

Original article

Identification and Antibiotic Susceptibility Testing of Bacterial Profiles in Libyan Diabetic Patients with Urinary Tract Infections

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Abstract

Diabetes mellitus is becoming remarkably more prevalent worldwide, and over time, it has a substantial effect on the genitourinary system, increasing the risk of urinary tract infections in diabetic patients. The purpose of this study is to reveal the distribution of uropathogens in diabetic patients according to age and sex, as well as their corresponding resistance patterns. Finding an efficient antibiotic treatment that reduces the risk of UTIs in individuals with diabetes is another goal. A cross-sectional study was conducted from September to December 2024 concurrently at the diabetes and endocrinology departments in Diabetes and Endocrinology Hospital, Al Khalil Hospital, and Libyan Swiss Hospital in Tripoli, Libya, among individuals aged 15 and older. This study included a total of 70 diabetic patients, consisting of 25 males and 45 females. To gather data on the study participants' demographics, clinical features, and risk factors, a standardized questionnaire was employed. A 10-mL midstream urine specimen was collected and transported as soon as possible to the microbiology lab for culture and antimicrobial susceptibility testing to detect a resistant bacterial pattern. Data were analyzed using SPSS and Microsoft Excel. Among 70 diabetic patients, the overall prevalence of UTI was 69%, with most of them being females. The predominant bacterial isolate was *Escherichia coli* 20/48 (42%), followed by *Klebsiella pneumonia* 11/48 (23%) and *Staphylococcus aureus* 9/48 (19%). Gram-negative isolates exhibited moderate resistance to nitrofurantoin F and ciprofloxacin, whereas Gram-positive isolates showed a moderate level of resistance to nitrofurantoin and ciprofloxacin. This study's findings showed that *E. coli* isolates were the predominant pathogens, along with the presence of bacterial isolates exhibiting moderate and low resistance to commonly prescribed drugs, which in turn leaves clinicians with very few alternative drug options for the treatment of UTIs. As drug resistance among bacterial pathogens is an evolving process, routine surveillance and monitoring studies should be conducted to provide physicians with knowledge of updated and most effective empirical treatments for UTIs.

Keywords: Urinary Tract Infection, Diabetes Mellitus, Bacterial Profile, Antimicrobial Susceptibility Pattern.

Introduction

Diabetes mellitus (DM), commonly referred to as diabetes, is a harmful and persistent metabolic disorder characterized by persistently elevated blood glucose levels caused by either insufficient insulin production or the body's inability to use the insulin that is produced [1]. Globally, 422 million adults were estimated to live with diabetes in 2014. Diabetes caused 1.5 million deaths in 2012. Higher-than-optimal blood glucose resulted in an additional 2.2 million deaths by increasing the risks of cardiovascular and other disorders [2]. Type 2 diabetes affects the vast majority of individuals with diabetes. Previously, this mostly affected adults, but now it also impacts children.

The prevalence of DM is predicted to rise to 643 million (11.3%) by 2030 and 783 million (12.2%) by 2045, which is concerning [3,4]. In 2021, North Africa and the Middle East experienced consecutive outbreaks of diabetes mellitus (DM) at a rate of 39.4%, with Qatar seeming to be the most affected country at 76.1% among all of them. Although Africa's prevalence projection is the lowest among International Diabetes Federation (IDF) regions at 4.5%, it is expected to experience the highest increases in the number of people with diabetes by 2045, with a staggering 129% rise, resulting in approximately 55 million cases [1].

The most prevalent types of DM, type 1 and type 2, both have established diagnostic standards [1]. Type 1 diabetes mellitus (T1DM), often referred to as juvenile diabetes, constitutes 5-10% of individuals afflicted by this condition. It is defined by the autoimmune destruction of beta cells in the pancreatic islets that produce insulin. As a result, insulin is completely absent. T1DM can occur at any age; however, it is more frequently observed in children and adolescents. Conversely, approximately 90% of all cases of diabetes are type 2 diabetes, or T2DM. Insulin resistance describes the reduced response to insulin in type 2 diabetes. Insulin is ineffective in this state, and to maintain glucose homeostasis, insulin production initially rises. However, over time, insulin production declines, leading to type 2 diabetes. The majority of individuals with type 2 diabetes are over 45. Nonetheless, obesity, physical inactivity, and energy-dense meals are contributing factors to its rising prevalence in children, adolescents, and younger adults [5-7]. Insufficient insulin production or an inability to respond to it results in elevated blood sugar levels, which can damage various organs or systems, particularly the nerves and arteries [8].

