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Progression of Antibiotic Resistance in Uropathogens over Five Years: A Retrospective Study in Nineveh, Iraq

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ABSTRACT

Background: Antibiotic resistance arises due to the overuse of antibiotics, leading to bacterial strains becoming resistant to previously effective treatments. This can result in infections that are harder to treat and can lead to longer hospital stays, increased healthcare costs, and even mortality.
Objectives: To determine the most common bacterial uropathogens and their sensitivity to antibiotics among patients diagnosed with urinary tract infections (UTIs).
Materials and methods: In Mosul, Iraq, researchers conducted a retrospective cross-sectional analysis to evaluate the effectiveness of antibiotics commonly used to treat UTIs. In this study, researchers collected and analyzed urine samples from three centers that conducted culture and sensitivity tests over five years, from January 2018 to December 2022.
Results: Of the 1326 urine samples collected during the study period, 1265 (95.5%) showed significant bacteriuria caused by a variety of bacterial strains, with *Escherichia coli* being the most common. The study evaluated the effectiveness of 21 antibiotics frequently used to treat UTIs against the identified bacterial strains. The results indicated that only a limited number of antibiotics have shown effectiveness against particular strains of *Escherichia coli*, with a mere 10 out of the 21 drugs exhibiting significant antibacterial efficiency. The presence of bacterial resistance to all tested antibiotics was observed, indicating a significant prevalence of antibiotic resistance and a decline in the availability of effective antibiotics.
Conclusion: This study revealed a concerning rise in antibiotic resistance in bacterial strains responsible for UTIs, as well as multidrug resistance, especially among gram-negative bacteria.
Keywords: Antibacterial Drug Resistance; Uropathogens; Antibiotics; Urinary tract infections; Multidrug Resistance.

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INTRODUCTION

Antibiotic resistance in pathogenic microorganisms can be comprehensively defined from both microbiological and therapeutic aspects: Microbial resistance is the existence of a genetically defined (acquired or mutated) resistance mechanism that determines whether a pathogen is resistant or susceptible based on the use of a phenotypic laboratory test. While clinical resistance is a degree of antimicrobial activity that is connected to a high risk of therapeutic failure. In other words, it is better to treat a bacterial infection with a treatment to which it has tested vulnerable rather than one to which it has tested resistant [1, 2].

Antibiotic resistance can be acquired or inherent, with the former occurring in all isolates of that species. Examples of inherent antibiotic resistance include Pseudomonas aeruginosa's natural resistance to multiple antibiotics, Enterobacteriaceae's resistance to glycopeptides and linezolid, and all Gram-positive bacteria's resistance to colistin. Additionally, bacteria may acquire resistance. This occurs when a particular kind of bacteria adapts to the antibiotic, sparing it from destruction. Bacteria can acquire resistance in two ways: either by obtaining DNA from other resistant bacteria or by creating a novel genetic modification that promotes the bacterium's survival [2].

Antibiotic resistance is becoming a major global concern, despite little successful antibiotic development. *Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae,*

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Acinetobacter baumannii, Pseudomonas aeruginosa, and *Enterobacter spp.* are of greatest importance. These microorganisms are especially relevant to nosocomial infections, as are other *Enterobacteriaceae* (e.g., *Escherichia coli*), *Mycobacterium tuberculosis*, and *Neisseria gonorrhoeae* [3]. As antibiotic medications lose their effectiveness and antibiotic-resistant infections persist in the body, the risk of morbidity and mortality increases significantly. In addition, the majority of antibiotic-resistant infections require more frequent follow-up appointments with doctors, prolonged hospital stays, and the use of expensive, toxic alternative antibiotics [4]. Since antibiotic resistance and antibiotic use are correlated, better antimicrobial preservation, along with infection prevention and diagnosis, can help preserve the antimicrobial agents that are currently on the market. To keep up with the rise in resistance, there needs to be significant global action and investment from both the public and private sectors [5].

