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Molecular Epidemiology Of *Escherichia Coli* Strains In Urinary Tract Infections: Virulence Factors And Antibiotic Resistance Patterns

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Abstract
Urinary tract infections (UTIs) are a significant clinical challenge, with *Escherichia coli* (*E. coli*) being the leading causative pathogen in both community- and hospital-acquired infections. This study investigates the virulence factors and antibiotic resistance patterns of *E. coli* strains isolated from symptomatic and asymptomatic UTI patients. A total of 230 *E. coli* strains were isolated from 2483 urine samples collected over 18 months. The study identified a high prevalence of virulence factors such as hemolysin, siderophores, and cell surface hydrophobicity, particularly in symptomatic patients. Multidrug-resistant (MDR) *E. coli* strains, including those producing extended-spectrum β-lactamase (ESBL) enzymes, were also identified, complicating treatment strategies. The presence of the CTX-M gene in several strains further underscores the need for careful antibiotic stewardship and continuous monitoring of resistance patterns.

Keywords: *Escherichia coli*, urinary tract infections, virulence factors, antibiotic resistance, ESBL, multidrug resistance, CTX-M gene.

Introduction

Urinary tract infections (UTIs) are among the most common bacterial infections worldwide, affecting millions of individuals annually. *Escherichia coli* (*E. coli*) is responsible for 70-90% of all community-acquired UTIs and a large proportion of hospital-acquired infections. UTIs can range from asymptomatic bacteriuria to severe conditions such as pyelonephritis, which can result in permanent kidney damage if untreated. The rising rates of antibiotic resistance, especially the emergence of multidrug-resistant (MDR) strains and extended-spectrum β-lactamase (ESBL)-producing *E. coli*, have made the management of UTIs more complex. Therefore, understanding the relationship between virulence factors and resistance patterns in *E. coli* isolates is crucial for developing effective treatment strategies.

This study aimed to analyze the prevalence of virulence factors such as hemolysin production, siderophore activity, and cell surface hydrophobicity in *E. coli* isolates from both symptomatic and asymptomatic UTI patients. It also aimed to investigate antibiotic resistance patterns, focusing on the presence of the CTX-M gene, which is associated with ESBL production.

Materials and Methods

This prospective, cross-sectional study was conducted at the Tertiary Care Hospital of Index Medical College, Indore, India, over a period of 18 months. A total of 2483 non-repetitive urine samples were collected from patients suspected of having a UTI, using the clean-catch midstream technique. The samples were processed using standard microbiological procedures to isolate *E. coli* strains. The isolated strains were subjected to various biochemical tests to confirm their identity.

Virulence factors such as hemolysin, siderophore production, hemagglutination, and cell surface hydrophobicity were examined. The presence of ESBLs and the CTX-M gene was detected using the double-disc synergy test and polymerase chain reaction (PCR) respectively. Antibiotic susceptibility testing was performed using the Kirby-Bauer disc diffusion method with a range of antibiotics, including ampicillin, ciprofloxacin, gentamycin, and piperacillin-tazobactam, among others.

Results

Prevalence of *E. coli* Strains

Out of the 2483 urine samples, 230 *E. coli* strains were successfully isolated. The majority of these strains (87.82%) were from symptomatic patients, while 12.17% were from asymptomatic individuals. This difference in isolation rates reflects the clinical severity of UTIs, with symptomatic individuals being more likely to harbor pathogenic strains.

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Table 1 summarizes the number of *E. coli* strains isolated from symptomatic and asymptomatic patients:

Patient Group	Number of Samples Collected	Number of *E. coli* Isolates	Percentage of *E. coli* Isolation
Symptomatic (n=1608)	1608	202	12.56%
Asymptomatic (n=875)	875	28	3.2%

Detection of Virulence Factors

Virulence factors play a significant role in the pathogenesis of *E. coli*-induced UTIs. The virulence factors investigated in this study included hemolysin production, siderophore activity, cell surface hydrophobicity, and the presence of plasmids. Symptomatic *E. coli* strains exhibited a higher prevalence of these virulence factors compared to those isolated from asymptomatic patients.