Glycosylated hemoglobin (HbA1c) is a form of hemoglobin that binds to sugar non-enzymatically. Patients exhibiting normal HbA1c levels are generally deemed to have managed diabetes, while those with abnormal HbA1c levels are classified as having unmanaged diabetes. An elevated or uncontrolled blood glucose level

can negatively affect the functioning of multiple body organs, leading to nephropathy, retinopathy, neuropathy, infarction, hypertension, arteriosclerosis, and stroke [9]. Controlled diabetes is associated with a significant decrease in the incidence of neuropathic and microvascular complications in type 2 diabetic patients [8].

DM is linked to reduced immunity, glycosuria, and bladder dysfunction, all of which increase a person's risk of developing a urinary tract infection (UTI). Urinary tract infections are more common in diabetics than in healthy individuals. Improper management of glucose levels increases the likelihood of UTIs in diabetics. UTIs in diabetic patients may present as either symptomatic or asymptomatic bacteriuria and are characterized by high prevalence, complexity, and complications. The most common type of UTI in diabetic individuals is asymptomatic, which can cause serious kidney damage and renal failure [10].

Numerous uropathogens can cause UTIs in diabetics, although the most commonly isolated species are *E. coli*, *K. pneumoniae*, *S. aureus*, and *A. baumannii* [8, 10, 11]. *E. coli* constitutes one of the most common bacteria that can impact all organs and systems in diabetics [12]. Therapeutic administration of insulin has been shown to significantly impact the transmission of infectious diseases among individuals with diabetes [8]. In fact, many Enterobacteriaceae, including *K. pneumoniae* and *Enterococcus faecalis*, proliferate more in the presence of insulin in the blood [8, 13]. Insulin promotes the production of the virulence factor aspartyl proteinase enzyme, which increases metabolic activity and facilitates biofilm formation, ultimately leading to bacterial resistance [13].

Antibiotic-resistant bacteria in the general population, and specifically in diabetics, pose a public health concern. Many Gram-negative bacteria responsible for UTIs produce the extended-spectrum β -lactamase (ESBL) enzyme, which is a major mechanism of drug resistance. This enzyme disassembles the β -lactam ring in penicillin, aztreonam, and first-, second-, and third-generation cephalosporins, enabling microorganisms to resist widely used antibiotics. Delays in identifying and reporting the production of ESBL by bacterial uropathogens often lead to increased mortality and morbidity rates, extended hospital stays, and higher medical expenses [10]. Moreover, urinary bacteria frequently become more resistant to the most widely used antimicrobial medications as a result of improper antibiotic administration [11]. Therefore, this study should prompt policymakers to formulate an antibiotic policy for the rational use of antibiotics. This study aims to identify the most common bacteria causing urinary tract infections in diabetic patients and their antibiotic resistance in relation to age and sex. A further goal is to find an effective antibiotic treatment that reduces the risk of UTIs in individuals with diabetes.

Methods

Study settings and population

A cross-sectional study was conducted concurrently at the diabetes and endocrinology departments in the Diabetes and Endocrinology Hospital, Al Khalil Hospital, and Libyan Swiss Hospital in Tripoli, Libya, over the course of four months, from September 2024 to December 2024, involving individuals aged 15 and above. A total of 70 diabetic individuals were recruited, comprising 25 males and 45 females.

Inclusion and exclusion criteria

This study included all diabetic patients, whether they were inpatients or outpatients, with or without symptoms of a UTI, who attended the diabetes and endocrinology departments at these hospitals during the research period. On the contrary, diabetic individuals who either declined to participate in the experiment or were pregnant, seriously ill, or undergoing antibiotic therapy were excluded.

Data collection

Written informed consent was obtained from each study participant prior to the collection of urine samples from diabetic patients. To gather data on the study participants' demographics, clinical features, and risk factors, a standardized questionnaire was used after receiving the necessary instructions.

Specimen collection

Approximately 10 mL of freshly voided midstream urine was collected from participants using a screw-capped, wide-mouth, sterile, leak-proof plastic container that was pre-labeled with the date, time, and identification code.

Specimen Transportation

The collected specimens were immediately transported to the microbiology lab of each diabetes and endocrinology hospital, Al Khalil Hospital, and Libyan Swiss Hospital, in an icebox, and processed within 30 minutes. Samples of urine that weren't processed in 30 minutes were kept at 4°C in a refrigerator.

Cultivation and Identification of Isolates

Midstream urine samples were transferred into 0.001 mL of Cystine Lactose Electrolyte Deficient (CLED) medium utilizing a calibrated wire loop. Colonies were counted in order to determine whether there had been any notable growth after cultures had been cultured for 24 hours at 37°C in an aerobic environment.