Urinary tract infections (UTIs) are one of the most prevalent bacterial infections in the human urinary system worldwide, caused by the presence and development of microorganisms in the genitourinary tract system [6]. The National Ambulatory Medical Care Survey reports that UTIs cause nearly seven million outpatient visits and up to one million hospital emergency room visits, leading to approximately 100,000 hospitalizations [7]. The majority of these infections, which can be symptomatic or asymptomatic, affect the lower urinary tract. Patients with significant bacteriuria, associated bladder mucosal invasion, or inflammation of the renal parenchyma, calices, or pelvis in acute pyelonephritis or acute cystitis, respectively, are considered symptomatic UTIs. Significant bacteriuria without the signs or symptoms of an acute UTI is referred to as asymptomatic bacteriuria [8, 9].

In countries with limited resources, the emergence of antimicrobial resistance in the treatment of UTIs poses a serious threat to public health due to a lack of infrastructure, the spread of fake medications, and the use of antibiotics without a prescription. Different bacteria, antibiotics, geographical regions, and institutions have varying antimicrobial resistance patterns regarding urinary tract isolates [10]. Therefore, it is essential to research the susceptibility profile of frequently used antibiotics at regular intervals to provide reliable information for the clinical management of infections because of the changing trend of antibiotic resistance. The purpose of this study was to find out the prevalence of bacteria associated with UTI in symptomatic patients as well as the antimicrobial susceptibility pattern of commonly used antibiotics among patients attending Mosul hospitals and private doctors' clinics in Iraq.

MATERIALS AND METHODS

Ethical approval

This study got ethical approval from Collegiate Committee for Medical Research Ethics, University of Mosul, Ministry of Higher Education and Scientific Research , 8/10/2022, Code CCMRE-phA-22-17.

Study Design and Setting

This was a retrospective cross-sectional analysis conducted at the College of Pharmacy, University of Mosul, in Nineveh, Iraq. We collected and analyzed urine samples from three different centers that performed culture and sensitivity tests over five years, from January 2018 to December 2022. These centers included: Dr. Wahda Al-Neaemi, Dr. Muna Kashmola, and Al-Sabah laboratories. We selected samples using a convenient sampling technique, as all participants were required to undergo culture and sensitivity tests as part of their laboratory investigations, in compliance with medical requirements. Based on inclusion and exclusion criteria, the study included the findings of all patients who underwent culture and sensitivity tests in the mentioned centers during the relevant period.

Inclusion criteria

- Patients diagnosed clinically with UTI who required culture and sensitivity tests to choose the right antibiotics.
- Patient with a history of recurrent UTI with or without antibiotic use.
- All age groups and both genders.

Exclusion criteria

- In-patients or those who have been hospitalized within the previous two months.
- Patients with catheters.
- Patients who had been using antibiotics within two weeks.
- Patients with structural abnormalities in the urinary tract.
- Patients who had been diagnosed with an acute infectious illness other than a UTI.
- Nosocomial infection.
- Tuberculosis of the urinary tract.
- Patient who refuses to join to study.

Samples collection and urine processing

We collected midstream urine samples in a sterile container and processed them within two hours of collection. Using a calibrated (1 μL) loop, a urine sample was inoculated onto a standard culture. We used three different types of agar media to culture urine samples: 5% sheep blood agar, a non-selective, universal agar medium; MacConkey agar, a selective culture medium for Gram-negative bacteria; and UriSelect 4 agar, a non-selective chromogenic medium to show the growth of various Gram-negative urinary pathogens) [11]. Culture plates were incubated for 24 hours in an ambient air incubator at 35–37°C. We examined the culture plates for the presence of bacterial colonies [6]. We identified the pure colony using gram stain and colony morphology. Positive urine cultures were further recognized by the features that appeared on the appropriate media and were verified by the biochemical reaction [12].

