Original Article

Urinary Biochemical Alterations Associated with Uropathogenic *Escherichia coli* Infection: A Cross-Sectional Study at Al-Ramadi Hospital

Mustafa M. Fahad *

Center of Desert Studies, University of Anbar, Ramadi, 31001, Anbar, Iraq.
* Corresponding author: mustafa.moh@uoanbar.edu.iq

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Abstract

Background: Urinary tract infections are among the most common bacterial infections worldwide and represent a considerable healthcare burden. Uropathogenic *Escherichia coli* remain the leading causative organism in both community-acquired and nosocomial urinary tract infections. **Objectives:** To investigate urinary biochemical changes associated with uropathogenic *Escherichia coli* infection and assess their diagnostic significance. **Materials and Methods:** Participants were selected based on convenience sampling from patients aged 18 years or more who had not been treated with antibiotics. Urine analysis was performed for pH, specific gravity, protein, nitrite, and leucocyte esterase followed by urinalysis for presence of leucocytes, erythrocytes, bacteria, and epithelial cells. The urine culture followed by identification of pathogens based on standard methods and the VITEK 2 system was done. **Results:** Out of 200 patients, 82 (41.0%) were positive for *Escherichia coli*. In comparison with *Escherichia coli*-negative samples, *Escherichia coli*-positive urine samples were characterized by increased values of pH (7.2 ± 0.8 versus 6.5 ± 0.9, $p < 0.001$), specific gravity (1.021 ± 0.007 versus 1.016 ± 0.009, $p < 0.001$), nitrite (68.3% versus 18.6%, $p < 0.001$), and leucocyte esterase (90.2% versus 69.5%, $p < 0.001$). Microscopy showed more cases with >10 white blood cells per high-power field (67.1% versus 31.3%, $p < 0.001$), many bacteria (39.0% versus 0.8%, $p < 0.001$), and red blood cells (41.5% versus 27.1%, $p = 0.045$) in *Escherichia coli*-positive samples. **Conclusion:** The study implies that uropathogenic *Escherichia coli* is associated with distinctive urine biochemical and microscopic changes.

Keywords: Uropathogenic *Escherichia coli*, Urinary Tract Infection, Urinalysis, Leukocyte Esterase, Antimicrobial Susceptibility.

Introduction

Urinary tract infections (UTIs) represent one of the most common forms of bacterial infection in the world and represent a considerable burden in health care systems with millions of people affected annually. From recent statistics from 2019, approximately 404.6 million symptomatic UTI cases were reported worldwide, which include both community and hospital acquired (UTIs) in which the infection affects older populations and under-served communities without easy access to health care [1, 2]. The mortality burden among (UTIs) cases has also shown to be increasingly burdensome, with approximately 236,790 deaths having occurred. These death rates have arisen mainly due to complications from (UTIs) like urosepsis rather than uncomplicated infections, and this represents an increase of 140% since 1990 [1]. The economic consequences are substantial and have been estimated at more than $2.8 billion annually for UTI treatment in the United States, with most of these costs due to direct medical care. However, indirect costs related to lost productivity are likely to be underestimated [3]. Among the potential bacterial causes of (UTIs), uropathogenic *Escherichia coli (E. coli*) remains the leading organism in community-acquired

