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Escherichia coli dominance and antimicrobial resistance in urinary tract infections among diabetic patients: Insights from Birnin Kebbi Metropolis, Nigeria

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ABSTRACT

Background: The global rise in antibiotic-resistant urinary tract infections (UTIs) is a growing concern, particularly among diabetic patients. This study examines the antibiotic resistance patterns of bacterial uropathogens in diabetic patients at Sir Yahaya Memorial Hospital in Birnin Kebbi.

Methods: A purposive sampling approach was used to collect 51 mid-stream urine samples in sterile containers. Cultural and biochemical methods were employed for the isolation and identification of uropathogenic bacteria. Antibiotic sensitivity testing was performed using the disc diffusion method, with results interpreted according to the Clinical Laboratory Standards Institute (CLSI) guidelines.

Results: UTIs were prevalent in 23.5% (12/51) of the samples. *Escherichia coli* was the most prevalent uropathogen, accounting for 41.3% (7/17) of cases, followed by *Klebsiella pneumoniae* at 23.5% (4/17). *Staphylococcus aureus* and *Proteus mirabilis* each contributed to 17.6% (3/17) of cases. Notably, *E. coli* and *K. pneumoniae* exhibited 100% resistance to chloramphenicol and sparfloxacin, respectively.

Conclusion: These findings underscore the need for further molecular research to characterize these uropathogens and identify the genes contributing to antibiotic resistance.

Keywords: antibiotic resistance, bacterial uropathogens, developing countries, diabetic patients, urinary tract infections

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistently high blood sugar levels. This condition manifests through symptoms such as frequent urination, intense thirst, and increased hunger. DM is classified into three primary types: type 1, type 2, and gestational diabetes, which occurs during pregnancy [1]. The global prevalence of diabetes is rising at an alarming rate, with an estimated 463 million people (9.3% of the population) currently affected. This number is projected to increase to 578 million (10.2%) by 2030 and further to 700 million (10.9%) by 2045 [1].

A significant concern for patients with DM is their increased susceptibility to urinary tract infections (UTIs) [2,3]. Although the exact cause of this heightened risk is not entirely clear, research suggests that it may be linked to immunological impairments and inefficient bladder emptying in diabetic individuals, leading to a need for more frequent urological interventions [4]. This situation is exacerbated by the higher sugar levels in the urine of diabetic patients, which can provide an ideal environment for the growth of harmful microorganisms. UTIs often develop asymptomatically in diabetic patients, eventually evolving into more serious infections. The incidence of UTIs is notably higher in females [5], particularly among those with type 2 diabetes and poor glycemic control, leading to severe complications.