We conducted a sensitivity test on 21 antibiotics, selecting them due to their high prescription rates for UTIs and their availability. It was done by using antibiotic discs, and their concentrations in μg were as follows: amikacin (30), co-amoxiclave: amoxicillin/clavulanic acid (30), cefotaxime (30), cefalothin (30), cephalexin (30), cephadroxil (30), cefepim (30), cefaclor (30), ciprofloxacin (5), cotrimoxazole trimethoprim-sulphamethoxazole (25), gentamicin (10), imipenem (10), meropenem (10), nalidixic acid (30), nitrofurantoin, (30), ofloxacin (5), ampicillin-cloxacillin (20), ceftriaxone (30), levofloxacin (5), norfloxacin (10) and the streptomycin (10). The inhibition zone of antibiotics was measured and interpreted according to the Kirby Bauer disk diffusion susceptibility test protocol [13]. The term susceptible, intermediately sensitive, or resistance are defined as:

Susceptible (s): A bacterial strain is said to be susceptible when it is in vitro inhibited by an antibiotic at a concentration that is expected to have a successful therapeutic result.

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Intermediate (i): A bacterial strain's sensitivity to an antibiotic is said to be intermediate when it suppresses the bacterial strain in vitro at a concentration of that antibiotic that is associated with an unidentified therapeutic effect.

Resistant (r): If a concentration of an antibiotic suppresses a bacterial strain in vitro at a risk of treatment failure, it is considered resistant to that antibiotic [14].

Statistical analysis

We managed the data using Microsoft Excel 2013 and analyzed them using the Statistical Package for the Social Sciences (SPSS) version 24. We presented categorical variables as frequency and percent. While continuous variables were presented as mean ± SD. A Chi-square test was used for the frequencies of non-parametric data. Antibiotic susceptibility and resistance for *Escherichia coli* were tested using a paired t-test and a one-way ANOVA. The differences in values were considered significant when P-value < 0.001, 0.05, and 0.01 using Tukey's post hoc analysis. A P-value < 0.05 was considered as a statistically significant difference when a Chi-square test was used.

RESULTS

Socio-Demographic Characteristics

The age range was within 3-82 years, with a mean age of 34.8 ± 17.3 years. About half of the participants were in two age groups 20-29 and 30-39 years old. The females (n = 604, 92.5%) were far larger than the males. The percentage of participants for each year was 16.2, 20.2, 20.2, 19.9, and 23.4 for 2018, 2019, 2020, 2021, and 2022 respectively (Table 1).

Causative pathogens

We collected a total of 1326 urine samples for culture and sensitivity over five years. Among these, 1265 samples (95.5%) yielded significant bacteriuria and 60 samples (4.5%) showed no growth. The results of the culture showed various types of bacterial causes of the UTIs, out of them, 653 (51.66%) were *Escherichia coli*. Other types included *Acinetobacter* (0.58%), *Enterobacter* (7.33%), *Klebsiella* (0.39%), *Proteus* (0.77%), *Pseudomonas species* (1.54%), *Staphylococcus species* (37.59%), and *Streptococcus species* (0.19%). There was a statistically significant (P-value = 0.0001) difference among isolated pathogens (Table 2).

Table 1. Socio-demographic characteristics of the participants.

Variable	Frequency	Percent(%)
Age group (per years)		
< 20	89	13.6
20-29	181	27.7
30-39	147	22.6
40-49	111	17.0
50-59	61	9.4
60-69	33	5.1
≥ 70	31	4.7
Gender		
Male	49	7.5
Female	604	92.5
Date		
2018	106	16.2
2019	132	20.2
2020	132	20.2
2021	130	19.9
2022	153	23.4
Total	653	

Antibiotic susceptibility pattern

The culture results revealed that *Escherichia coli* exhibited a high percentage of antibiotic resistance, and in addition they may show some multidrug-resistant pathogens. In the beta-lactam class, resistance percentages for certain drugs, such as narrow and extended-spectrum penicillin, and first and second-generation cephalosporins, were high, and sometimes reached 100%. For instance, we detected no sensitive pathogen in 282 cephalexin cultures of *Escherichia coli* conducted over five years. Adding a beta-lactamase inhibitor (clavulanic acid) did not make the susceptibility pattern much better, but adding a beta-lactamase-resistant penicillin (cloxacillin) made the bacteria more sensitive to antibiotics. However, the resistance rates did not fall below 90%, except in 2018, when they were 88.4%. The third-generation cephalosporin displayed a high resistance ratio, and resistance increased with time. For example, the resistance to cefotaxime increased from 75.6% in 2018 to 100% in 2021 and 2022. The fourth-generation cephalosporin, cefepime, also displayed an increase in bacterial resistance to antibiotics over the years, and its susceptibility fell to zero in 174 cultures conducted in 2020, 2021, and 2022. Carbapenems demonstrated good antibiotic activity against *Escherichia coli*, but the highest resistance percentage toward imipenem was observed in 2022, reaching 20.9%. The highest resistance ratio toward meropenem was detected in 2021, reaching 40%. The next group under consideration is the aminoglycosides: amikacin, gentamycin, and streptomycin, which were included in this study. Despite their strong antibiotic activity against *Escherichia coli* and widespread use in UTI treatment, these antibiotics exhibited high resistance rates, with gentamycin showing the highest resistance, reaching a peak value of 93% in 2020. *Escherichia coli's* susceptibility to aminoglycosides decreased over time.

