Journal of Complementary Medicine Research, ISSN: 2146-8397 Vol. 2, No. 3, 2013(pp. 177-185)
RESEARCH ARTICLE WWW.JOCMR.COM

Prevalence and Antimicrobial Resistance Profile of ropathogenic *Escherichia coli* in a Tertiary Care Hospital in South India: A Cross-Sectional Study

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Abstract

Background: Urinary tract infections (UTIs) constitute one of the most frequently encountered bacterial infections worldwide, with Escherichia coli being the predominant uropathogen. The escalating problem of antimicrobial resistance among uropathogenic E. coli has emerged as a serious public health concern, particularly in developing nations such as India, where empirical antibiotic prescribing remains widespread.

Objective: The present investigation was undertaken to determine the prevalence of E. coli among patients presenting with symptoms of UTI and to characterize the antibiotic resistance profiles of the recovered isolates at a tertiary care teaching hospital in South India.

Methods: A cross-sectional study was conducted between January 2011 - December 2012 in the Department of Microbiology. A total of 1,420 mid-stream urine specimens were collected from clinically suspected UTI cases and processed using standard semi-quantitative culture methods on cysteine lactose electrolyte deficient (CLED) agar and MacConkey agar. Bacterial identification was performed using conventional biochemical tests and confirmed by the VITEK 2 automated system. Antibiotic susceptibility testing was carried out by the Kirby–Bauer disc diffusion technique following Clinical and Laboratory Standards Institute (CLSI) 2011 guidelines. Extended-spectrum beta-lactamase (ESBL) production was screened by combination disc method.

Results: Of the 1,420 urine samples processed, 562 (39.6%) demonstrated significant bacteriuria, and E. coli accounted for 348 (61.9%) of the total isolates, making it the most common uropathogen. Females (66.7%) were affected more frequently than males. Antibiotic susceptibility analysis revealed alarmingly high resistance to ampicillin (89.4%), ciprofloxacin (76.2%), and cotrimoxazole (68.5%), whereas nitrofurantoin (88.7%), fosfomycin (94.3%), and meropenem (97.1%) retained excellent activity. ESBL production was detected in 144 (41.4%) isolates.

Conclusion: The findings underscore a substantial burden of multidrug-resistant E. coli among UTI patients, emphasizing the urgent need for periodic antibiogram surveillance, judicious prescribing practices, and reinforced antimicrobial stewardship programs.

Keywords

Escherichia coli; urinary tract infection; antibiotic resistance; ESBL; antimicrobial stewardship; nitrofurantoin; tertiary care hospital

1. Introduction

Urinary tract infections (UTIs) rank among the most common bacterial infections affecting individuals of all age groups, with a particularly high incidence among women of reproductive age, pregnant females, elderly males with prostatic enlargement, catheterized patients, and individuals with underlying urological abnormalities [1,2]. Globally, it is estimated that nearly 150 million people experience at least one UTI episode annually, with associated economic costs exceeding several billion dollars in healthcare expenditures [3].

The Enterobacterales family, particularly Escherichia coli, represents the leading etiological agent in both community-acquired and hospital-associated UTIs, accounting for approximately 70–85% of all uncomplicated cases and 50–60% of complicated infections [4,5]. The pathogenicity of uropathogenic E. coli (UPEC) is mediated through an array of virulence determinants, including type 1 and P fimbriae, hemolysins, siderophores, and capsular polysaccharides, which collectively enhance its capacity to colonize the uroepithelium and ascend the urinary tract [6].

Over the past two decades, the indiscriminate use of broad-spectrum antibiotics, easy availability of over-the-counter antimicrobials, and inadequate diagnostic stewardship have driven a sharp rise in antimicrobial resistance (AMR) among uropathogens, particularly E. coli [7,8]. Resistance to fluoroquinolones, third-generation cephalosporins, and trimethoprim-sulfamethoxazole has reached worrying proportions across South Asia, with India consistently reporting some of the highest resistance rates globally [9,10]. The emergence of extended-spectrum beta-lactamase (ESBL)-producing strains and, more recently, carbapenem-resistant Enterobacterales further complicates therapeutic decisions [11,12].