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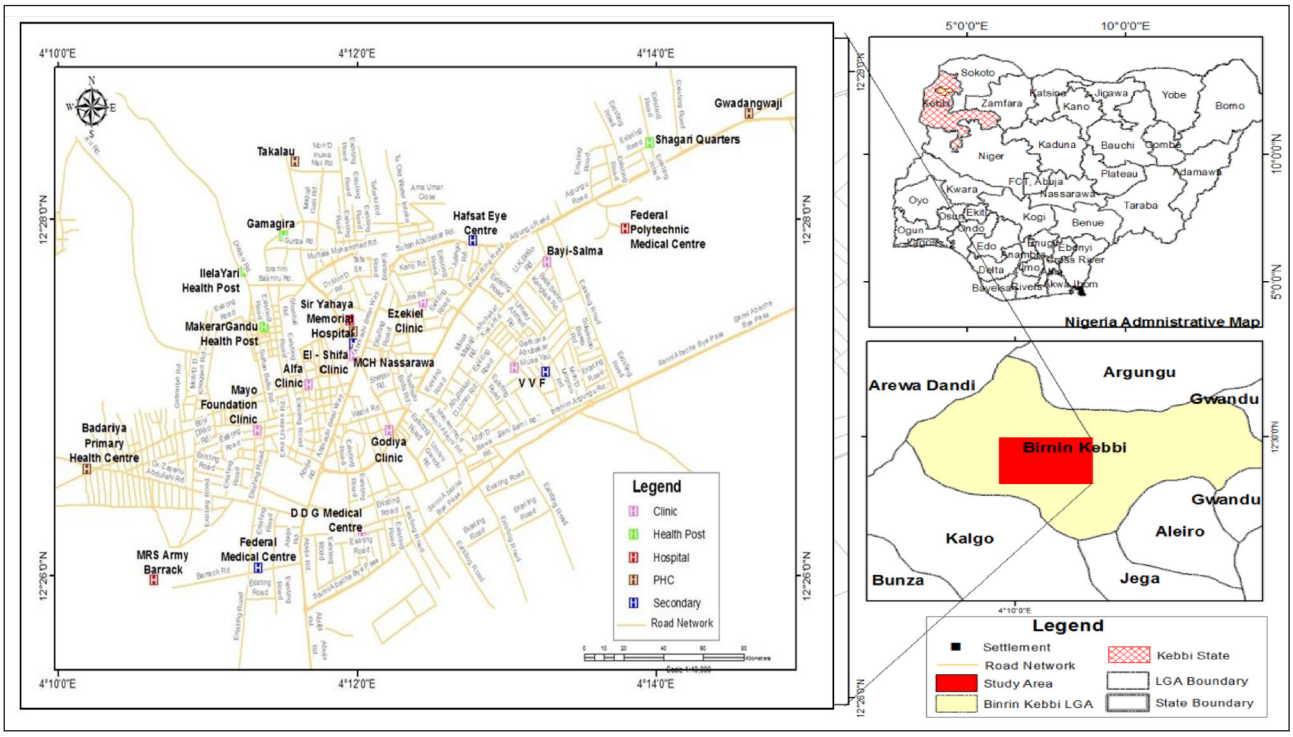

Figure 1. Map of Kebbi State showing the Sir Yahaya Memorial Hospital with other major health facilities in Birnin Kebbi, Kebbi State Nigeria [14]

Globally, UTIs impact over 150 million people annually, particularly in developing countries, and pose a financial burden exceeding 6 billion US dollars [6-8]. While comprehensive data on the global burden of UTIs is lacking, estimates suggest a staggering incidence of at least 250 million cases per year. These infections result in approximately 7 million outpatient visits, 1 million emergency department visits, and 100,000 hospitalizations annually [8]. Common pathogens include *Escherichia coli, Klebsiella* spp., *Proteus* spp., Group B *Streptococcus*, and others, with varying frequencies [9].

Another growing concern is antibiotic resistance, a major global health challenge that is particularly acute in low-income countries due to high infection rates, irrational antibiotic use, and limited resources. This issue is compounded in the context of increasing DM prevalence in these regions, creating significant challenges for healthcare providers [10,11].

In many developing countries, routine culture and sensitivity testing for UTI patients is not a standard practice. As a result, antibiotics are often prescribed before laboratory results are available [9], leading to potential treatment inefficiencies and increased antibiotic resistance. Accurate susceptibility testing is crucial for reducing recurrence and treatment failures in UTI patients with diabetes. Empirical treatment relies on selecting the most effective antibiotics based on regional susceptibility profiles, genomic trends, and local prescribing patterns [12]. Therefore, local studies are vital to guide empirical treatment choices and to curb the development of resistance. This study aims to report on the prevalence and antibiotic resistance patterns of uropathogenic bacteria in diabetic patients in the specified study area.

Methods

Study area and design

The study was conducted in Birnin Kebbi Metropolis, which houses 24 healthcare facilities including the Sir Yahaya Memorial Hospital. This hospital, located on Ahmadu Bello Road in Birnin Kebbi, Kebbi State, Northern Nigeria, serves a significant portion of Kebbi State's population (Figure 1), especially those from low-income backgrounds. As a key referral center, it boasts over 290 beds and averages 200 to 220 patient admissions annually [13,14].

Inclusion and exclusion criteria

Participants included diabetic patients aged 18 years and above with or without UTI symptoms, who consented to participate in the study. Those who did not provide consent were excluded.

Ethical consideration

The study received approval from the ethics committees of both the Department of Microbiology, Kebbi State University of Science and Technology Aliero (KSUSTA), and Sir Yahaya Memorial Hospital, Birnin Kebbi. Informed consent was obtained from all participants, and confidentiality of data was strictly maintained.

