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Predominance of multidrug-resistant bacteria causing urinary tract infections among men with prostate enlargement attending a tertiary hospital in Dar es Salaam, Tanzania

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Abstract

Background Patients with prostate enlargement have an increased risk of recurrent urinary tract infections. This study determined the resistance profile of bacteria causing urinary tract infection (UTI) and the magnitude of multidrug-resistant (MDR) bacteria among patients with symptomatic prostate enlargement in a tertiary hospital in Dar es Salaam.

Methods This cross-sectional study was conducted at Muhimbili National Hospital between August 2021 and January 2022. Male patients aged 40–90 years with symptomatic enlarged prostate, confirmed by digital rectal examination, were enrolled consecutively. We used conventional biochemical methods and analytical profile index (API) 20-E & API 20-NE to identify the uropathogens. In addition, antimicrobial susceptibility testing was performed using the Kirby–Bauer disc diffusion method.

Results A total of 422 participants were enrolled, of whom 196 (46.4%) had laboratory-confirmed UTI. In total, 203 bacterial pathogens were isolated. Gram-negative bacteria (GNB) were the predominant uropathogens accounting to 165/203 (81.3%). The prevalent isolates were *E. coli* 49 (24.1%), followed by *K. pneumoniae* 40 (19.7%). Most, 157 (77.3%) pathogens were MDR, of which 33 (21.0%) were resistant to all tested antibiotic classes. The proportion of methicillin-resistant *Staphylococcus aureus* was 75.8%, while 45.5% of *S. aureus* were inducible clindamycin resistant. Among Enterobacterales, 98 (70.5%) were Extended-spectrum beta-lactamases (ESBL) producers, and 33 (20.0%) were carbapenem resistant. Four of forty-one (9.6%) non-ESBL producers were class C β-lactamase producers.

Conclusions There is a relatively high proportion of MDR strains of uropathogens, which limits treatment options for UTI among men with prostate enlargement. These findings call for the revision of the current UTI treatment guidelines and continuous antimicrobial resistance surveillance to monitor antibiotic resistance and guide treatment options within the hospital.

Keywords Multidrug resistance, Urinary tract infection, Extended-spectrum β-lactamase, Carbapenemase-producing organism, Prostate enlargement

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Background

Urinary tract infection (UTI) is one of the common complications of men with urine retention secondary to urinary bladder outlet obstruction (BOO) (Dougherty and Aeddula 2022). Urine in a normal urinary bladder is voided through the urethra; thus, the transient bacteria in the urethra are eliminated in the normal urine flow (Wu et al. 2017). Obstructed urinary bladder impairs urine flow, allowing bacteria to grow, leading to significant bacteriuria or UTI (Godbole et al. 2020). As the prostate gland enlarges due to physiological changes, it blocks the urinary bladder leading to urine retention, renal insufficiency, and recurrent UTI (Lee and Kuo 2017; Ng and Baradhi 2022). About 15–20% of men with BOO due to enlarged prostate present with recurrent UTI (Aaron et al. 2016; Lee and Kuo 2017).

Recurrent UTI and symptoms of prostatism lead to irrational antibiotic prescriptions for UTI and even self-treatment by patients, consequentially causing the emergence of multidrug resistance (MDR) bacteria (Josephs-Spaulding et al. 2021). Further, to prevent surgical site infection (SSI) following urological surgery or procedure among these patients, pre-operative and post-operative antibiotics are usually given, but this has contributed to the increased risk of antimicrobial resistance (AMR) (Călina et al. 2017; Menz et al. 2021). Globally, the incidence of multidrug resistance (MDR) bacteria causing UTI was reported to be < 20% in Europe (Gomila et al. 2018) and up to 60% in low-middle-income countries (LMIC) (Gashaw et al. 2018; Khan et al. 2019) in which one of the contributing factors is the use of antibiotics inappropriately (Gomila et al. 2018).

Gram-negative bacteria (GNB) are the most common cause of community-acquired and hospital-acquired UTI (Schmider et al. 2022; Seifu and Gebissa 2018). Cephalosporins, fluoroquinolones, and penicillin are the common antibiotic classes used for the empirical treatment of UTI in Tanzania (Ministry of Health 2021; Sangeda et al. 2021; Sonda et al. 2019). However, extensive use of cephalosporins has led to extended-spectrum-beta-lactamases (ESBL) production by Enterobacteriaceae, which correlate with resistance to other common antibiotics (Ibrahim et al. 2023).

The inability to do routine urine cultures and antimicrobial susceptibility testing (AST) due to resource limitations has led to excessive use of apparently inappropriate antibiotics and inadequate treatment of UTI. This scenario has contributed to the failure to identify patients at risk of UTI caused by MDR, the emergence of MDR bacterial infections associated with complications such as sepsis, increased health cost, prolonged hospital stays, and increased mortality (Madrazo et al. 2021). Current treatment guidelines stipulate using amoxicillin/clavulanic acid, ciprofloxacin, and nitrofurantoin as empirical antibiotics for UTI (Ministry of Health 2021). However, with the widespread antimicrobial resistance among uropathogens, the suggested regimens may be ineffective. In addition, a recent study found very high levels of MDR pathogens in patients with UTI in Tanzania (Silago et al. 2022). Therefore, we hypothesize that the prevalence of MDR would be higher among patients with prostate enlargement due to the prolonged use of antibiotics and the tendency to retain urine (Sabih and Leslie 2022).

In the absence of current data, we conducted this study to provide updated information on the status of resistant bacteria causing UTI in patients with an enlarged prostate and, in the process, provide data that can be used to revisit the management of such patients.

Methods

Study design, duration, and setting

We conducted a cross-sectional study in Dar es Salaam between August 2021 and January 2022 at Muhimbili National Hospital (MNH), Tanzania's largest tertiary healthcare facility. The hospital has about 1500-bed capacity; the urology unit has more than 30-bed capacity. The urology unit admits about ten patients daily and performs over 70 urological procedures monthly.

Study population

We enrolled male patients with enlarged prostate, confirmed by digital rectal examination (DRE) or radiologically, presenting with clinical features of UTI. Patients were admitted to the wards (before or after urology surgery) or attended a urology clinic (referral cases or follow-up). Admitted patients included those scheduled for surgery (prostatectomy and trans-urethral resection of the prostate (TURP) and patients referred with urosepsis. Outpatients comprised patients scheduled for a biopsy, follow-up for biopsy results, medical therapy for benign prostate hyperplasia (BPH), and patients with prostate cancer.

Sample size and sampling procedure

The sample size was estimated using the Kish Leslie formula (1965), considering the 30% prevalence of MDR bacteria among patients with healthcare-associated infections in Ethiopia (Gashaw et al. 2018). Therefore, the adjusted minimum sample size was 324. Male patients attending the urology clinic or admitted to the urology ward were consecutively enrolled upon fulfilling the eligibility criteria.

Urine specimen collection

Mid-stream urine (MSU) was collected from patients without urinary catheters. For patients with indwelling catheters, a clump with forceps was placed above the port for 30 min to allow urine to collect in the bladder. The port was disinfected with 70% alcohol, followed by clump release to allow urine to flow from the port to the sterile urine container. Ten millilitres of urine was collected from each participant into a labelled sterile container. Urine specimens were sent to the microbiology laboratory at MNH for processing within 2 h of collection.

Bacterial isolation and identification

Urine specimens were directly inoculated onto cysteine lactose electrolyte deficient agar (CLED) and blood agar (BA) (Oxoid Ltd, Hampshire, UK) plates. The inoculated culture plates were incubated aerobically at 37 °C for 18–24 h. Culture plates with significant bacteria growth ($\geq 10^5$ (CFU/ml)) were read for colonial morphology and then identified by Gram stain and biochemical reactions. Identification of GNB was made by oxidase test, urease, citrate, Kligler iron agar (KIA), and Sulphur, Indole, and Motility (SIM) (Oxoid Ltd, Hampshire, UK). Analytical Profile Index (API) 20E and API 20-NE (BioMérieux, France) tests were also used to identify and differentiate members of Enterobacterales and non-Enterobacterales. Gram-positive bacteria were identified by catalase, coagulase, and DNAase tests (Remel Europe Ltd, Dartford, UK). Catalase-negative Gram-positive bacteria were identified by bile esculin (Oxoid Ltd, Hampshire, UK) and pyrrolidinyl arylamidase (PYR) test (Remel Europe Ltd, Dartford, UK).

Antimicrobial susceptibility testing

We used the Kirby–Bauer disc diffusion method for AST with commonly prescribed antibiotics per 2022 CLSI guidelines (CLSI 2022). We included ampicillin (10 µg), ciprofloxacin (5 µg), trimethoprim/sulfamethoxazole (1.25/23.75 µg), gentamicin (10 µg), amikacin (30 µg), meropenem (10 µg), nitrofurantoin (300 µg), amoxicillin/clavulanic acid (20 µg), ceftriaxone (30 µg) and ceftazidime (30 µg) for GNB. For Gram-positive bacteria, we used ciprofloxacin (5 µg), trimethoprim/sulfamethoxazole (1.25/23.75 µg), gentamicin (10 µg), nitrofurantoin (300 µg), erythromycin (15 µg), clindamycin (2 µg) and cefoxitin (30 µg).

Briefly, bacterial colonies were suspended in normal saline, adjusted to 0.5 McFarland standard turbidity, and then swabbed evenly on Mueller Hinton Agar (MHA) (Oxoid, UK). A maximum of five antibiotic discs were placed on the inoculated MHA plates using a disc dispenser and incubated aerobically at 37 °C for 16–18 h. Inhibition zones were measured and interpreted per CLSI guidelines (CLSI 2022). *E. coli* ATCC 25922, *P. aeruginosa* ATCC 27853 and *S. aureus* ATCC 25923 were used as control organisms. An isolate resistant to at least three antibiotic classes was considered MDR strain.

Detection of methicillin-resistant *Staphylococcus aureus* (MRSA)

MRSA was phenotypically determined during the AST procedure using a cefoxitin (30 µg) disc per CLSI guidelines (CLSI 2022). A $\leq$ 21 mm inhibition zone diameter around the cefoxitin disc incubated at 37 °C for 16–18 h indicated MRSA. Methicillin susceptible *Staphylococcus aureus* (MSSA) ATCC 25923 and MRSA ATCC 43300 were used as controls.

Detection of inducible clindamycin resistance

The inducible clindamycin resistance in *S. aureus* was detected using the D test method per CLSI guidelines (CLSI 2022). *S. aureus* isolates resistant to erythromycin but susceptible to clindamycin were inoculated on MHA plates; Erythromycin (15 mg) and clindamycin (2 µg) discs were applied 15–26 mm apart on the same plate, incubated aerobically for 16–18 h at 37 °C. Flattening the zone of inhibition of clindamycin adjacent to the erythromycin disc (D-zone) was confirmed as inducible clindamycin resistance *S. aureus* (CLSI 2022). The *S. aureus* ATCC BAA-977 D test positive and *S. aureus* ATCC BAA-976 D test negative were used as the controls.

Detection of extended spectrum β-lactamase production

Ceftazidime discs (30 µg) and ceftriaxone (30 µg) were used to screen for ESBL production among Enterobacterales during AST. Isolates with inhibition zones of $\leq$ 22 mm for ceftazidime and $\leq$ 25 mm for ceftriaxone were subjected to a confirmatory test. ESBL production was confirmed using the disc combination method (CLSI 2022). Isolates showing an increased zone of inhibition of $\geq$ 5 mm between ceftazidime or cefotaxime disc with clavulanic acid and without clavulanic acid were considered ESBL producers (CLSI 2022).

For non-ESBL producers, class C β-lactamase producers were tested for cefoxitin resistance and an increased zone of inhibition when cefepime was added to the combination disc method and was phenotypically confirmed as class C β-lactamase. We used standard reference strains of non-ESBL-producing *E. coli* ATCC 25922 and ESBL-producing *K. pneumoniae* ATCC 700603 for quality control.

Detection of carbapenemase production

Carbapenemase production was tested using modified carbapenem inactivation methods (mCIM) per CLSI

guidelines (CLSI 2022). Briefly, a 1µ loopful of Enterobacterales and 10µ loopful of *P. aeruginosa* were emulsified in 2 millilitres of tryptic soy broth (TSB) and vortexed for 15 s. Then meropenem (10 µg) disc was added to the suspension and incubated at 37 °C for 4 h. Immediately following the TSB-meropenem disc suspension incubation, a 0.5 McFarland suspension of meropenem susceptible *E. coli* ATCC 25922 in normal saline was made and inoculated on MHA plate. The meropenem discs from each TSB-meropenem disc suspension were removed using a sterile loop and implanted on the MHA plate inoculated with meropenem susceptible *E. coli* ATCC 25922, incubated aerobically at 37 °C for 24 h. The inhibition zones were measured and interpreted using CLSI guidelines (CLSI 2022). The inhibition zone of 6–15 mm diameter or small colonies within 16–18 mm diameter were confirmed as carbapenemase positive, and zone of inhibition ≥ 19 mm diameter were considered as carbapenemase negative. *K. pneumoniae* ATCC-1705 and *K. pneumoniae* ATCC-1706 were used as a positive and negative control for carbapenemase-producing bacteria, respectively.

Statistical analysis

We performed statistical analysis using the statistical package for the social sciences (SPSS) version 27 (Armonk, NY: IBM Corp). Frequencies and percentages were used for categorical variables, and mean (standard deviation (SD)) were used for continuous variables.

Results

Description of study participants

A total of 422 participants were enrolled in the study, aged between 40 and 90 years and a mean age of 68 ± 11 years. The majority, 233 (55.2%), were enrolled from outpatients. Most participants, 291 (70%) had BPH. Regarding genitourinary symptoms, 241/422 (57.1%) complained of incomplete bladder emptying, 263/422 (62.3%) had increased frequency, 201/422 (47.3%) reported urgency, and 227/422 (53.8%) complained of hesitancy. The laboratory-confirmed UTI was found in 196/422, 46.5% (95% CI 41.56–51.53%).

Spectrum of bacteria causing UTI

A total of 203 bacterial isolates were obtained from 196 urine cultures. Seven urine specimens yielded two types of clinical isolates. GNB were the predominant pathogens accounting for 165/203 (81.3%). *E. coli*, 24.1% ($n=49$); *K. pneumoniae*, 19.7% ($n=40$); *S. aureus*, 16.3% ($n=33$) and *P. aeruginosa*, 7.9% ($n=16$) were the frequently isolated pathogens. In addition, *Chromobacterium violaceum*, a rare pathogenic bacterium accounted for one isolate (Fig. 1). The flow chart of isolates identification results is provided as an Additional file 1.

Antimicrobial resistance pattern

Gram-negative bacteria (GNB) demonstrated an overall resistance rate of 96% towards ampicillin, 80% towards ceftriaxone and ceftazidime, and 77% towards amoxicillin/clavulanic acid. Among Gram-positive bacteria, a high resistance rate was demonstrated towards erythromycin (84%), followed by penicillin (71%). Both Gram-positive and Gram-negative bacteria showed a high resistance rate against gentamicin (78%), trimethoprim/sulfamethoxazole (72%), ciprofloxacin (71%), and nitrofurantoin (50%). GNB had a low resistance rate towards

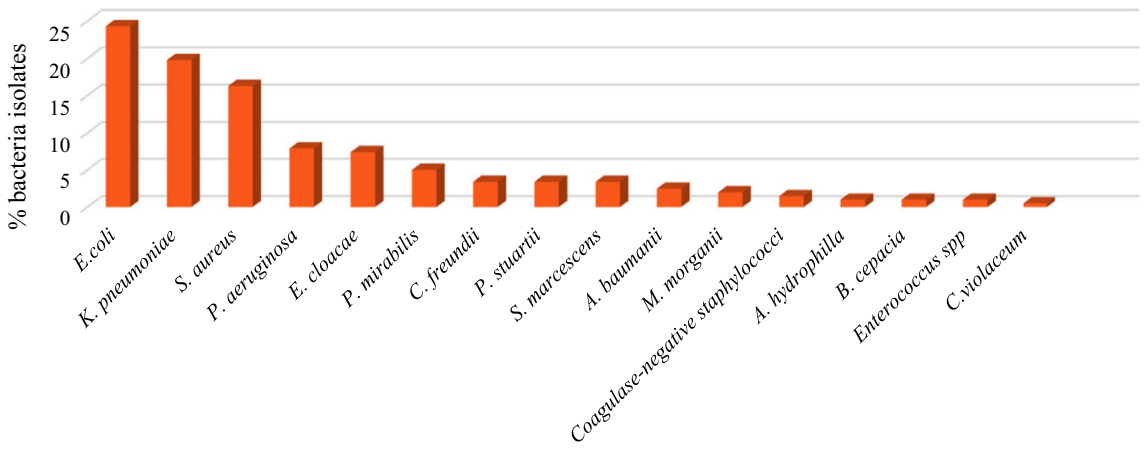

Fig. 1 Uropathogens causing UTI among men with prostate enlargement at Muhimbili National Hospital, Dar es Salaam-Tanzania

Table 1 Antimicrobial resistance pattern of bacterial pathogens causing UTI among men with prostate enlargement at Muhimbili National Hospital, Dar es Salaam-Tanzania

Isolate	*N*	% Antimicrobial resistance												
		AMP	CN	AMC	CRO	ME	AK	CIP	SXT	CAZ	F	P	E	DA
E. coli	49	95	73	95	79	18	38	98	91	75	53	–	–	–
K. pneumoniae	40	100	55	74	81	22	19	74	95	75	51	–	–	–
P. aeruginosa	16	–	80	–	–	63	50	63	–	87	–	–	–	–
E. cloacae	15	100	79	100	85	26	26	92	100	86	79	–	–	–
P. mirabilis	10	75	50	50	66	33	50	50	50	55	83	–	–	–
A. baumanii	5	–	75	–	100	25	50	75	100	75	–	–	–	–
Other GNB	30	96	68	76	82	31	37	78	82	76	61	–	–	–
S. aureus	33	–	55	–	–	–	–	58	67	–	21	97	85	50
CoNS	3	–	33	–	–	–	–	67	67	–	0.0	67	67	33
Enterococcus spp	2	0	50	–	–	–	–	50	0.0	–	50	50	100	0.0
Total	203	96	78	77	80	33	36	71	72	80	50	71	84	28

Other GNB include: *A. hydrophila*, *B. cepacia*, *C. freundii*, *C. violaceum*, *M. morganii*, *P. stuartii*, *S. marmarcescens*

N Number of isolates, *AMP* Ampicillin, *CN* Gentamicin, *AMC* Amoxicillin/Clavulanic acid, *CRO* Ceftriaxone, *ME* Meropenem, *AK* Amikacin, *CIP* Ciprofloxacin, *SXT* Trimethoprim/Sulfamethoxazole, *CAZ* Ceftazidime, *F* Nitrofurantoin, *P* Penicillin, *E* Erythromycin, *DA* Clindamycin, *CoNS* Coagulase-negative staphylococci

amikacin (35%) and meropenem (33%), while Gram-positive bacteria showed a low resistance rate to clindamycin (28%) (Table 1).

Multidrug-resistant uropathogens

In total, 157 (77.3%) uropathogens were MDR. Thirty-three (21.0%) MDR strains were resistant to seven classes of antibiotics tested. The antibiotic classes included: penicillin, aminoglycosides, carbapenems, cephalosporins, fluoroquinolones, nitrofuran and sulphonamides for Gram-negative bacteria, and penicillin, aminoglycosides, fluoroquinolones, lincosamide, macrolides, nitrofuran and sulphonamides for Gram-positive bacteria. All *Enterobacter cloacae* were MDR, followed by *E. coli*, 45/49 (91.8%,) and *K. pneumoniae*, 31/40 (77.5%) (Table 2). Most *S. aureus*, 25/33 (75.8%), were MRSA and 45.5% of *S. aureus* strains were inducible clindamycin resistant. The proportion of ESBL-producing Enterobacterales was 70.5% (98/139), whereby *E. cloacae* (73.3%) and *E. coli* (71.4%) were the most prevalent ESBL-producing Enterobacterales (Table 2). For non-ESBL producers, 4/41 (9.6%) bacterial isolates tested positive for class

Table 2 Proportion of multidrug resistance phenotypes of bacterial pathogens causing UTI among men with prostate enlargement at Muhimbili National Hospital, Dar es Salaam-Tanzania

Isolate	*N*	Multidrug resistance phenotype					
		MDR	ESBL	CPO	AmpC	MRS	iCR
		N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
E. coli	49	45 (91.8)	35 (71.4)	7 (14.3)	1 (2.0)	–	–
K. pneumoniae	40	31 (77.5)	25 (62.5)	4 (10.0)	1 (2.5)	–	–
P. aeruginosa	16	9 (56.3)	–	8 (50.0)	–	–	–
E. cloacae	15	15 (100.0)	11 (73.3)	4 (26.7)	1 (6.7)	–	–
P. mirabilis	10	7 (70.0)	5 (50.0)	3 (30.0)		–	–
Other GNB*	35	24 (68.5)	22 (88.0)	7 (20.6)	1 (4.0)	–	–
S.aureus	33	24 (72.7)	–	–	–	25 (75.8)	15 (45.5)
CoNS	3	1 (33.3)	–	–	–	1 (33.3)	0
Enterococcus spp	2	1 (50.0)	–	–	–	–	–
Overall	203	157 (77.3)	98 (70.5)	33 (20.0)	4 (9.6)	26 (72.2)	15 (41.7)

Other GNB include: *A. baumanii*, *A. hydrophila*, *B. cepacia*, *C. freundii*, *C. violaceum*, *M. morganii*, *P. stuartii*, *S. marcescens.* *Twenty-five isolates of the other GNB were Enterobacterales

N Number, *CoNS* Coagulase-negative staphylococci, *MDR* Multidrug resistance, *ESBL* Extended-spectrum β-lactamase, *CPO* Carbapenemase-producing organisms, *MRS* Methicillin-resistance *Staphylococci*, *iCR* inducible clindamycin resistance

C β-lactamase. Fifty-four (32.9%) isolates were meropenem-resistant GNB, of which 20.0% (33/165) were carbapenemase producers (Table 2).

Antimicrobial resistance rate for ESBL and non-ESBL-producing Enterobacterales

ESBL producers demonstrated a higher resistance rate towards amikacin, amoxicillin/clavulanic acid, gentamicin, and trimethoprim/sulfamethoxazole than non-ESBL producers ($p < 0.05$). There was no significant difference in resistance rate between ESBL-producing and non-ESBL-producing bacteria towards ciprofloxacin, meropenem, and nitrofurantoin (Table 3).

Discussion

To our knowledge, this is the first study in Tanzania and Sub-Saharan Africa to report the magnitude of MDR bacteria causing UTI among patients with prostate enlargement. The current study found that nearly half of the patients with enlarged prostates had laboratory-confirmed UTI. More than 80% of pathogens causing UTI were GNB; *E. coli* and *K. pneumoniae* 89 (54%) account for more than half of GNB. The pathogens demonstrated high resistance rates of > 70% to common antibiotics like ampicillin, erythromycin, ceftriaxone, ceftazidime, gentamicin, amoxicillin/clavulanic acid, trimethoprim/sulfamethoxazole, ciprofloxacin, and penicillin. In addition, more than three-quarters of the pathogens were MDR strains implying significant challenges in treating UTI in this population.

The proportion of UTI observed in the current study among men with prostate enlargement is comparable with the study in Nigeria (44.7%) and a bit lower than a study in India (62.8%) among a similar population (Agbugui et al. 2016; Mishra et al. 2016). Nonetheless, our study found a high proportion of MDR strains, including 70.5% ESBL-PE, 20% carbapenemase-producing GNB, and 76% MRSA. Furthermore, studies have shown that infections with MDR are significantly severe and associated with treatment failure leading to increased hospital stay and mortality (Lee et al. 2016; Madrazo et al. 2021; Mitchell et al. 2016; Perez and van Duin 2013).

The current study revealed *E. coli* and *K. pneumoniae* as the most frequent GNB pathogens causing UTI among men with prostate enlargement, with more than three-quarters being MDR strains. