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The Efficacy of Cephalosporin Antibiotics Against Urinary Tract Infection (UTI)-Causing Bacteria

Ali Y.A. Saleh
Department of Science, College of Basic Education, University of Al-Mustansiriyah, Baghdad, Iraq.
Email: aliyahyaabboud@uomustansiriyah.edu.iq

Abstract. Urinary tract infections (UTIs) represent one of the most common bacterial infections worldwide, with over 150 million cases annually, causing significant health and economic burdens. Cephalosporins, a class of β-lactam antibiotics, are widely prescribed for UTIs due to their broad-spectrum activity and low toxicity; however, increasing resistance limits their effectiveness. Despite their extensive use, little is known about the prevalence of resistance mechanisms such as biofilm formation and β-lactamase production in UTI pathogens against different generations of cephalosporins in Baghdad. This study aimed to evaluate the efficacy of 14 cephalosporin antibiotics against UTI-causing bacteria, with particular focus on resistance rates, biofilm formation, and β-lactamase enzyme production. From 140 bacterial isolates, Escherichia coli was the predominant pathogen (82.14%), with infections occurring more frequently in females (84.95%). Resistance to cephalosporins was high (68.5%), particularly against second-generation cefuroxime (97.8%), whereas cefepime, a fourth-generation antibiotic, showed the highest sensitivity (30%). Biofilm production was detected in 62.2% of isolates, while β-lactamase production was observed in 63.5%, both contributing to multidrug resistance. This research provides the first comprehensive evaluation of cephalosporin efficacy against UTI pathogens in Baghdad, combining antimicrobial susceptibility testing with virulence factor analysis. The findings highlight the urgent need for continuous surveillance of antibiotic resistance, rational prescription practices, and consideration of advanced-generation cephalosporins or alternative therapies to manage UTIs effectively.

Highlights:

1. Escherichia coli accounted for 82.14% of UTI cases, with infections significantly higher in females (84.95%) than males.
2. Bacterial isolates showed a high resistance rate of 68.5% to cephalosporin antibiotics, with the highest resistance to cefuroxime (97.8%).
3. Virulence factors were prominent, with 62.2% of isolates forming biofilms and 63.5% producing β-lactamase enzymes.

Keywords: Antibiotic resistance, Uropathogens

Introduction

Urinary tract infections (UTIs) are inflammatory disorders caused by the abnormal proliferation of microorganisms in the urinary tract. Annually, around 150 million UTIs are diagnosed globally, resulting in healthcare costs of at least $6 billion [1]. UTIs rank just behind lower respiratory tract infections, accounting 24% of these cases in developing nations [2].

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Women have a higher likelihood to develop UTIs at various stages of their lives, and with over 20% suffering recurrent UTIs [3]. UTIs, especially during pregnancy, may recur and pose significant risks for both mother and developing baby. Recurrent UTIs frequently occur among older adults. Reports suggested that 50%-60% of women will encounter at least one infection during their lifetime [4].

Cephalosporins belong to class of beta-lactam antibiotics. Their extensive applications can be attributed to their high efficacy and minimal adverse effects As a result, there has been a rise in antibiotic resistance, particularly with cephalosporins, among pathogens [5]. requiring ongoing assessment of the antibiotic sensitivity of the pathogen responsible for urinary tract infections [6].

This study aimed to investigate the susceptibility of UTI pathogens against cephalosporins. By acquiring updated epidemiological data which is crucial, as it can potentially anticipate insight into recent advancements in cephalosporin therapies for UTIs.

Materials And Methods

Collection of bacterial isolates

A total of 140 bacterial isolates were obtained from Al-Shaheed Al-Sadr General Hospital, Ibn Al-Baladi Hospital for Children, and the Gynecology department in Baghdad Governorate. The identification of isolates were conducted utilizing the VITEK 2 technique, with the samples obtained from the urine of patients diagnosed with UTIs.

Sensitivity testing of bacterial isolates to antibiotics

The method described by [7] Mehmood et al (2024) was employed , utilizing the Kirby–Bauer disk diffusion method to assess bacterial sensitivity to antibiotics, by the utilization of Mueller–Hinton agar as the growth medium. Fourteen types of antibiotics belonging to cephalosporin family have been accredited, as shown in (Table 1).The results were analyzed in accordance with the Clinical Laboratory Standards Institute (CLSI) guidelines (2025).