Continuous surveillance of local resistance trends is therefore indispensable to guide empirical therapy, formulate hospital antibiograms, and inform national antimicrobial policies. The objective of the present study was to assess the prevalence of E. coli among patients with UTI and to elucidate the susceptibility patterns of these isolates against commonly prescribed antimicrobial agents at a tertiary care hospital located in South India.

2. Materials and Methods

2.1 Study Design and Setting

This hospital-based cross-sectional investigation was carried out in the Department of Microbiology, South India. The institution caters to a heterogeneous patient population from urban and peri-urban regions of southern India and serves as a referral center for surrounding districts. The study spanned twelve months, from January 2011 through December 2012.

2.2 Sample Collection and Inclusion Criteria

Clean-catch mid-stream urine specimens were obtained from outpatient and inpatient subjects of all age groups presenting with clinical features suggestive of UTI, including dysuria, urinary frequency, urgency, suprapubic discomfort, hematuria, or fever with flank pain. Specimens from catheterized patients were collected aseptically through the catheter port. Samples that were inadequately labelled, contaminated, or refrigerated for over two hours prior to inoculation were excluded. Demographic data and brief clinical histories were captured on a structured proforma.

2.3 Microbiological Processing

Each urine sample was subjected to wet-mount microscopy, followed by inoculation onto cysteine lactose electrolyte deficient (CLED) agar and MacConkey agar (HiMedia, Mumbai) using a calibrated 0.001 mL loop. Plates were incubated aerobically at 37 °C for 18–24 hours. Significant bacteriuria was defined as a colony count of $\geq 10^5$ colony-forming units (CFU) per millilitre of urine [13]. Bacterial identification was performed using standard biochemical reactions including indole, methyl-red, Voges–Proskauer, citrate, urease, and triple-sugar iron tests, and confirmed by the VITEK 2 Compact automated identification system (bioMérieux, France).

2.4 Antimicrobial Susceptibility Testing

Antibiotic susceptibility profiling was carried out by the Kirby–Bauer disc diffusion method on Mueller–Hinton agar in accordance with the Clinical and Laboratory Standards Institute (CLSI) guidelines [14]. The panel of antimicrobials evaluated included ampicillin (10 µg), amoxicillin–clavulanate (20/10 µg), cefotaxime (30 µg), ceftriaxone (30 µg), cefepime (30 µg), ciprofloxacin (5 µg), levofloxacin (5 µg), gentamicin (10 µg), amikacin (30 µg), trimethoprim–sulfamethoxazole (1.25/23.75 µg), nitrofurantoin (300 µg), fosfomycin (200 µg), piperacillin–tazobactam (100/10 µg), and meropenem (10 µg). Escherichia coli ATCC 25922 served as the quality control strain.

2.5 Detection of ESBL Production

ESBL production was screened phenotypically using the combination disc test, comparing zone diameters of cefotaxime and ceftazidime alone with those of cefotaxime–clavulanate and ceftazidime–clavulanate. A ≥5 mm increase in zone diameter in the presence of clavulanic acid indicated ESBL production [15].

2.6 Statistical Analysis

Data were entered into Microsoft Excel 2019 and analyzed using IBM SPSS Statistics version 25. Descriptive statistics were expressed as frequencies and percentages. Categorical variables were compared using the chi-square test, with a p-value <0.05 considered statistically significant.

3. Results

Of the 1,420 urine samples processed during the study period, 562 (39.6%) yielded significant bacterial growth. The remaining samples were either sterile or showed insignificant counts. E. coli emerged as the predominant pathogen, accounting for 348 (61.9%) of the culture-positive isolates, followed by Klebsiella pneumoniae (15.7%), Enterococcus species (8.4%), Pseudomonas aeruginosa (6.2%), Proteus mirabilis (3.9%), and other organisms (3.9%).