(UTIs) (70–95%) and nosocomial infections (about 50%) [4, 5]. Uropathogenic *Escherichia coli* (UPEC) pathogenesis can be attributed to various virulence factors. Adhesive factors, such as type 1 fimbriae and the P fimbriae, are crucial for the adhesion of bacteria to the cells lining the urinary tract. Iron acquisition strategies like siderophores, enterobactin, and aerobactin help to acquire iron in the iron-depleted environment [6]. Toxins like hemolysin and cytotoxic necrotizing factor 1 are involved in causing host tissue damage, modulating the host immunity system, and bacterial spread. The biofilm-forming capacity as well as the formation of intracellular bacterial communities by (UPEC) can be considered as other factors that contribute to their pathogenicity. Apart from providing protection from the host's immune response, the biofilm contributes to the resistance of the pathogen to antibiotics, which leads to recurrent and persistent infections. The development of (UTIs) caused by (UPEC) occurs in stages; first of all, the bacteria colonize the periurethral areas. Next, the bacteria ascend up through the urethra to the bladder [8, 9]. The bacteria in the bladder can survive by forming intracellular niches in order to evade host responses [7]. When the infection is not treated, or when the patient is at high risk, it may progress to pyelonephritis. In severe cases, it may also develop into bacteremia and sepsis. Studies have reported a higher risk among elderly patients, patients with an indwelling catheter, and immunocompromised patients [9]. Indeed, the diagnostic methods for (UTIs) currently used by the clinicians rely mostly on classical methods of urine culture and simple biochemical analyses. Still, in reality, they often suffer from considerable drawbacks linked to their low sensitivity and limited specificity. For the nitrite test, sensitivity has been reported at 35-85%, with specificity of 84-95%. For leukocyte esterase, sensitivity ranges from 72-97%, while specificity ranges from 41-86% [10, 11]. It clearly highlights the drawbacks of using these tests. In addition, the results of classical cultures can be obtained only in 24-48 hours, with limited ability to identify the microbes causing urinary infection [12]. Antimicrobial resistance in (UPEC) infections has become another factor that makes treatment more difficult. Resistance has been reported at about 42% for third-generation cephalosporins and about 20% for fluoroquinolones. These figures mainly represent global averages, and resistance rates may differ between regions, especially in parts of Asia, the Middle East, and Africa [13]. Extended-spectrum beta-lactamases (ESBLs) and carbapenem resistance pose further problems, with the last one being especially concerning in connection with carbapenem-resistant Enterobacterales [13]. Taking into account all the factors listed above, World Health Organization included (UPEC) as part of Enterobacterales in its list of top-priority pathogens for which novel antibiotics are needed [14]. These data emphasize the importance of continuous local and global surveillance to inform effective antimicrobial stewardship strategies. Detection of biomarkers that correspond to the presence of (UPEC) infection presents promising chances to improve UTI diagnostics. The existing tests include nitrites and leukocyte esterase, which although effective, display varied degrees of sensitivity (35-85%) and specificity (84-95%) [11]. Leukocyte esterase was found to have a sensitivity of (72-97%) and specificity of (41-86%) [10]. However, novel biomarkers exhibit improved accuracy rates in current research findings. Specifically, interleukin-8 is known to have higher sensitivity of 82 90% and specificity of 75 88%, whereas neutrophil gelatinase-associated lipocalin showed an area under the curve of (0.85-0.92) when discriminating between (UTIs) and

asymptomatic bacteriuria cases [15, 16]. Azurocidin, on the other hand, was noted to have high sensitivity (81%) and specificity (79%) [11]. Despite the promising results, it must be noted that novel biomarkers have yet to be introduced into medical practice. Nonetheless, the use of new biomarkers combined with current screening techniques could lead to improved early, more accurate and pathogen-specific diagnosis of (UTIs), especially in resource-limited settings.

Materials and Methods

The total number of 200 subjects who exhibited symptoms of UTI was selected in this cross-sectional study at Al Ramadi Teaching Hospital in Iraq by using convenient sampling methods. The period of sample collection was from May 2024 to April 2025. The inclusion criteria involved selecting adults 18 years or older with symptoms of UTI such as dysuria, urgency, frequency, suprapubic pain, or fever who had not been administered any antibiotics in at least one week before sample collection. Patients below 18 years, patients on antibiotic medication, pregnant women, and patients with indwelling catheters for over 48 hours were excluded from the study.