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Table 1 Types of Cephalosporin antibiotics classified by generation and used in this study.

No.	code	Antibiotics
First generation		
1	KF	Cephalothin
2	CN	Cephalexin
3	KZ	Cefazolin
Second generation		
4	CXM	Cefuroxime
5	CX	Cefoxitin
Third generation		
6	CFP	Cefoperazone
7	CFM	Cefixime
8	CTR	Ceftriaxone
9	CDR	Cefdinir
10	CPD	Cefpodoxime
11	CAZ	Ceftazidime
12	CTX	Cefotaxime
Fourth generation		
13	FEP	Cefepime
14	CR	Cefpirome

Investigation of some virulence factors of bacterial isolates

Detection of the ability of bacterial isolates to form biofilms

The Congo red agar method, as described by [8], was utilized to assess the susceptibility of isolates for biofilm production. The formulation included37 g/L of Brain Heart Infusion broth medium and 10 g/L of agar, followed by the addition of 80 g/L of glucose to the medium. A suspension of Congo red dye at a concentration of 0.8 g/L Congo red dye was prepared, followed by autoclaving of the dye suspension separately from the medium. The dye was added into the medium once the agar temperature had lowered to 55°C. Plates were cultured and incubated for a duration of 48 hours at a temperature of 37°C. Isolates that produced biofilm displayed a gray or black color, whereas strains that did not produce biofilm retained a white or pink coloration.

Detection of Beta-Lactamase (ESBL) production in bacterial isolates

The double disc synergy test method was employed . Following the spreading of bacteria onto Mueller–Hinton agar medium, a disc with 30 µg of the antibiotic Cefotaxime and another with 30 µg of the antibiotic Ceftazidime was positioned, with 30 µg of the antibiotic Amoxicillin-clavulanate was placed in between them [9].

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Results

Collection of bacterial isolates

A total of 140 bacterial isolates were obtained from the urine samples of both male and female patients diagnosed with UTIs.. The study revealed that *Escherichia coli* was accounted for the highest percentage of total infections, with findings indicated that that *E. coli* bacteria were the most predominant cause of UTIs in females, comprising 82.14%,.The current study indicated that the bacterial isolates with the lowest likelihood of causing urinary tract infections are *Pseudomonas aeruginosa* and *Staphylococcus saprophyticus*. As shown in (Table 2).

Table 2 Types of Bacterial isolates, overall infection rates, and gender-based infection distribution

Type the Isolate bacteria	(%) incidence rate	incidence rate(%)	
		Females	Males
Escherichia coli	82.14%	69.28%	12.86%
Klebsiella pneumoniae	7.14%	6.42%	0.72%
Staphylococcus aureus	3.57%	2.85%	0.72%
Proteus mirabilis	2.86%	2.14%	0.72%
Enterococcus faecium	1.42%	1.42%	0%
Morganella morganii	1.42%	1.42%	0%
Pseudomonas aeruginosa	0.71%	0.71%	0%
Staphylococcus saprophyticus	0.71%	0.71%	0%
incidence rate(%)	**99.97%**	**84.95%**	**15.02%**

Antibiotic Sensitivity Testing of Bacterial Isolates

A total of 140 bacterial isolates were tested against 14 different cephalosporin antibiotics. The isolates exhibited multi-resistance to all antibiotics, with a prevalence rate of 68.5%.The sensitivity to antibiotics was observed to be 31.5%. The isolates exhibited the highest resistance rate to the second-generation CXM antibiotic, reaching 97.8%. The antibiotic that demonstrated the highest sensitivity among the fourth-generation cephalosporin antibiotic FEP, exhibiting a sensitivity rate of 30%. The isolates exhibited 76% resistance rate to the well-known third-generation cephalosporin antibiotic, CTR, also referred to as Ceftriaxone, as illustrated in Figure. 1.