Samples collection

A cross-sectional study was carried out in October 2021. Registered laboratory personnel assisted in collecting clean-catch mid-stream urine samples (5 mL) from 50 confirmed diabetic patients. The samples were collected in sterile, screw-capped, wide-mouth containers, labelled appropriately, and transported to KSUSTA's microbiology laboratory in a cooler box. If not processed immediately, samples were refrigerated at 4°C.

Culture and identification of bacteriuria species

Urine samples were cultured on Nutrient Agar (Oxoid LTD, UK) using sterile wire loops and incubated at 37°C for 24 hours. Post-incubation, individual colonies were sub-cultured for purification. Bacterial isolates were then identified through morphological testing (Gram staining) and biochemical tests including catalase, coagulase, oxidase, indole, citrate, and TSI [15,16].

Antibiotic susceptibility test

Antibiotic susceptibility was assessed using the disc diffusion method, following the procedure outlined by Odoki et al. [16]. The test organism, adjusted to 0.5 McFarland standard, was inoculated onto freshly prepared Muller Hinton Agar and spread evenly. Antibiotic discs (including amoxicillin/clavulanate (30 µg), chloramphenicol (30 µg), gentamicin (30 µg), penicillin (10 IU), co-trimoxazole (25 µg), sparfloxacin (10 µg), tarvid (10 µg), perfloxacin (30 µg), augmentin (10 µg), ampiclox (30 µg), zinnacef (20 µg), rocephin (25 µg) and ciprofloxacin (30 µg)) were placed on the agar, and plates were incubated for 24 hours at 37°C. Results were interpreted according to CLSI guidelines [17].

Results

Out of the 51 urine samples from confirmed diabetic patients that were processed, 12 (23.5%) exhibited significant bacterial growth, while the remaining samples tested negative for bacterial presence. An analysis of UTI prevalence based on gender revealed that males exhibited a higher incidence rate at 13.7% (7/51), compared to females (Table 1).

Table 1. Urinary tract infection among diabetic patients

Variable	Number of sample collected	Number of positive (%)
Sex		
Male	34	7 (13.7)
Female	17	5 (9.8)
Total	**51**	**12 (23.5)**
Age		
25-30	2	0 (0.0)
31-35	5	2 (3.9)
36-40	9	2 (3.9)
41-45	7	1 (2.0)
46-50	6	2 (3.9)
51-60	10	1 (2.0)
61-65	8	3 (5.8)
66-70	4	1 (2.0)
Total	**51**	**12 (23.5)**

Table 2. Frequency of occurrence of uropathogenic bacterial species

Bacterial species	Frequency of occurrence (%)
Gram negative rods	
Escherichia coli	7 (41.3)
Klebsiella pneumonia	4 (23.5)
Proteus mirabilis	3 (17.6)
Gram positive coccus	
Staphylococcus aureus	3 (17.6)
Total	**17 (100)**

In total, 17 bacterial isolates were identified, classified into four distinct species. Among these, Gram-negative bacteria accounted for the majority, with 14 isolates (83.4%), while Gram-positive bacteria comprised 3 isolates (17.6%). *Escherichia coli* was the most frequently occurring bacterium, representing 41.3% (7/17) of the isolates, followed by *Klebsiella pneumoniae* at 23.5% (4/17). *Proteus mirabilis* and *Staphylococcus aureus* each accounted for 17.6% (3/17) of the isolates, marking them as the least frequent (Table 2).

Antibiotic susceptibility testing revealed distinct resistance patterns. Notably, *E. coli* isolates demonstrated

Table 3. Antibiotics resistant pattern of bacterial uropathogens isolated from diabetic patients

