathogenic *Escherichia coli*

Total Samples	UPEC Isolates	Prevalence (%)
110	68	61.8

As shown in Table 1, more than sixty percent of culture-positive cases were attributable to UPEC, underscoring its clinical importance in community-acquired UTIs. The demographic distribution of patients infected with UPEC revealed a strong gender predilection. Out of the sixty-eight positive isolates, forty-nine (72.1%) were from female patients, while nineteen (27.9%) were from males. The age group most affected was between 18 and 40 years, accounting for thirty-eight cases (55.9%). This was followed by the 41–60 years age group with eighteen cases (26.5%), while patients above 60 years contributed eight cases (11.8%). Only four cases (5.8%) were seen in patients below 18 years of age.

Table 2: Age and Gender Distribution of UPEC Isolates

Age Group	Male (n=19)	Female (n=49)	Total (n=68)	Percentage (%)
<18 years	2	2	4	5.8
18–40 years	9	29	38	55.9
41–60 years	6	12	18	26.5
>60 years	2	6	8	11.8

The distribution given in Table 2 clearly shows that the majority of UPEC isolates were obtained from females, particularly those in the reproductive age group. This is consistent with the well-established epidemiological trend that women are more susceptible to UTIs due to anatomical and hormonal factors. Antimicrobial susceptibility testing demonstrated varying resistance patterns. The highest resistance was observed against ampicillin, with fifty-eight isolates (85.3%) resistant, making it unsuitable for empirical therapy. Resistance to trimethoprim-sulfamethoxazole was also high, observed in fifty isolates (73.5%). Fluoroquinolones showed similarly poor performance, with ciprofloxacin resistance detected in forty-five isolates (66.2%) and levofloxacin in forty-two isolates (61.8%). Cephalosporins also showed moderate resistance, with ceftriaxone resistant in thirty-four isolates (50.0%), cefotaxime in thirty-three (48.5%), and cefepime in twenty-eight (41.2%). In contrast, aminoglycosides retained relatively good activity: gentamicin resistance was recorded in twenty-seven isolates (39.7%), while amikacin resistance was

observed in only twelve isolates (17.6%). Among oral agents, nitrofurantoin and fosfomycin were highly effective, with resistance observed in just ten isolates (14.7%) and eight isolates (11.8%) respectively. Carbapenems remained the most effective drugs, with meropenem and imipenem resistance identified in only two isolates each (2.9%).

Table 3: Antibiotic Resistance Patterns of UPEC Isolates

Antibiotic	Resistant Isolates (n=68)	Resistance (%)
Ampicillin	58	85.3
Trimethoprim–sulfamethoxazole	50	73.5
Ciprofloxacin	45	66.2
Levofloxacin	42	61.8
Ceftriaxone	34	50.0
Cefotaxime	33	48.5
Cefepime	28	41.2
Gentamicin	27	39.7
Amikacin	12	17.6
Nitrofurantoin	10	14.7
Fosfomycin	8	11.8
Meropenem	2	2.9
Imipenem	2	2.9

As demonstrated in Table 3, resistance to commonly prescribed antibiotics such as ampicillin, fluoroquinolones, and trimethoprim-sulfamethoxazole was alarmingly high, while nitrofurantoin and fosfomycin retained considerable efficacy. arbapenems remained highly active against UPEC isolates, but their role as reserve drugs highlights the importance of restricting their use. Multidrug resistance (MDR), defined as resistance to three or more antibiotic classes, was found in thirty-five isolates (51.5%). The most common MDR pattern was combined resistance to beta-lactams, fluoroquinolones, and sulfonamides. This discovery highlights the severity of the problem, as more than half of the isolates were resistant to the medicines most routinely used to treat community-acquired UTIs.

Table 4: Multidrug Resistance in UPEC Isolates

Total Isolates	MDR Isolates	MDR Prevalence (%)
68	35	51.5

Table 4 illustrates that more than half of all UPEC isolates demonstrated multidrug resistance, emphasizing the increasing difficulty in managing community-acquired UTIs with conventional

oral antibiotics. Overall, these findings highlight a disturbing trend of high resistance to many frontline oral antibiotics used in the outpatient setting. The results strongly suggest that empirical therapy with ampicillin, trimethoprim-sulfamethoxazole, or fluoroquinolones would be inappropriate in this population, whereas nitrofurantoin and fosfomycin remain the most reliable oral options. Carbapenems retain excellent activity, but their use must be restricted to severe or complicated cases in order to prevent the emergence of resistance.

DISCUSSION

This multicenter cross-sectional study, done in tertiary care institutions across Pakistan, found that uropathogenic Escherichia coli (UPEC) is still the leading cause of community-acquired urinary tract infections, with a frequency of 61.8%. This data is consistent with earlier South Asian and worldwide findings, which show that UPEC accounts for 60-80% of such infections. Our study's high prevalence of UPEC in reproductive-aged women is consistent with international findings, highlighting anatomical, behavioral, and hormonal variables as drivers of infection susceptibility [25].