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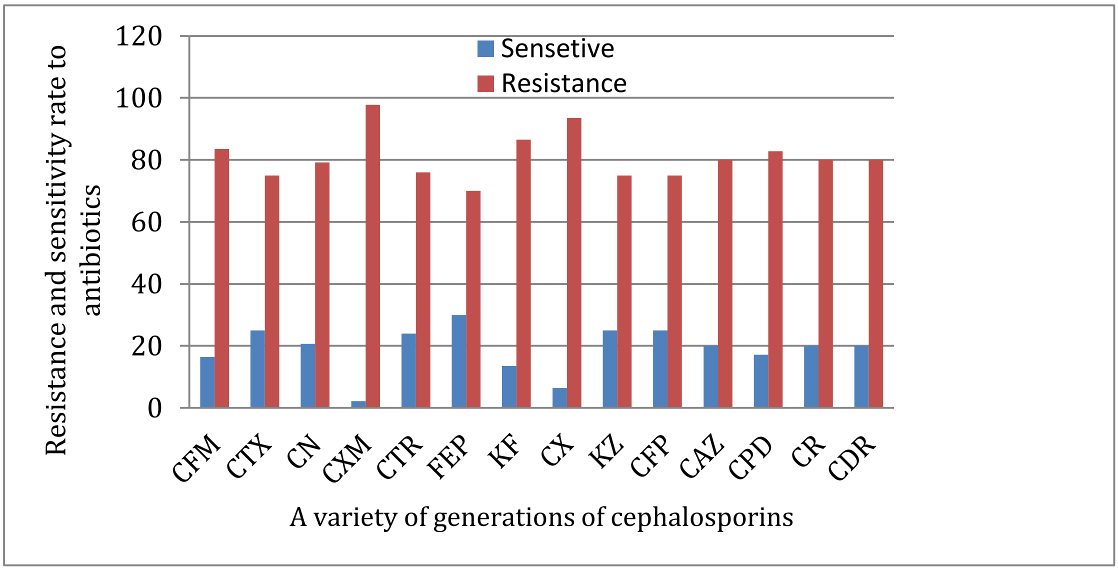

Figure 1. Antibiotic Resistance and Susceptibility Patterns Across Cephalosporin Generations

Investigation of some virulence factors of bacterial isolates

Detection of Biofilm Formation in Bacterial Isolates

A total of 82 bacterial isolates were evaluated for their ability to produce biofilms, with selection criteria based on their multiple resistance to antibiotics of the cephalosporin family. The isolates demonstrated a biofilm formation capacity of 62.2%, as illustrated in Figure. 2.

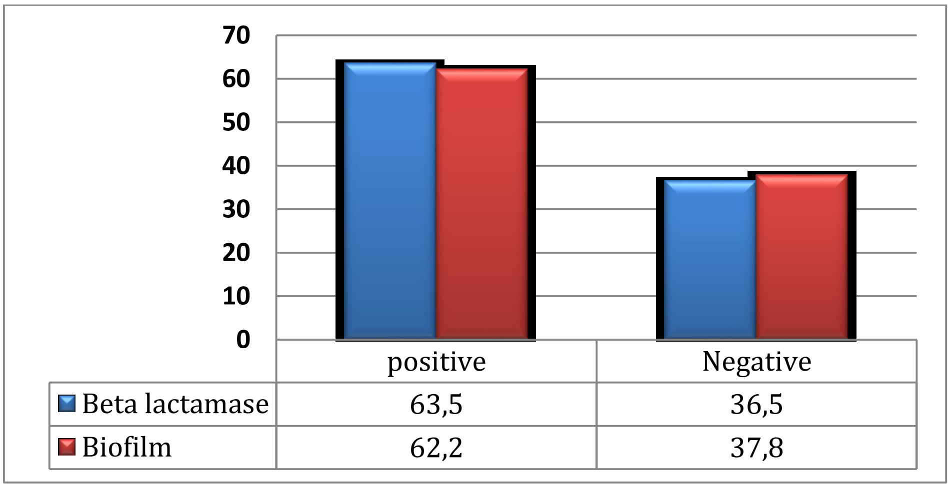

Figure 2. Percentages of Bacterial Isolates Positive and Negative for Biofilm Formation and Beta-Lactamase Production

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Testing Bacterial Isolates for Extended-Spectrum Beta-Lactamase (ESBL) Production

A total of 82 antibiotic-resistant bacterial isolates underwent double disc synergy test to investigate their ability to produce beta-lactamase enzymes. The bacterial isolates demonstrated 63.5% positive results for the production of β-lactamase enzymes, as illustrated in Figure 2. The diffusion of the amoxicillin-clavulanate antibiotic inhibited the beta-lactamase enzymes associated with Cefotaxime and Ceftazidime, subsequently affected the diffusion of cephalosporin antibiotics The results in inhibitory effectiveness, with the inhibition zone resembling a key, as illustrated in Figure. 3.