The non-fluorinated quinolone, nalidixic acid, had a high bacterial resistance to its action in the last five years, surpassing 90% in the last four years. Several fluorinated quinolones, like ciprofloxacin, norfloxacin, ofloxacin, and levofloxacin, also had high resistance rates. However, lev-

Table 2. The prevalence of uropathogens among the urinary isolates. A Chi-square test was used, and the P-value=0.0001.

Bacteria	Frequency	Percent(%)
Acinetobacter	7	0.58
Escherichia coli	653	51.66
Enterobacter•	93	7.33
Klebsiella	5	0.39
Proteus	10	0.77
Pseudomonas species	19	1.54
Staphylococcus species	475	37.59
Streptococcus species	2	0.19
Total	1265	100

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Table 3. Percentage of antibiotics susceptibility/resistance for *Escherichia coli* in urine culture *.

Antibiotics	2018				2019				2020				2021				2022			
	n	S(%)	I(%)	R(%)	n	S(%)	I(%)	R(%)	n	S(%)	I(%)	R(%)	n	S(%)	I(%)	R(%)	n	S(%)	I(%)	R(%)
Co-amoxiclav	98	0	6.1	93.9	132	0	3	97	132	0	0	100	130	0	0	100	153	0	0	100
Ampicillin+ Cloxacillin	86	2.3	9.3	88.4	130	1.5	4.6	93.8	132	1.5	6.1	92.4	130	1.5	4.6	93.8	150	6	2.7	91.3
Cephalothin	62	0	0.0	100	101	0	2	98	91	0	18.7	81.3	64	0	9.4	90.6	75	0	4	96
Cephalexin	36	0	0.0	100	33	0	0	100	55	0	0	100	75	0	0	100	83	0	0	100
Cephadroxil	96	4.2	8.3	87.5	132	1.5	1.5	97	122	1.6	2.4	96.1	130	0	1.5	98.5	143	2.6	3.9	93.5
Cefaclor	44	0	0.0	100	101	0	2	98	79	0	0	100	55	0	0	100	73	0	0	100
Ceftriaxone	86	2.3	7.0	90.7	130	0	4.6	95.4	132	0	1.5	98.5	126	0	3.2	96.8	153	2	4.6	93.5
Cefotaxime	90	4.4	20.0	75.6	130	0	1.5	98.5	123	0	1.6	98.4	112	0	0	100	150	0	0	100
Cefepime	86	0	23.3	76.7	53	3.8	22.6	73.6	44	0	0	100	50	0	0	100	80	0	0	100
Imipenem	30	66.7	20.0	13.3	16	75	25	0	34	79.4	20.6	0	74	85.1	14.9	0	91	69.2	9.9	20.9
Meropenem	0	0	0	0	14	85.7	14.1	0	89	80.9	15.7	3.4	60	56.7	3.3	40	62	85.5	14.5	0
Amikacin	96	2.1	29.2	68.8	126	11.9	50.8	37.3	129	3.9	46.5	49.6	128	0	47.7	52.3	147	4.1	40.8	55.1
Gentamycin	74	0.0	16.2	83.8	116	5.2	24.1	70.7	86	0	7	93	67	4.5	19.4	76.1	90	0	18.9	81.1
Streptomycin	70	14.3	45.7	40.0	66	9.1	50	40.9	82	0	57.3	42.7	90	0	40	60	123	2.4	21.1	76.4
Nalidixic acid	106	0	17.0	83.0	132	0	3	97	130	0	6.2	92.4	128	3.9	5.5	90.6	147	0	7.5	92.5
Ciprofloxacin	90	2.2	11.1	86.7	124	8.1	16.9	75	109	6.4	19.3	74.3	98	3.1	13.3	83.7	94	9.6	25.5	64.9
Norfloxacin	52	11.5	7.7	80.8	47	17	29.8	53.2	61	11.5	24.6	63.9	76	9.2	9.2	81.6	94	19.1	7.4	73.4
Ofloxacin	90	4.4	0.0	95.6	124	9.7	20.2	70.2	116	0	1.7	98.3	117	0	10.3	89.7	138	4.3	2.2	93.5
Levofloxacin	86	0	18.6	81.4	120	30	18.3	51.7	108	26.9	30.6	42.6	108	13.9	46.3	39.8	141	23.4	35.5	41.1
Co-trimoxazole	58	3.4	6.9	89.7	83	2.4	7.2	90.4	103	1.9	7.8	90.3	59	5.1	20.3	74.6	120	5.8	10	84.2
Nitrofurantoin	106	0	54.7	45.3	132	1.5	28.8	69.7	132	2.3	47	50.8	130	0	49.2	50.8	153	0	41.8	58.2