Sample Collection and Processing

The urine samples were obtained by means of midstream clean catch technique since it is widely considered an optimal method for urine culture and sensitivity tests. Patients were asked to clean their urethral areas by means of supplied antiseptic wipes, discard the first stream of urine, and then collect the midstream urine sample into sterile containers. Specimens were analyzed within 30 minutes after collection or refrigerated at 2–8°C and assayed within 4–6 hours to maintain specimen integrity [17].

Laboratory Methods

Urinalysis and Biochemical Testing

Urinary analysis involved visual inspection for characteristics such as color, clarity, and odor. The following parameters were then analyzed using the chemical dipstick method: protein content, glucose, ketones, pH, specific gravity, nitrites, and leukocyte esterase. Protein content ranged from trace to 4+. The nitrite test was used as a preliminary test for urinary infection, with a sensitivity of 35–85% and a specificity of 84–95%.

Bacterial Culture and Identification

The urine samples were then inoculated on appropriate selective media, including cystine lactose electrolyte-deficient agar and eosin methylene blue agar. A bacterial count of $\geq 10^3$ colony-forming units per milliliter (CFU/mL) was taken to be significant in the diagnosis of UTI. E. coli was then characterized biochemically and using the VITEK 2 system when available.

Quality Control

The culture media were tested to check for bacterial growth support, physical condition, and sterility. Quality control tests were conducted using standard strains. Sterility tests were performed on 10% of the prepared media batches, while growth-support testing was conducted using strains with known characteristics.

Antibiotic Susceptibility Testing

The Kirby–Bauer disk diffusion technique was used for antibiotic susceptibility testing, following Clinical and Laboratory Standards Institute recommendations [18]. Twelve commonly used antibiotics were tested including ampicillin, amoxicillin clavulanic acid, ceftriaxone, cefotaxime, ciprofloxacin, levofloxacin, gentamicin, amikacin, trimethoprim sulfamethoxazole, nitrofurantoin, meropenem, and imipenem.

Statistical Analysis

The statistical analysis was done with Statistical Package for the Social Sciences version 25.0. Categorical variables were expressed as numbers and percentages, and continuous variables as mean ± standard deviation. Associations between categorical variables were analyzed using the Chi-square test, where $p < 0.05$ was taken as statistically significant. Prevalence rates were calculated using formulas for cross-sectional studies.

Ethical Considerations

The study was approved by the Ethical Approval Committee, University of Anbar (Approval No. 126, dated 3 February 2024). Patient confidentiality was ensured throughout the research process.

Results

Prevalence of E. coli in UTI Cases

Out of the total 200 patients analyzed, 82 (41.0%) were positive for E. coli infection, whereas 118 (59.0%) were negative for E. coli infection. The prevalence rate in this study is in line with those found in other hospital-based studies in which E. coli constitutes 37–52% of (UTIs).

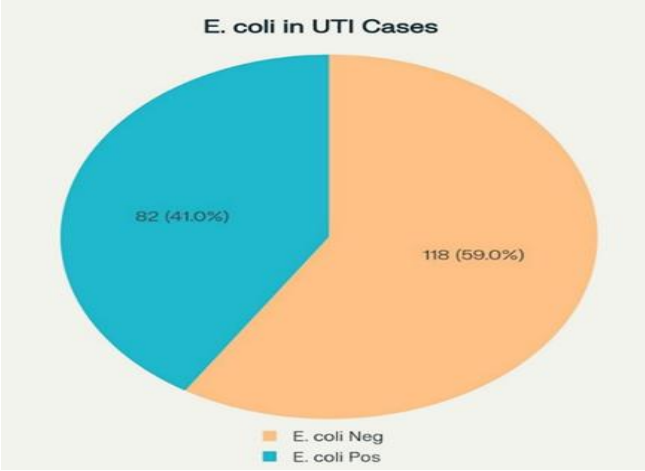

Figure 1. Prevalence of *E. coli* in Urinary Tract Infection Cases.

Demographic Data and Clinical Details

The study included 200 patients with symptoms of UTI. Their mean age was 45.2 ± 18.7 years, with an age range of 18–82 years, as shown in Table 1.