Figure 3. Positive Results for Beta-Lactamase Production Using the Double-Disc Synergy Test

Discussion

The incidence of urinary tract infections among females was 84.95%, and among males it was 15.02%. Studies by [10, 11, 12] discussed why females suffer more from urinary tract infections than males. These include anatomical factors such as the longer urethra of males compared to the shorter urethra of females, and the proximity of the anus to the urethra. Hormonal factors include the loss of estrogen, especially after menopause, which makes the urinary tract susceptible to infection due to its role in maintaining the lactobacilli bacteria that protect against disease. Sexual intercourse may also increase the risk of UTIs. The results of this study are consistent with what [13] found, that most UTI infections are caused by *E. coli* bacteria.

The majority of bacterial isolates demonstrated resistance to cephalosporin antibiotics, as concluded by [14] Resistance of bacteria, especially Enterobacteriaceae, to cephalosporin antibiotics. The resistance rate observed in bacterial isolates against different cephalosporin antibiotics was recorded at 68.5%. [15] explained three distinct mechanisms that enabled isolates to resist cephalosporin antibiotics. Bacterial isolates possessed enzymes that disrupted the effectiveness of antibiotics, with beta-lactamase enzymes being the most

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prominent among them. These enzymes were characterized by their ability to break the beta-lactam ring based on the principle of hydrolysis. The bacterial isolates examined demonstrated a 63.5% ability for enzyme production. The ability of bacteria to modify the protein that was targeted by cephalosporin antibiotics, This phenomenon can be attributed to mutations that alter the protein, resulting in reduced affinity for beta-lactam antibiotics, or the ability of bacteria to adapt their proteins in a way that prevents binding to the beta-lactam structure. (III) The quantities of antibiotics that effectively reach their intended targets plays a significant role in the development of antibiotic-resistant phenotypes.

[16] demonstrated that bacteria can obtain resistance genes, including beta-lactam enzymes through plasmids. These plasmids facilitate the transfer of beta-lactam enzyme trait , thereby enhancing the spread of bacterial resistance to cephalosporin antibiotics.

[17] stated that for a contributing factor to bacterial resistance to cephalosporin antibiotics is the enhanced activity of efflux pumps, as these pumps work to expel antibiotics from the cell.

The results of this study aligned with those reported by [18] which indicated that the significant proportion of UTIs can generate biofilm at a rate of 50%. A study conducted by [19] reported that bacteria capable of forming biofilms exhibited a elevated resistance to antibiotics, attributed to mechanisms such as a polymeric matrix encasing the bacteria that reduced the penetration of antibiotics into the bacteria, the effectiveness of the antibiotic reduced as a result of its interaction with the biofilm and lastly alteration in metabolic activity due to the development of biofilm formation.

A study conducted by [20] demonstrated that all bacterial isolates obtained from patients with UTIs exhibited 100% ability to produce beta-lactam enzymes. Consequently, the results of this study aligned with this current study related to the ability of bacterial isolates to produce beta-lactam enzymes Research by [21, 22] indicated that the routine and excessive use of beta-lactam antibiotics contributed to the proliferation of resistant strains, , which also increased their release into hospital wastewater. This pollution subsequently facilitated the spread of strains resistant to cephalosporin antibiotics.

Conclusion

The majority of UTIs in women are predominantly attributed to *E. coli* bacteria, followed by other microbial pathogens. Furthermore, the majority of bacterial pathogens responsible for UTIs exhibited resistance to various cephalosporin antibiotics, attributed to their ability to produce beta-lactamase enzymes and form biofilms.

Conflict Of Interest Statement

The author declares no conflicts of interest.

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