* n: number of cultured Escherichia coli strains, S (%) present of highly Susceptible pathogens, I (%) present of intermediately sensitive pathogens, R (%) present of resistance pathogens.

ofloxacin, the third-generation quinolone, worked better overall than ciprofloxacin, norfloxacin, and ofloxacin, the second-generation quinolones. According to this study, levofloxacin was the quinolone with the highest antibiotic activity against *Escherichia coli*.

Co-trimoxazole had a high resistance rate that exceeded 90% in 2019 and 2020. An approximately half of the cultured *Escherichia coli* strains in this study were susceptible to nitrofurantoin (Table 3).

Multiple drug resistance patterns

According to the results of the current investigation, only a small number of antibiotics–no more than 10 out of 21–were effective against a particular *Escherichia coli* strain. From 2018 to 2021, we found no strains resistant to all included antibiotics. However, in 2022, 3.9% of the participants showed bacteria with resistance to multiple antibiotics, including strains of *Escherichia coli* that were resistant to all tested antibiotics. Generally, the number of antibiotics that exhibited activity against the studied strains mainly fell into three groups, with 3–5 antibiotics being effective against the particular strain. The strains with lower susceptibility had a slightly higher incidence (Table 4).

DISCUSSION

This study conducted was conducted on antimicrobial identification and sensitivity tests over five years (January 2018 to December 2022) at three medical centers in Mosul. Out of the 1326 urine samples tested, 1265 showed bacteriuria. This indicates a growth rate of about 95%, which is a high rate of UTIs compared to 45% of those who have UTIs, which is the result observed by Al-Jebouri et al, in 2013 [15], and consistent with the result of Salman et al., 2022 [16].

The predominant bacterial species identified were *Escherichia coli*, which represented approximately 51% of all tested bacteria, followed by *Klebsiella species*, *Acinetobacter species*, and *Pseudomonas species*. These gram-negative organisms were found to be the most prevalent in all hospital units. The results in our study comply with the same findings of the study by Naqid, I.A. et al., which found that *Escherichia coli* was the most common uropathogenic isolate in Duhok province, followed by K. pneumonia [17]. Our results are also consistent with previous studies reporting *Escherichia coli* as the primary cause of UTIs [18]. Additionally, a meta-analysis reported an increase in drug-resistant *Escherichia coli* isolated from different sources, including human, animal, food, and environmental samples, from 2000 to 2018 [19].