Table 1. Demographic Characteristics and Clinical Presentation of Study Participants (N=200).

Characteristic	Total (n=200)	*E. coli* Positive (n=82)	*E. coli* Negative (n=118)	P-value
Age (years)				
Mean ± SD	45.2 ± 18.7	43.8 ± 17.2	46.1 ± 19.8	0.432
Range	18-82	19-78	18-82	
Sex				
Male	74 (37.0)	28 (34.1)	46 (39.0)	0.512
Female	126 (63.0)	54 (65.9)	72 (61.0)	
Clinical Symptoms				
Dysuria	158 (79.0)	67 (81.7)	91 (77.1)	0.456
Urgency	142 (71.0)	59 (72.0)	83 (70.3)	0.821
Frequency	136 (68.0)	56 (68.3)	80 (67.8)	0.948
Suprapubic pain	98 (49.0)	42 (51.2)	56 (47.5)	0.632
Fever	67 (33.5)	29 (35.4)	38 (32.2)	0.678
Risk Factors				
Diabetes mellitus	31 (15.5)	14 (17.1)	17 (14.4)	0.623
Previous UTI history	76 (38.0)	34 (41.5)	42 (35.6)	0.432
Catheterization	19 (9.5)	8 (9.8)	11 (9.3)	0.892
Immunocompromised	12 (6.0)	5 (6.1)	7 (5.9)	0.954

In the sample used for this research, 63.0% (126/200) were female patients, whereas males constituted 37.0% (74/200). The most common symptoms were dysuria (79.0%), urgency (71.0%), and increased urinary frequency (68.0%). The risk factors identified in the sample included previous history of UTI (38.0%), diabetes mellitus (15.5%), catheterization (9.5%), and immunocompromised status (6.0%).

Biochemical Alterations in Urine Parameters

Significant biochemical differences were observed between *E. coli* positive and negative UTI cases, as shown in Table 2.

Table 2. Comparison of Biochemical Parameters between *E. coli* Positive and Negative UTI Cases.

Parameter	Total (n=200)	*E. coli*		P-value
		Positive (n=82)	Negative (n=118)	
Protein (mg/dL)				
Trace	89 (44.5)	29 (35.4)	60 (50.8)	0.032*
1+	56 (28.0)	24 (29.3)	32 (27.1)	
2+	31 (15.5)	17 (20.7)	14 (11.9)	
3+	18 (9.0)	9 (11.0)	9 (7.6)	
4+	6 (3.0)	3 (3.7)	3 (2.5)	
Glucose				
Negative	173 (86.5)	71 (86.6)	102 (86.4)	0.978
Positive	27 (13.5)	11 (13.4)	16 (13.6)	
Ketones				
Negative	184 (92.0)	75 (91.5)	109 (92.4)	0.856
Small	12 (6.0)	5 (6.1)	7 (5.9)	
Moderate	3 (1.5)	1 (1.2)	2 (1.7)	
Large	1 (0.5)	1 (1.2)	0 (0.0)	
Ph				
Mean ± SD	6.8 ± 0.9	7.2 ± 0.8	6.5 ± 0.9	0.001*
Range	5.2-8.4	5.8-8.2	5.2-8.4	
Specific Gravity				
Mean ± SD	1.018 ± 0.008	1.021 ± 0.007	1.016 ± 0.009	0.001*
Range	1.005-1.035	1.008-1.032	1.005-1.035	
Nitrite Test				
Positive	78 (39.0)	56 (68.3)	22 (18.6)	<0.001*
Negative	122 (61.0)	26 (31.7)	96 (81.4)	
Leukocyte Esterase				
Positive	156 (78.0)	74 (90.2)	82 (69.5)	<0.001*
Negative	44 (22.0)	8 (9.8)	36 (30.5)	