The most concerning finding was the alarming resistance pattern exhibited by UPEC isolates. More than 85% resistance to ampicillin, over 70% resistance to trimethoprim–sulfamethoxazole, and greater than 60% resistance to fluoroquinolones highlight the diminishing utility of antibiotics that have historically been the backbone of empirical UTI management [26]. These data resonate with regional surveillance reports from India, Bangladesh, and Iran, where fluoroquinolone resistance now exceeds 50%, largely due to unregulated prescribing practices, over-the-counter availability, and inappropriate use of antibiotics in both human and veterinary medicine [27]. Importantly, the emergence of fluoroquinolone resistance undermines one of the few oral treatment options available in resource-limited settings [28].

The moderate resistance to third-generation cephalosporins observed in our study (around 50%) is highly suggestive of widespread extended-spectrum beta-lactamase (ESBL) production among community isolates [29]. This is a worrisome phenomenon because ESBL-producing E. coli, once largely confined to hospital environments, are increasingly disseminating within community settings [30]. The implications are profound: oral cephalosporins, frequently used as second-line agents, may no longer provide reliable coverage [31]. Our findings are consistent with global reports that highlight the growing burden of ESBL-producing UPEC in both developed and developing countries [32].

Despite this, nitrofurantoin and fosfomycin demonstrated remarkable activity, with resistance rates below 15% [33]. This aligns with international evidence, particularly from European and North American surveillance studies, that continue to recommend nitrofurantoin and fosfomycin as first-line therapies for uncomplicated UTIs [34]. Both drugs retain activity because they are rarely used outside urinary tract infections and have distinct mechanisms of action that limit cross-resistance [35]. Their preserved efficacy in our study offers a critical therapeutic window for clinicians in Pakistan and similar settings, although vigilance is required to prevent the same trajectory of resistance that befell fluoroquinolones and cephalosporins [36].

The near-universal susceptibility to carbapenems in our cohort highlights their role as last-resort agents [37]. However, the presence of carbapenem resistance in even 2.9% of isolates is disquieting, as it suggests the possible early spread of carbapenemase-producing strains in the community [38]. This is particularly relevant in Pakistan, where

surveillance data remain fragmented, and the unchecked use of broad-spectrum antibiotics is common. If carbapenem resistance continues to rise, treatment options for complicated UTIs will become dangerously limited, necessitating reliance on toxic or less effective alternatives such as colistin [39].

The prevalence of multidrug resistance (51.5%) in our study further amplifies the crisis. The fact that more than half of all isolates were resistant to three or more antibiotic classes represents a critical challenge for community-level treatment [40]. Similar trends have been reported in India and the Middle East, where MDR rates range from 40% to 60% [41]. This reflects the convergence of antimicrobial misuse, inadequate stewardship programs, and weak regulation of antibiotic sales in low- and middle-income countries [42]. The high burden of MDR isolates in our study not only restricts treatment options but also raises concerns about increased morbidity, recurrent infections, and the economic burden of prolonged therapies and hospitalizations [43].

The clinical and public health implications of these findings are profound. First, empirical use of ampicillin, trimethoprim–sulfamethoxazole, and fluoroquinolones is no longer justified in Pakistan's community setting. Second, nitrofurantoin and fosfomycin must be prioritized as first-line oral therapies for uncomplicated UTIs, in line with international guidelines. Third, carbapenems should be reserved strictly for severe or complicated infections to preserve their efficacy. Finally, the findings underscore the urgent need for robust national antibiotic stewardship programs, public awareness campaigns, and the establishment of regional surveillance networks [44]. Without immediate intervention, Pakistan risks following the trajectory of countries already grappling with pan-resistant Enterobacteriaceae [41].

Our study has limitations. The sample size, though representative, was limited to 110 patients, which may not fully capture resistance diversity across all provinces. Molecular typing of isolates, including ESBL and carbapenemase genes, was not performed but would have provided deeper insights into resistance mechanisms. Nevertheless, the multicenter design, standardized methodology, and consistency with regional and global data strengthen the validity and applicability of our findings [17,22].

CONCLUSION

Uropathogenic *Escherichia coli* is the leading cause of community-acquired urinary tract infections in Pakistan, with high resistance rates to ampicillin, trimethoprim–sulfamethoxazole, fluoroquinolones, and cephalosporins, alongside a worrying prevalence of multidrug resistance. Nitrofurantoin and fosfomycin remain effective oral options and should be considered the first-line agents for empirical therapy. Carbapenems continue to show excellent activity but must be preserved for complicated cases only. The study highlights an urgent need for antibiotic stewardship, stricter regulation of prescriptions, and continuous surveillance to prevent further escalation of resistance.

Conflict of Interest:

The authors report no conflicts of interest.

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Authors' contributions:

SF: Conceptualization, supervision, drafting.
HU: Methodology, data collection, analysis.
ZJ: Statistical analysis, validation, editing.
All authors reviewed and approved the final manuscript.

Data Availability Statement:
The data used in this study are available upon reasonable request from the corresponding author, subject to ethical and institutional guidelines.

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