The results also found that gram-positive *Staphylococcal species* (37.59%) were a common cause of UTIs, which is in agreement with evidence that Staphylococcus saprophyticus is the second most common cause of primary, non-obstructive UTIs in younger individuals, both male and female [20]. Our findings were aligned with previous studies conducted in African hospitals, which reported UTIs as a common issue in intensive care unit patients [21]. It was not surprising that female patients and those in the age groups of 20-29 and 30-39 years old had a higher risk of developing UTIs than their male counterparts and those in other age groups. Numerous factors contribute to this, such as the shorter urethra in females' urinary systems, which enables bacteria to swiftly

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Table 4. Multiple drug resistance pattern *.

Years	2018	2019	2020	2021	2022	2018–2022
Strains with resistance to all tested antibiotics	0(0%)	0(0%)	0(0%)	0(0%)	6(3.9%)	6(0.9%)
Strains with resistance to 20 of tested antibiotics	2(1.9%)	2(1.5%)	5(3.8%)	3(2.3%)	0(0%)	12(1.8%)
Strains with resistance to 19 of tested antibiotics	22(20.8%)	12(9.1%)	18(13.6%)	14(10.8%)	9(5.9%)	75(11.5%)$^{***,+++}$
Strains with resistance to 18 of tested antibiotics	30(28.3%)	40(30.35)	26(19.7%)	38(29.2%)	48(31.4%)	182(27.9%)$^{***,++,\wedge\wedge}$
Strains with resistance to 17 of tested antibiotics	24(22.6%)	35(26.5%)	33(25%)	48(36.9%)	32(20.9%)	172(26.3%)$^{***,++,\wedge\wedge}$
Strains with resistance to 16 of tested antibiotics	16(15.1%)	29(22.0%)	41(31.1%)	18(13.8%)	38(24.8%)	142(21.7%)$^{***,++,\wedge}$
Strains with resistance to 15 of tested antibiotics	12(11.3%)	10(7.6%)	5(3.8%)	7(5.4%)	14(9.2%)	48(7.4%)$^{**,++,a^3,b^3,c^2}$
Strains with resistance to 14 of tested antibiotics	0(0%)	2(1.5%)	4(3.0%)	0(0%)	6(3.9%)	12(1.8%) $^{\wedge\wedge,a^2,b^3,c^2,d^2}$
Strains with resistance to 13 of tested antibiotics	0(0%)	0(0%)	0(0%)	2(1.5%)	0(0%)	2(0.3%)$^{\wedge\wedge\wedge,a^3,b^3,c^3,d^3}$
Strains with resistance to 12 of tested antibiotics	0(0%)	2(1.5)	0(0%)	0(0%)	0(0%)	2(0.3%)$^{\wedge\wedge\wedge,a^3,b^3,c^3,d^3}$
Strains with resistance to 11 or less of tested antibiotics	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)$^{+,\wedge\wedge\wedge,a^3,b^3,c^3,d^3}$

* The results showed as frequency (percent). ** and ***P-value < 0.01 and 0.001 respectively in comparison to strains with resistance to all tested antibiotics. +, ++ and +++ P-value < 0.05, 0.01 and 0.001 respectively in comparison to strains with resistance to 20 of the tested antibiotics. ∧, ∧∧ and ∧ ∧ ∧ P-value < 0.05, 0.01 and 0.001 respectively in comparison to strains with resistance to 19 of the tested antibiotics. a^2 and a^3 P-value < 0.01 and 0.001 respectively in comparison to strains with resistance to 18 of the tested antibiotics. b^3 P-value < 0.001 in comparison to strains with resistance to 17 of the tested antibiotics. c^2 and c^3 P-value < 0.01 and 0.001 respectively in comparison to strains with resistance to 16 of the tested antibiotics. d^2 and d^3 P-value < 0.01 and 0.001 respectively in comparison to strains with resistance to 15 of the tested antibiotics. No significant difference was obtained when the total resistance for each year was compared to other years.

enter the bladder. Other prevalent risk factors for UTIs in young women include sexual intercourse [22].