pH levels were significantly higher in *E. coli* positive cases (7.2 ± 0.8) compared to negative cases (6.5 ± 0.9, p=0.001), indicating more alkaline urine in bacterial infections. Specific gravity was also elevated in *E. coli* positive samples (1.021 ± 0.007 vs 1.016 ± 0.009, p=0.001), suggesting increased urine concentration. There were significant differences in the levels of proteins among groups (p = 0.032) as patients testing positive for *E. coli* had more severe levels of proteinuria. There were significantly more positives with regards to the nitrite test in those testing positive for *E. coli* (68.3% vs. 18.6%, p<0.001), proving the usefulness of nitrites as a screening tool even though they are considered insensitive. Leukocyte esterase was positive in 90.2% of *E. coli* cases compared to 69.5% in negative cases (p<0.001), indicating increased inflammatory response, as shown in Figure 2.

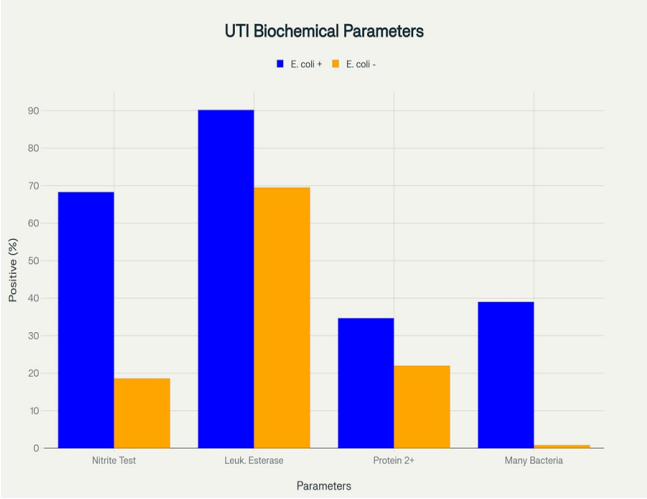

Figure 2. Differences in Biochemical Parameters between *E. coli*-Positive and *E. coli*-Negative UTI Patients.

Microscopic Examination Findings

Microscopic examination showed clear differences in cellular components between *E. coli*-positive and *E. coli*-negative cases, as shown in Table 3.

Table 3. Microscopic Examination Findings in *E. coli* Positive versus Negative Urine Samples

Parameter	Total (n=200)	*E. coli*		P-value
		Positive (n=82)	Negative (n=118)	
White Blood Cells (/hpf)				
0-5	45 (22.5)	8 (9.8)	37 (31.4)	<0.001*
6-10	63 (31.5)	19 (23.2)	44 (37.3)	
11-20	67 (33.5)	35 (42.7)	32 (27.1)	
>20	25 (12.5)	20 (24.4)	5 (4.2)	
Red Blood Cells (/hpf)				
0-2	134 (67.0)	48 (58.5)	86 (72.9)	0.045*
3-5	38 (19.0)	19 (23.2)	19 (16.1)	
6-10	21 (10.5)	12 (14.6)	9 (7.6)	
>10	7 (3.5)	3 (3.7)	4 (3.4)	
Bacteria				
Few	78 (39.0)	12 (14.6)	66 (55.9)	<0.001*
Moderate	89 (44.5)	38 (46.3)	51 (43.2)	
Many	33 (16.5)	32 (39.0)	1 (0.8)	
Epithelial Cells (/hpf)				
0-5	167 (83.5)	62 (75.6)	105 (89.0)	0.023*
6-10	28 (14.0)	17 (20.7)	11 (9.3)	
>10	5 (2.5)	3 (3.7)	2 (1.7)	
Casts				
None	182 (91.0)	70 (85.4)	112 (94.9)	0.045*
Hyaline	15 (7.5)	10 (12.2)	5 (4.2)	
Granular	3 (1.5)	2 (2.4)	1 (0.8)	