Significant bacteriuria refers to bacterial growth in urine with colony counts of $\geq 10^5$ CFU/mL. The isolates were then differentiated and identified based on colony morphology, Gram stain, and the key biochemical tests.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing (AST) of all identified bacterial isolates from significant bacteriuria specimens was conducted according to the criteria of the Clinical and Laboratory Standards Institute (CLSI) using the Kirby–Bauer disk diffusion method on Mueller–Hinton Agar. 24-hour pure culture colonies were suspended in 4 milliliters of physiological saline to produce bacterial inocula, ensuring that the turbidity achieved the 0.5 McFarland standard. A sterile cotton swab was dipped and rotated against the wall of the tube to remove excess fluid before being evenly inoculated on Mueller-Hinton agar, after which the antibiotic disks were placed on MHA plates.

Data analysis

Data analysis was performed using Statistical Package for the Social Sciences (SPSS) software version 27 and Microsoft Excel. Descriptive statistics were used to describe the demographic characteristics of the participants. Numerical data were presented as mean $\pm$ standard deviation or median as appropriate, while qualitative data were expressed as percentages (%) and frequencies.

Results

In the current study, 70 diabetic patients—both with and without symptoms of a urinary tract infection—were recruited from the diabetes and endocrinology departments of the Libyan Swiss Hospital, Al Khalil Hospital, and Diabetes and Endocrinology Hospital in Tripoli, Libya. As shown in Figure 1, out of all the research participants, 45 (64%) were female and 25 (36%) were male, making women the majority.

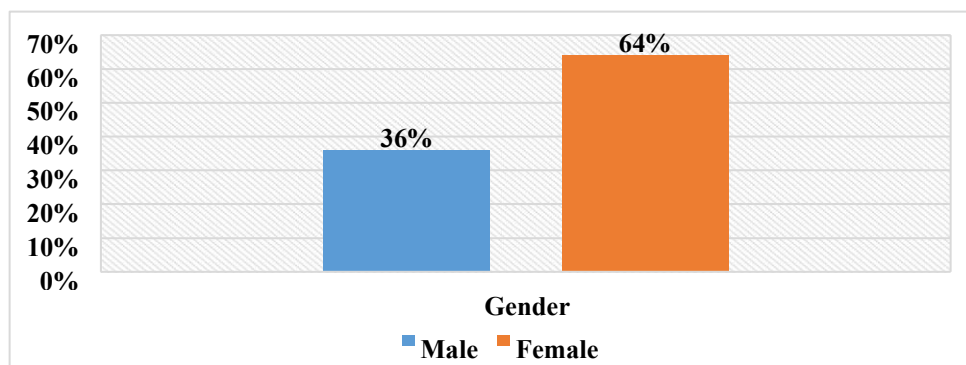


Figure (1). Frequency distribution of diabetic patients according to gender

According to the findings of this study, the highest number of patients with diabetes mellitus were in the age group of 50 years and above, with 51 (72.8%), followed by patients in the age group of 45-54 years, with 8 (11.4%), and the age group of 15-24 years, with 6 (8.6%). On the other hand, the lowest number of diabetes mellitus cases was in the age group between 25 and 44, with 5 (2.9%) and 3 (4.3%), respectively. Regarding participants' ages, which ranged from 15 to over 50, the mean age of the patients in this study was 61.1 ± 17.9 years, indicating that the majority of the diabetic patients were elderly, as listed below in Table 2.

Table 2. Frequency distribution of diabetic patients according to age

Age	Frequency (N)	Percent (%)
15-24	6	8.6%
25-34	2	2.9%
35-44	3	4.3%
45-54	8	11.4%
≥ 55	51	72.8%
Total	70	100%
M $\pm$ St.d	61.1 $\pm$ 17.9	

The data indicate that the prevalence of diabetic patients with positive urinary tract infections was higher at 48 (69%) than that of diabetic patients with negative urinary tract infections at 22 (31%), as summarized in (Figure 3).

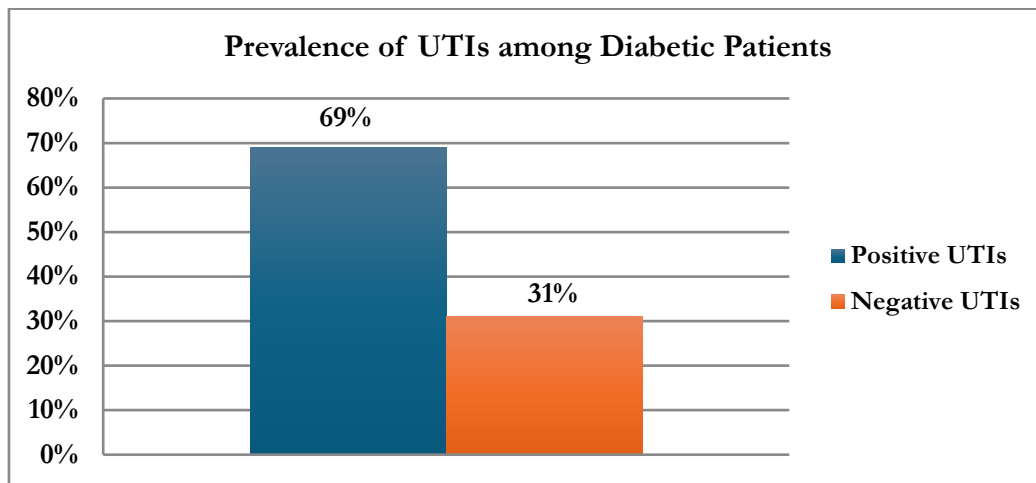


Figure 3. Prevalence of Urinary Tract Infection among Diabetic Patients

The results indicated that female diabetic patients had a significantly higher likelihood of developing a UTI, with 36 (75%) compared to males, 12 (25%), as shown in (Fig. 4).

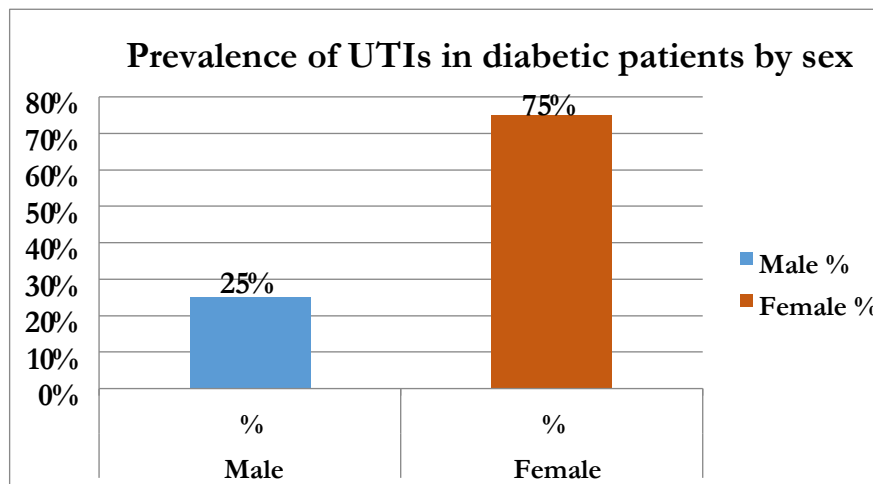


Figure 4. Prevalence of urinary tract infections in diabetic patients by sex

Concerning the age of the participants in this study, the highest number of diabetic patients with UTI was in the age group of 50 years and above, with 37 (77.1%), followed by patients in the age groups of 15-24 years and 45-54 years, with 4 (8.3%) at each. On the other hand, diabetic patients with UTIs who were between the ages of 25-34 and 40-44 made up the smallest percentage, with 2 (4.2%) and 1 (2.1%), respectively. Overall, the mean age of the patients in this study was 63.9 ± 14.52 years (Table 5).

Table 5. Prevalence of urinary tract infections in diabetic patients by age

Age (years)	Frequency (N)	Percent (%)
15-24	4	8.3%
25-34	2	4.2%
35-44	1	2.1%
45-54	4	8.3%
≥55	37	77.1%
Total	48	100%
M ± St.d	63.9±14.52	

This result indicates that there was an extremely high prevalence of *E. coli* infections (42%, 20 cases), whereas *K. pneumoniae* was found in 11 cases (23%), making it the second highest causative pathogen. The proportions of *S. aureus*, *Streptococci*, and *Enterococci* were 19%, 2%, and 2% respectively, while the other pathogens accounted for 8% of infections. Additionally, Gram-negative bacteria were more prevalent, 37 (77%), than Gram-positive bacteria, 11 (23%). Overall, the predominant isolated bacteria in this study were *E. coli* (Fig. 6).