Antibiotic (dose µg)	*Escherichia coli* n = 7 (%)	*Klebsiella pneumonia* n = 4 (%)	*Proteus mirabilis* n = 3 (%)	*Staphylococcus aureus* n= 3 (%)
Sparfloxacin (30)	3 (42.9)	3 (75.0)	0 (0.0)	ND
Chloramphenicol (30)	7 (100)	2 (50.0)	2 (66.7)	ND
Penicillin (10 iu)	5 (71.2)	3 (75.0)	1 (33.3)	ND
Sparfloxacin (10)	6 (85.7)	3 (100.0)	0 (0.0)	ND
Ciprofloxacin (30)	2 (28.6)	2 (50.0)	0 (0.0)	1 (33.3)
Amoxicillin/ clavulanate (30)	1 (14.3)	1 (25)	3 (100)	2 (66.7)
Augmentin (10)	4 (57.1)	0 (0.0)	0 (0.0)	ND
Gentamicin (30)	2 (28.6)	1 (25.0)	3 (100)	0 (0.0)
Pefloxacin (30)	2 (28.6)	0 (0.0)	0 (0.0)	0 (0.0)
Ofloxacin/Tarvid (10)	1 (14.3)	0 (0.0)	0 (0.0)	ND
Ampiclox (30)	ND	ND	ND	1 (33.3)
Zinnacef (20)	ND	ND	ND	0 (0.0)
Roceptin (25)	ND	ND	ND	0 (0.0)

ND: not done

a 100% resistance rate to chloramphenicol. However, a smaller fraction, 14.3%, showed resistance to both amoxicillin and ofloxacin/Tarvid (Table 3).

Discussion

The significant bacterial growth observed in urine specimens from confirmed diabetic patients aligns with previous findings. A study in Ago Iwoye, Ogun State, Nigeria, reported a 17.3% prevalence of UTIs among asymptomatic diabetic patients [18]. Comparable prevalence rates were documented in other studies, such as 10.4–14% at Tikur Anbessa Specialized University Hospital in Addis Ababa, Ethiopia [19,20], and 13.8% at Hawassa University Referral Hospital in Southern Ethiopia [11]. A study in Khartoum, Sudan, indicated an even higher prevalence of 19.5% among diabetic patients [21]. These findings are consistent with the understanding that diabetic patients, particularly those with poor glycemic control commonly seen in developing countries, are at increased risk of UTIs [21].

Interestingly, our study found a higher UTI prevalence in males compared to females, potentially influenced by the greater number of male participants. Age-wise, the highest prevalence of UTIs (5.8%) was noted in the 61-65 age group, with no cases in the 25-30 age group. While UTIs tend to increase with age, they are more prevalent in women during their sexually active years [22,23]. This pattern did not show a significant correlation with the age of diabetic patients in our study area [11].

Escherichia coli emerged as the predominant uropathogenic bacterium, mirroring findings from Hawassa University Referral Hospital [11] and in Khartoum, Sudan [21]. Our study revealed a 100% resistance of E. coli isolates to chloramphenicol, while showing resistance to amoxicillin and ofloxacin/Tarvid. The high resistance to chloramphenicol might be attributed to its frequent prescription, over-the-counter availability, cost considerations, the presence of unqualified health personnel, and patient non-compliance with the prescribed dosage. These factors are known to exacerbate antibiotic resistance in African countries, particularly Nigeria [24,25].

While chloramphenicol was once a go-to drug for UTIs, concerns over resistance and safety have relegated it from first-line treatment in developed nations [26]. A similar policy shift in low and middle-income countries could help address the persistent issue of antibiotic resistance. Another notable finding was the 100% resistance of *K. pneumoniae* to sparfloxacin, aligning with studies from the Bafoussam Regional Hospital in the West Cameroon Region [26]. The resistance of uropathogenic bacteria, especially Gram-negative ones, poses a significant concern, considering that UTIs are common in both community-acquired and nosocomial infections.

Conclusions

The predominance of Escherichia coli as the main uropathogenic bacterium is consistent with global trends. However, the alarming 100% resistance of *E. coli* to chloramphenicol and significant resistance to other antibiotics like amoxicillin and ofloxacin/ Tarvid are concerning. These findings underscore the urgent need to review and revise antibiotic prescribing practices, particularly in regions with limited healthcare resources.

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Author contributions

MSM, AAA designed this study; HAY, AIB, SSM assisted with data collection; AAA, FAT, AM wrote the initial script; FAT, AM, MSM assisted with statistical analysis; and all authors contributed to data interpretation and final approval of the manuscript.

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