WBC count was significantly higher in patients with *E. coli*, with 67.1% of patients having >10 WBCs/hpf compared with 31.3% in patients without *E. coli* (p<0.001). The bacterial count showed significant variation with 39.0% of patients having "many bacteria" compare with 0.8% of patients without *E. coli* (p<0.001). The presence of red blood cells was common in cases where *E. coli* was present (41.5% showed >2 red blood cells (RBCs)/hpf compared to 27.1% in those cases without *E. coli*, p=0.045), indicating greater urinary tract inflammation. The shedding of epithelial cells was more common in cases with *E. coli* infection (24.4% showing >5 cells/hpf vs 11.0%, p=0.023) suggesting enhanced tissue damage.

Antibiotic Susceptibility Pattern

All 82 *E. coli* isolates were sensitive to meropenem and imipenem, while sensitivity to amikacin and nitrofurantoin reached 97.6% and 95.1%, respectively, as shown in Table 4.

Table 4. Antibiotic Susceptibility Pattern of Uropathogenic *E. coli* Isolates (N=82).

Antibiotic	Sensitive N (%)	Intermediate N (%)	Resistant N (%)
Ampicillin	28 (34.1)	6 (7.3)	48 (58.5)
Amoxicillin-Clavulanic acid	52 (63.4)	8 (9.8)	22 (26.8)
Ceftriaxone	76 (92.7)	3 (3.7)	3 (3.7)
Cefotaxime	74 (90.2)	4 (4.9)	4 (4.9)
Ciprofloxacin	68 (82.9)	7 (8.5)	7 (8.5)
Levofloxacin	71 (86.6)	5 (6.1)	6 (7.3)
Gentamicin	75 (91.5)	4 (4.9)	3 (3.7)
Amikacin	80 (97.6)	2 (2.4)	0 (0.0)
Trimethoprim-Sulfamethoxazole	51 (62.2)	9 (11.0)	22 (26.8)
Nitrofurantoin	78 (95.1)	2 (2.4)	2 (2.4)
Meropenem	82 (100.0)	0 (0.0)	0 (0.0)
Imipenem	82 (100.0)	0 (0.0)	0 (0.0)

The third-generation cephalosporins had very good sensitivity levels with ceftriaxone and cefotaxime being greater than 90%. Fluoroquinolones also showed good activity, with ciprofloxacin and levofloxacin both exceeding 82% sensitivity. For resistance, ampicillin recorded the highest rate (58.5%), followed by trimethoprim-sulfamethoxazole and amoxicillin-clavulanic acid, each at 26.8%. There was production of extended-spectrum beta-lactamase (ESBL) in 4.9% of isolates based on third-generation cephalosporin resistance patterns. These findings are shown in Figure 3.

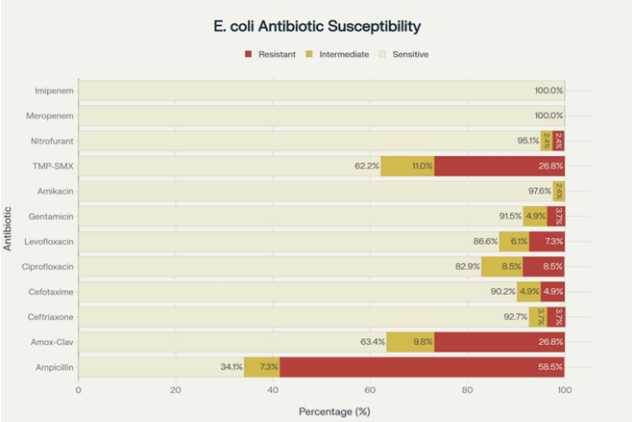

Figure 3. Antibiotic Susceptibility Pattern of *E. coli* Isolates (n=82).