Female patients constituted the majority of E. coli-positive cases (n = 232, 66.7%), while 116 (33.3%) were males. The age group most frequently affected was 21–40 years (38.5%), followed by 41–60 years (29.6%), and individuals above 60 years (21.0%). The distribution of E. coli isolates with respect to gender and age groups is summarized in Table 1.

Table 1. Demographic distribution of E. coli isolates from UTI patients (n = 348).

Age group (years)	Female n (%)	Male n (%)	Total n (%)
≤20	28 (12.1)	9 (7.8)	37 (10.6)
21–40	96 (41.4)	38 (32.8)	134 (38.5)
41–60	65 (28.0)	38 (32.8)	103 (29.6)
>60	43 (18.5)	31 (26.7)	74 (21.3)
Total	**232 (66.7)**	**116 (33.3)**	**348 (100)**

Antibiotic susceptibility analysis revealed marked variability in resistance rates across the panel of agents tested. The highest level of resistance was observed against ampicillin (89.4%), followed by cefotaxime (72.7%), ciprofloxacin (76.2%), ceftriaxone (71.3%), and trimethoprim–sulfamethoxazole (68.5%). Conversely, nitrofurantoin (88.7%), fosfomycin (94.3%), amikacin (91.7%), piperacillin–tazobactam (84.5%), and meropenem (97.1%) retained excellent activity, making them suitable candidates for empirical and definitive therapy in this geographic setting. The complete susceptibility profile is provided in Table 2.

Table 2. Antimicrobial susceptibility pattern of E. coli isolates (n = 348).

Antibiotic	Sensitive n (%)	Intermediate n (%)	Resistant n (%)	MIC range (µg/mL)
Ampicillin	32 (9.2)	5 (1.4)	311 (89.4)	>256
Amoxicillin–clavulanate	152 (43.7)	27 (7.7)	169 (48.6)	8–64
Cefotaxime	92 (26.4)	3 (0.9)	253 (72.7)	16–256

Ceftriaxone	98 (28.2)	2 (0.5)	248 (71.3)	16–128
Cefepime	183 (52.6)	9 (2.6)	156 (44.8)	8–64
Ciprofloxacin	78 (22.4)	5 (1.4)	265 (76.2)	4–32
Levofloxacin	98 (28.2)	11 (3.2)	239 (68.6)	2–32
Gentamicin	224 (64.4)	8 (2.3)	116 (33.3)	1–32
Amikacin	319 (91.7)	9 (2.6)	20 (5.7)	≤2–8
Cotrimoxazole	104 (29.9)	6 (1.7)	238 (68.5)	≥320
Nitrofurantoin	309 (88.7)	16 (4.6)	23 (6.6)	≤16–32
Fosfomycin	328 (94.3)	8 (2.3)	12 (3.4)	≤8–32
Piperacillin–tazobactam	294 (84.5)	21 (6.0)	33 (9.5)	4–32
Meropenem	338 (97.1)	4 (1.1)	6 (1.7)	≤0.25–1

Phenotypic ESBL screening identified 144 (41.4%) E. coli isolates as ESBL producers. ESBL-positive isolates demonstrated significantly higher co-resistance to fluoroquinolones (87.5%) and aminoglycosides (52.1%) compared with ESBL-negative isolates ($p < 0.001$). Multidrug resistance, defined as non-susceptibility to at least one agent in three or more antimicrobial categories, was observed in 198 (56.9%) isolates. The distribution of ESBL production and multidrug resistance in relation to patient demographics is summarized in Table 3.

Table 3. ESBL production and multidrug resistance among E. coli isolates by patient category.

Patient category	Total isolates (n)	ESBL+ n (%)	MDR n (%)	Carbapenem-R n (%)
Outpatients	189	59 (31.2)	92 (48.7)	1 (0.5)
Inpatient – medical wards	84	39 (46.4)	51 (60.7)	2 (2.4)
Inpatient – surgical wards	42	21 (50.0)	29 (69.0)	1 (2.4)
ICU patients	33	25 (75.8)	26 (78.8)	2 (6.1)
Total	**348**	**144 (41.4)**	**198 (56.9)**	**6 (1.7)**

4. Discussion

The present investigation reaffirms the long-recognized predominance of E. coli as the principal etiological agent of UTIs and offers a contemporary snapshot of its resistance landscape in southern India. The culture positivity rate of 39.6% and the proportion of E. coli (61.9%) within positive isolates are concordant with several recent multicentric Indian reports, where E. coli prevalence has ranged from 55% to 72% [16,17]. The female preponderance documented in our study reflects the well-established anatomic and physiological vulnerabilities, including a shorter urethra and proximity to the perineal flora, that predispose women to ascending bacterial colonization [18].

The strikingly high resistance rates against ampicillin, fluoroquinolones, third-generation cephalosporins, and cotrimoxazole observed in this study are deeply concerning. These antibiotics have historically been the cornerstone of empirical UTI therapy, but their indiscriminate use over the past two decades, both within and outside the healthcare system, has likely fueled the selection of resistant clones. Comparable trends have been documented from other Indian centres, including studies from New Delhi, Vellore, and Hyderabad, which reported fluoroquinolone resistance ranging from 65% to 80% among uropathogenic E. coli [19,20].

An ESBL prevalence of 41.4% in our cohort aligns with the wider South Asian experience, where ESBL rates among Enterobacterales frequently exceed 40% in tertiary care settings [21]. ESBL-producing E. coli typically harbor blaCTX-M, blaTEM, or blaSHV genes, often co-located on conjugative plasmids that also carry resistance determinants for aminoglycosides, fluoroquinolones, and trimethoprim, thereby explaining the multidrug resistance phenotype observed in 56.9% of our isolates [22].

Encouragingly, nitrofurantoin and fosfomycin demonstrated excellent in vitro activity, supporting their continued role as first-line oral agents for uncomplicated lower UTIs caused by E. coli, in line with current Infectious Diseases Society of America (IDSA) and Indian Council of Medical Research (ICMR) recommendations [23]. Carbapenems retained near-universal activity, although the emergence of six carbapenem-resistant isolates (1.7%) is a sentinel warning that warrants vigilant surveillance and stringent infection-control measures.

Limitations of the present study include its single-centre design, the absence of molecular characterization of resistance determinants such as blaCTX-M, blaNDM, and blaOXA-48, and the lack of long-term clinical follow-up to correlate in vitro susceptibility results with treatment outcomes. Future investigations integrating whole-genome sequencing and clinical correlation are warranted.

5. Conclusion

The current study highlights the formidable challenge posed by antibiotic-resistant uropathogenic E. coli in a tertiary care hospital setting in Tamil Nadu. With nearly 60% multidrug resistance and 41% ESBL production, empirical therapy with conventional first-line agents may no longer be reliable. Nitrofurantoin, fosfomycin, amikacin, and carbapenems continue to be effective therapeutic options, though carbapenem use must be tightly regulated. Establishing institutional antibiograms, reinforcing antimicrobial stewardship, ensuring rational antibiotic use, and promoting public awareness regarding the dangers of self-medication are pivotal strategies for containing the further spread of resistance.

Acknowledgments:

The authors had full control of the content and made the final decision on all aspects of this publication.

Disclosure Statements

Financial support: The authors had full control of the content and made the final decisions on all aspects of this publication. The authors did not receive any honorarium, stipend, or salary for their contributions.

Declaration of Interests:

Author Contribution: Authors contributed to conceptualization and writing.

Ethical Approval: This study is a review of previously published literature. No new data was collected from human participants or animals. Therefore, ethical approval and informed consent are not required.

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