Furthermore, the results highlighted the emergence of microbial resistance, particularly among gram-negative bacteria, which has been steadily increasing over the past years. This trend was consistent with reports from various regions worldwide, indicating the dangerous nature of this issue [23]. This study revealed a concerning increase in antibiotic resistance over the past few years. There are various possible reasons for this rise, including the inappropriate use of antibiotics, which has increased during the coronavirus disease 2019 (COVID-19) pandemic. In 2021, a staggering 70% of COVID-19 patients, whether as outpatients or inpatients, received antimicrobials due to non-specific symptoms that could potentially misidentify as a disease in areas where antibiotic use has increased [24]. Gram-negative bacteria, especially *Escherichia coli*, have become increasingly resistant to antimicrobial agents, posing a significant threat to public health worldwide due to the high morbidity and mortality rates associated with infections caused by these pathogens [25]. There are different ways for Gram-negative bacteria to become resistant to antibiotics. These include natural resistance and acquired resistance. Acquired resistance can happen when genes are transferred from one microorganism to another by plasmids (conjugation or transformation), integrons, and bacteriophages (transduction) [26]. These findings are consistent with trends observed in other regions worldwide, indicating a growing problem [25].

Several antibiotic families, including beta-lactamase inhibitors (such as clavulanic acid), penicillins, and first to fourth generation cephalosporins, are commonly used in Iraqi hospitals to treat and prevent different types of infections. However, the results indicate an increase in antibiotic resistance to cefepime over the past 5 years. Nitrofurantoin can also be used to treat uncomplicated UTIs [27]. All strains of S. aureus are resistant to natural penicillin, amino-penicillin, and anti-pseudomonal penicillin. Resistance to these drugs occurs because of the acquisition of genes that encode drug-inactivating enzymes [28].

The resistance rate in this study showed a higher resistance rate compared to many studies conducted in our locality [15, 16]. The setting may have contributed to this, as the patients in this study underwent culture and sensitivity tests following treatment failure. They typically reflect people who have UTIs and use inadequate antibiotic regimens; hence, the rate of resistance in these patients is typically higher than the rate of resistance in the general population. Although, it is bad practice, it is well known that patients in our locality do not preform culture and sensitivity tests before starting an antibiotic treatment or to confirm the correct choice of antibiotics, so peoples who come to have culture and sensitivity tests usually had infections for a long duration and use inef-

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fective treatment for a considerable period, which gives them a high chance of carrying resistance microorganisms. There are numerous studies that show that using antibiotics irrationally is a typical problem in the third world and that this is connected to an incredible rate of resistance [29].

The study's large participant count and extended duration revealed a high prevalence of multiple antibiotic-resistant bacteria, detectable even by a routine medical base. The available culture and sensitivity tests were limited and did not provide a reliable indication of the bacterial susceptibility pattern. This may be due to the small sample size, limited centers, and short duration of the study. These were considered the limitations of the current investigation. Due to the above-mentioned limitations, the results of the study cannot be generalized

CONCLUSION

Escherichia coli was found to be the most common pathogen, followed by *Klebsiella species* , *Acinetobacter species*, and *Pseudomonas species*. *Staphylococcal species* were also identified as a common cause of UTI. Female patients and those in the age groups of 20–29 and 30–39 years had a higher risk of developing UTIs than their male counterparts and those in other age groups. The study also revealed a concerning increase in antibiotic resistance, particularly among gram-negative bacteria, over the past few years, which could be attributed to various factors, including the inappropriate use of antibiotics. The emergence of antimicrobial resistance is a growing problem and poses a significant threat to public health worldwide. The study highlights the need for appropriate antimicrobial stewardship programs to minimize the emergence and spread of resistance.

ETHICAL DECLARATIONS

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Ethics Approval and Consent to Participate

The Collegiate Committee for Medical Research Ethics, University of Mosul, Ministry of Higher Education and Scientific Research, Iraq, approved this study. Due to the retrospective study, informed consent was not obtained from the participants.

Consent for Publication

Not applicable (no individual personal data included).

Availability of Data and Material

Data generated during this study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that there is no conflict of interest.

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Authors' Contributions

Al-Zidan RN developed the research idea and designed the research methods. While Yahya NA, Ibrahim HF, and Azeez AR were responsible for validating and analyzing the data and writing the draft. Finally, Al-Zidan RN and Abdulhakim A reviewed and edited the manuscript, and all the authors read and approved the final draft.

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