Discussion

The present study showed that (UPEC) was detected in 41% of UTI cases. This percentage is within the range reported for community-acquired (UTIs) in previous studies [19]. The finding confirms the important role of (UPEC) as a common cause of urinary tract infections and is comparable with findings reported from other hospitals, including Erbil Hospital [20]. The higher urine pH (7.2 ± 0.8) observed in (UPEC)-positive patients may reflect changes in the urinary environment associated with infection [19, 21]. The high pH favors biofilm production, which is another important virulence factor for (UPEC) seen in 62% of the clinical strains [20]. The specific gravity of the patients' urine (1.021 ± 0.007) signifies concentrated urine which may facilitate the adhesion of the bacteria as a consequence of osmotic changes [20, 22]. Positive nitrite test is the direct effect of the enzyme nitrate reductase produced by (UPEC), although sensitivity is strain-dependent, being variable between 35% and 85% [19]. The high prevalence of leukocyte esterase positivity (90.2%) demonstrates a considerable pyuria as (UPEC) causes an inflammatory response in the mucosa [23]. Microscopic findings, including elevated WBCs, RBCs, and epithelial cells, are consistent with (UPEC)-related cytolytic damage mediated by toxins such as hemolysin and CNF1 [22]. (UPEC) isolates showed 100% sensitivity to carbapenems (meropenem / imipenem), as in the data of the hospitals from Erbil (88.89 - 85.19% sensitivity) [19, 23]. Yet, the presence of ampicillin resistance (58.5%) can be linked to the increased prevalence of (ESBL) globally, such as CTX-M-15 in ST131 H30Rx strains [20]. Similarly, there is a high prevalence rate of resistance against fluoroquinolones (>17%) among ST1193 isolates that commonly contain genes for plasmid-encoded resistance [22, 23]. On the other hand, the activity of nitrofurantoin was highly maintained (95.1% sensitivity), emphasizing its importance as the primary treatment option for uncomplicated (UTIs) [19, 24]. Adhesins such as P fimbriae coded by papC are probable in these (UPEC) strains, which facilitate renal colonization and the development of biofilms [22, 23]. Lack of hemolysin genes (hlyA) in certain isolates may be attributed to differences in pathotype, because only 41.36% of (UPEC) isolates showed hemolysin production during phenotypic screening [19]. Genotypic studies indicate that iron acquisition mechanisms (e.g., enterobactin) and serum resistance are important in (UPEC) bladder colonization (32.72% among cases and 24% among controls) [22]. The biochemistry analysis (high pH, nitrite, leucocyte esterase) provides fast diagnostic indicators for (UPEC), but microscopy is important for evaluating the degree of inflammation. In cases of high resistance, carbapenems and nitrofurantoin are empiric therapies, and avoidance of use of ampicillin and trimethoprim-sulfamethoxazole is advised [19, 24]. It would be helpful to associate virulent genotypes (such as papC, cnf1) with phenotypes at the point of care [22, 23]. This information is useful from a clinical perspective; since there is evidence that (UPEC) infection is accompanied by specific changes in

biochemistry that may help with quick decision-making. The combination of high pH, positive nitrite, and leukocyte esterase may help predict the organism responsible for infection before culture findings are available. Microscopy and antibiotic susceptibility testing can guide treatment selection. In addition, due to emerging antibiotic resistance trends, continuous monitoring and proper use of effective antibiotics, such as carbapenems and nitrofurantoin, are needed. Further multicenter investigations with the molecular analysis of genes responsible for resistance and virulence will be necessary to confirm these results and make conclusions and to guide the development of more accurate diagnostic and therapeutic strategies.

Conclusion

The findings of this study indicate that urinary biochemical and microscopic examination may provide useful early indicators of (UPEC) infection before culture results are available. These routine parameters may therefore support the early assessment of suspected UTI cases, while culture and antimicrobial susceptibility testing remain important for confirming the infection and selecting appropriate therapy based on local resistance patterns. More research is required, including those using molecular identification of virulence and antibiotic resistance genes, in other medical facilities to substantiate these findings and improve diagnosis and treatment of (UTIs).

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