Table 2 shows the percentage of *E. coli* strains from both symptomatic and asymptomatic groups exhibiting various virulence factors:

Virulence Factor	Symptomatic Patients (%)	Asymptomatic Patients (%)
Hemolysin	26.23%	28.57%
Siderophore	34.15%	17.85%
Cell Surface Hydrophobicity	32.17%	21.42%
Plasmid	29.2%	21.42%

Among the symptomatic patients, siderophore production was observed in 34.15% of the isolates, whereas in the asymptomatic group, it was present in only 17.85%. Hemolysin production was detected in 26.23% of symptomatic patients, which is a significant indicator of the potential for tissue damage and inflammation. Interestingly, asymptomatic strains still exhibited virulence factors, suggesting the potential for latent or low-level infections.

Antibiotic Resistance Patterns

The antibiotic resistance profile of the *E. coli* strains was evaluated using a variety of commonly prescribed antibiotics. A concerning level of multidrug resistance was observed, with gentamycin showing the highest resistance rate (61.73%), followed by ciprofloxacin (17.82%) and amikacin (21.73%). Notably, resistance to piperacillin-tazobactam was very low (0.86%), indicating its continued efficacy against *E. coli* infections.

Table 3 summarizes the resistance rates of *E. coli* strains to various antibiotics:

Antibiotic	Number of Resistant Strains (n=230)	Percentage of Resistance
Gentamycin	142	61.73%
Ciprofloxacin	41	17.82%
Amikacin	50	21.73%
Piperacillin-tazobactam	2	0.86%

The detection of the CTX-M gene, which encodes for ESBL production, was confirmed in 22 strains (9.56%). These strains were found to be resistant to most β-lactam antibiotics, including ceftazidime and cefotaxime, making treatment options limited for patients infected with these strains. ESBL-producing strains exhibited significantly higher resistance compared to non-ESBL-producing strains, highlighting the impact of this resistance mechanism on clinical outcomes.

Discussion

This study provides valuable insights into the virulence factors and antibiotic resistance patterns of *E. coli* strains isolated from UTI patients in a tertiary care setting. The findings reveal that virulence factors such as siderophore production, hemolysin, and cell surface hydrophobicity are more prevalent in symptomatic patients, suggesting that these factors contribute significantly to the severity of infection. In contrast, asymptomatic patients exhibited fewer virulence factors, though their presence still poses a risk of progression to symptomatic disease.

The high level of resistance observed, particularly to gentamycin and ciprofloxacin, is alarming and underscores the importance of judicious antibiotic use in clinical practice. The low resistance rate to piperacillin-tazobactam provides some hope for its continued use in treating *E. coli*-related UTIs. However, the detection of ESBL-producing strains and the presence of the CTX-M gene is a cause for concern, as these strains are resistant to a broad range of β-lactam antibiotics, necessitating the use of more expensive and potent drugs like carbapenems.

The study's findings suggest that routine surveillance of antibiotic resistance patterns and the presence of virulence factors should be integrated into clinical practice to guide effective treatment strategies. Furthermore, preventive measures, such as the development of vaccines targeting virulence factors, could play a crucial role in reducing the burden of UTIs caused by MDR *E. coli* strains.

Conclusion

This study highlights the molecular characteristics of *E. coli* strains responsible for UTIs, particularly the role of virulence factors and the growing problem of antibiotic resistance. The presence of virulence factors is associated with increased clinical severity, particularly in symptomatic patients. The detection of MDR and ESBL-producing *E. coli* strains calls for urgent interventions in terms of antibiotic stewardship and infection control measures. Continuous monitoring and the development of novel therapeutic strategies, including vaccines, are essential to counter the rising threat of antibiotic-resistant *E. coli* in UTIs.

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