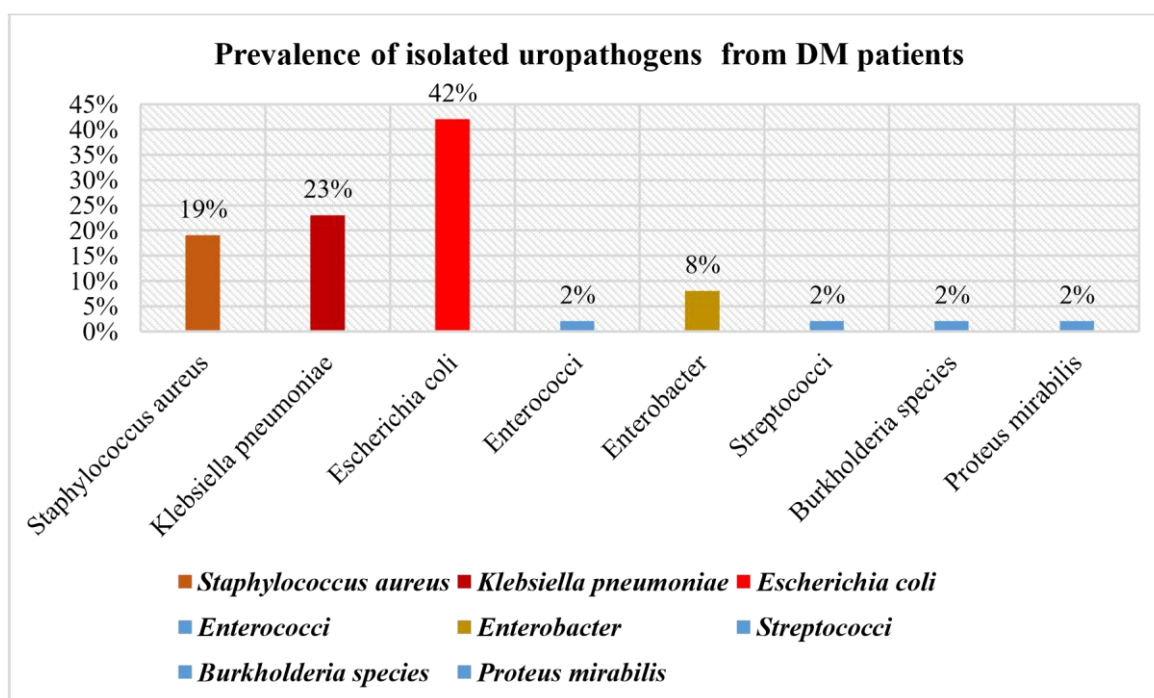


Figure 6. Prevalence of isolated uropathogens isolated from diabetic patients

Tables 7 and 8 collectively summarize the antimicrobial susceptibility patterns for the Gram-negative and Gram-positive isolates, respectively. Overall, among the Gram-negative isolates, ciprofloxacin proved to be the most effective antibiotic, with a sensitivity rate of 51.4%. In contrast, for the Gram-positive isolates, the most effective antibiotics were levofloxacin, meropenem, and vancomycin, each with a sensitivity rate of 36.36%. Furthermore, the antimicrobial susceptibility patterns of the Gram-positive bacterial isolates (Table 7) revealed that the most prevalent isolate, *S. aureus*, exhibited moderate resistance to both ciprofloxacin and nitrofurantoin and low resistance to other tested antibiotics. Nevertheless, it was found that trimethoprim-sulfamethoxazole, levofloxacin, and meropenem were the most sensitive antibiotics (33.3%), followed by amoxicillin-clavulanic acid and vancomycin (22.2%). Moreover, nitrofurantoin, amoxicillin-clavulanic acid, and vancomycin (100%) were highly effective antibiotics against *Enterococcus* species, whereas these species were resistant to ciprofloxacin and levofloxacin. Additionally, *Streptococcus* species were resistant only to trimethoprim-sulfamethoxazole but, conversely, were highly susceptible to ciprofloxacin, levofloxacin, and vancomycin (100%).

The antimicrobial susceptibility patterns of the Gram-negative bacterial isolates (Table 8) clearly indicated that *E. coli* exhibited 60% sensitivity to nitrofurantoin (F), 45% sensitivity to ciprofloxacin, 35% sensitivity to both amoxicillin-clavulanic acid and ceftriaxone, and 30% sensitivity to cefoxitin and cefotaxime. However, despite these levels of sensitivity, it exhibited moderate resistance to trimethoprim-sulfamethoxazole and ciprofloxacin (35%), as well as to nitrofurantoin (F), amoxicillin-clavulanic acid, and ceftriaxone. Moreover, *K. pneumoniae*, the second most prevalent Gram-negative isolate, demonstrated susceptibility to the majority of the antibiotics evaluated. Specifically, piperacillin-tazobactam exhibited the greatest sensitivity at 63.6%, followed by ceftriaxone at 36%, trimethoprim-sulfamethoxazole at 27.3%, ciprofloxacin at 45.5%, and nitrofurantoin at 27%. Nevertheless, it demonstrated moderate resistance to nitrofurantoin, ciprofloxacin, trimethoprim-sulfamethoxazole, and ceftriaxone.

In addition, for *Enterobacter* isolates, the most sensitive antibiotic was ciprofloxacin (CIP 100%), while resistance was observed only to nitrofurantoin (25%). Conversely, *Burkholderia* species exhibited high resistance to most of the tested antibiotics. In contrast, no resistance was observed for the majority of the antibiotics tested against the *Proteus mirabilis* isolate, thereby indicating their overall effectiveness.

Table 7. The antimicrobial susceptibility pattern of Gram-positive bacteria (n=11)

Uropathogens	Pattern	CIP	Nitrofurantin.	AMC	Levofloxacin	Meropenem	Cefuroxime	SXT	VA
Staphylococcus aureus (9)	S	(1) 11.1%	(2) 22.2%	(2) 22.2%	(3) 33.3%	(3) 33.3%	(2) 22.2%	(3) 33.3%	(2) 22.2%
	R	(4) 44.4%	(5) 55.5%	(2) 22.2%	(1) 11.1%	(1) 11.1%	(2) 22.2%	(1) 11.1%	(1) 11.1%
	I	(1) 11.1%	(0) 0%	(1) 11.1%	(1) 11.1%	(0) 0%	(0) 0%	(0) 0%	(1) 11.1%
Enterococci spp (1)	S	(0) 0%	(1) 100%	(1) 100%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(1) 100%
	R	(1) 100%	(0) 0%	(0) 0%	(1) 100%	(0) 0%	(0) 0%	(1) 100%	(0) 0%
	I	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
Streptococci spp (1)	S	(1) 100%	(0) 0%	(0) 0%	(1) 100%	(1) 100%	(0) 0%	(0) 0%	(1) 100%
	R	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(1) 100%	(0) 0%
	I	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%

Abbreviations: (AMC) Amoxicillin-clavulanic acid, (SXT) Trimethoprim-sulfamethoxazole, (VA) Vancomycin, (CIP) Ciprofloxacin *:

Table 8. Antimicrobial susceptibility pattern of the gram-negative bacteria (n=37)

<i>Uropathogens</i>	Pattern	CIP	Nitrofurantoin	AMC	CRO	CTX	Piperacillin Tazobactam T	SXT	Cefoxitin
<i>Klebsiella pneumoniae</i> (11)	S	(5) 45.5%	(3) 27%	(2) 18%	(4) 36%	(0) 0%	(7) 63.6%	(3) 27.3%	(1) 9%
	R	(5) 45.5%	(6) 54.5%	(0) 0%	(3) 27%	(0) 0%	(0) 0%	(4) 36.4%	(2) 18%
	I	(1) 9%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
<i>E. coli</i> (20)	S	(9) 45%	(12) 60%	(7) 35%	(7) 35%	(6) 30%	(3) 15%	(2) 10%	(1) 100%
	R	(7) 35%	(3) 15%	(3) 15%	(3) 15%	(3) 15%	(2) 10%	(7) 35%	(1) 5%
	I	(1) 5%	(1) 5%	(3) 15%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
<i>Enterobacter</i> (4)	S	(4) 100%	(2) 50%	(3) 75%	(0) 0%	(3) 75%	(1) 25%	(1) 25%	(2) 50%
	R	(0) 0%	(1) 5%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
	I	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
<i>Burkholderia</i> (1)	S	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
	R	(1) 100%	(1) 100%	(1) 100%	(1) 100%	(0) 0%	(0) 0%	(1) 100%	(1) 100%
	I	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
<i>Proteus mirabilis</i> (1)	S	(1) 100%	(0) 0%	(1) 100%	(1) 100%	(0) 0%	(0) 0%	(1) 100%	(1) 100%
	R	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%
	I	(0) 0%	(1) 100%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%	(0) 0%

Abbreviations: (AMC) Amoxicillin-clavulanic acid, (SXT) Trimethoprim-sulfamethoxazole, (CTX) cefotaxime, (CIP) Ciprofloxacin, (CRO) ceftriaxone *:

Discussion

Diabetes mellitus (DM) is a harmful and chronic metabolic disorder characterized by persistently high blood glucose levels, mainly as a result of defects in insulin action, secretion, or both [1, 2]. Furthermore, diabetes mellitus is associated with bladder dysfunction, glycosuria, and low immunity, all of which predispose an individual to urinary tract infections (UTIs) [2]. Accordingly, the purpose of this study was to evaluate the prevalence of UTIs among diabetic patients in Libya using a cross-sectional study and to identify the most common bacteria causing UTIs in diabetic patients and their antibiotic resistance in relation to age and sex. In terms of the gender distribution of all study participants, there were more females than males. Consistently, a Saudi Arabian study revealed that women had a greater proportion of diabetic patients than men (73.3% and 26.7%, respectively), which aligns with the current findings [14]. Similarly, research conducted in the United States found that a higher proportion of females (42% of males compared to 58% of females) had diabetes [14]. In addition, a different study indicated that women are more likely to develop diabetes than men due to their greater exposure to psychological problems and pressures, as well as stronger reactions when faced with certain shocks [15, 16]. However, those results disagree with Canadian findings, which reported a higher proportion of males than females (54% males, 46% females) with diabetes [14]. Moreover, Al-Nozha *et al.* found that the prevalence in males and females was 26.2% and 21.5% ($p < 0.00001$) [14]. Consistent with these results, a Saudi study revealed that the prevalence of diabetes was 34.1% in males and 27.6% in females ($p < 0.0001$) [17].

Age is also known to be an important determinant of diabetes, as blood glucose concentrations tend to rise with age [14]. This result was consistent with a previous investigation that found a relationship between the number of diagnosed cases of diabetes and age [14, 15, 18, 19, 20]. In disagreement with these findings, a Saudi Arabian study revealed that the prevalence of diabetes decreased in patients older than 70 years [14]. Regarding participants' ages, the mean age of the patients in this study was 61.1 ± 17.9 years. Comparable to this result, a study conducted in Saudi Arabia showed that the mean ($\pm$ SD) age for onset of diabetes in males and females was 57.5 (13.1) and 53.4 (13.1) years, respectively ($p < 0.0001$). Similarly, a study in Riyadh, Saudi Arabia, revealed that the mean age of 99 type 2 diabetic patients was 57 years.

Moreover, UTIs are a significant health problem in diabetic patients due to the multiple effects of this disease on the urinary tract and host immune system [21]. In this study, the overall prevalence of urinary tract infection in both symptomatic and asymptomatic diabetic patients was 69%. Comparable findings have been reported in previous studies conducted in Uganda (22.0%), Kuwait (35%), India (49.15%), and Nepal (54.76%) [30]. The variation might be explained by differences in geographical features, host factors, and practices such as the social habits of the community, standards of personal hygiene, and health education practices. However, this finding was relatively higher compared to studies conducted in Harar (15.4%), Addis Ababa (14.9%), Gondar (17.8%), Metu, Ethiopia (16.7%), Nekemet, Ethiopia (16.5%), and Sudan (19.5%) [10]. Furthermore, the study found that females have a significantly higher likelihood of substantial bacterial growth in UTIs compared to males. This finding aligns with previous studies reporting a higher prevalence of bacterial growth in females [22]. Similarly, earlier research using administrative data from the US population found that women had a significantly higher annual incidence of UTIs than men (12.9% vs. 3.9%) [23]. Moreover, these outcomes were consistent with several research studies conducted in Iraq and Kuwait [15, 24, 25]. This variation is primarily due to the short urethra, absence of prostatic secretion, pregnancy, and easy contamination of the urinary tract with fecal flora [26]. Because much of the previous research on UTIs in diabetic patients was conducted on females, there is limited evidence describing aspects of UTIs in diabetic men [24].

Although age is an established risk factor for UTIs in diabetic patients, this study found that 37 (77.1%) of diabetic individuals with UTIs were aged 50 and older, and the mean age was 63.9 ± 14.52 . This study agrees with research conducted in Mogadishu, Somalia, which revealed that the highest number of patients with urinary tract infections were in the age group of 50–60 years, with 87 (36.8%) individuals falling into this category [24, 26]. In contrast to these results, a study conducted in South Ethiopia showed that the age of the respondents was not significantly associated with UTI. Notably, the majority of the respondents were aged 20–35 years, which concurs with a previous study conducted at Gondar University Hospital in Gondar, Ethiopia [27]. A bacteriological study indicates that UTIs are caused by Gram-negative enteric organisms, including *E. coli*, *Klebsiella species*, *Enterobacter species*, and *Proteus species*. Similarly, these causative agents were the predominant cause of UTIs in Harar, Gondar, rural South India, Iraq, Nepal, Sudan, Palestine, Egypt, and Kuwait [2, 28]. The current study found that the second reported isolate was *K. pneumoniae*, which aligns with the findings of Khameneh *et al.* and Chin *et al.* [2]. In accordance with these findings, a study conducted in Sudan revealed that *E. coli* (56.4%) and *K. pneumoniae* (23%) were the most common isolates in UTI patients. This study also found a high incidence of UTI and asymptomatic bacteriuria among diabetic patients compared to non-diabetic patients [29]. In contrast, another study identified the second reported isolate as a *Staphylococcus species* [2].

UTIs are less likely to be caused by Gram-positive cocci. In this investigation, *S. aureus* accounted for 11 (23%), the most prevalent isolate among patients infected with Gram-positive cocci. *Streptococci spp.* and *Enterococci* each had one (2%) isolate. However, according to other studies, CoNS species are more prevalent than *S. aureus* [11]. This previous research is supported by a study conducted in Nigeria [30]. On the other

hand, a study conducted in Sudan showed *E. faecalis* was more prevalent among Gram-positive bacteria than *S. aureus*, which supports the theory of fecal contamination [28].

Recent systematic reviews have shown alarming rates of resistant uropathogenic bacteria worldwide, especially *E. coli*, to commonly used antibiotics. In Sudan, there is an increase in resistance to antibiotics used for treating UTIs, particularly among Gram-negative bacteria [28]. Similarly, the present study found a higher resistance pattern for Gram-negative isolates compared to Gram-positive ones. Moreover, this study demonstrated moderate and low resistance of *E. coli* and *K. pneumoniae* isolates to trimethoprim-sulfamethoxazole, ciprofloxacin, and nitrofurantoin. In contrast, a study carried out in southwest Ethiopia revealed that isolates of *K. pneumoniae* and *E. coli* were 100% resistant to ampicillin and amoxicillin. This implies that these antibiotics cannot be used as empirical therapy for UTIs, especially in that study area. Conversely, other researchers found very low levels of resistance to antibiotics such as gentamicin, ceftriaxone, and nitrofurantoin. Similarly, studies conducted in South Croatia, Ethiopia, Kosovo, and Iran found comparable rates of sensitivity to these antibiotics [31].

Regarding the antimicrobial resistance characteristics of uropathogens, the present study found that *E. coli* showed moderate to low resistance levels to one or more antibiotics. In particular, it demonstrated resistance mainly to trimethoprim-sulfamethoxazole and ciprofloxacin. In contrast to this finding, a study from Somalia revealed resistance primarily to cefotaxime, ciprofloxacin, ofloxacin, and amikacin. These results correspond with earlier studies from Ethiopia [11, 26]. Research conducted in India found that widely used antibiotics such as ciprofloxacin and norfloxacin exhibited notable levels of resistance. Similarly, research conducted in Zimbabwe found significant resistance to cefotaxime and ciprofloxacin [32]. When comparing the findings of the current study with other research carried out beyond the study area and in Africa, it is evident that antimicrobial resistance in *E. coli* infections is a worldwide issue [32].

Gram-positive bacteria, particularly *S. aureus*, exhibited moderate resistance to nitrofurantoin (60%) and ciprofloxacin (45%). Conversely, 90.9% of the Gram-positive isolates tested showed sensitivity to nitrofurantoin. This aligns with other studies conducted in Arba Minch, Ethiopia, and Hawassa, Addis Ababa [2, 31]. The tested isolates also exhibited a high sensitivity to trimethoprim-sulfamethoxazole (81.8%), which contrasted with studies conducted in Hawassa and Arba Minch [2, 33, 34]. In contrast, a significant finding of this study was that among the Gram-negative isolates, ciprofloxacin demonstrated the highest efficacy as an antibiotic, exhibiting a sensitivity rate of 51.4%. In Gram-positive isolates, levofloxacin, meropenem, and vancomycin showed the highest efficacy, each exhibiting a sensitivity rate of 36.36%. This finding suggests that these antibiotics could be utilized effectively in the treatment of urinary tract infections in the studied region. Nevertheless, in disagreement with these results, a study conducted in South Ethiopia showed that all the bacterial isolates demonstrated 100% sensitivity to nitrofurantoin, amikacin, doxycycline, and ceftriaxone, which were the drugs of choice for managing both Gram-negative and Gram-positive uropathogenic bacteria of UTIs [27].

Conclusion

This study highlights the considerable burden of UTIs in diabetic patients, especially elderly women, indicating a distinct correlation between DM, aging, and vulnerability to infections. Gram-negative bacteria, primarily *E. coli* and *K. pneumoniae*, were predominant and demonstrated heightened antimicrobial resistance relative to Gram-positive isolates. Ciprofloxacin was the most efficacious treatment for Gram-negative pathogens, while levofloxacin, meropenem, and vancomycin exhibited greater activity against Gram-positive strains. Ongoing surveillance of antimicrobial resistance, timely diagnosis, and evidence-based antibiotic stewardship are crucial for enhancing UTI management in diabetic populations and for reducing the emergence of multidrug-resistant pathogens.

Conflict of interest. Nil

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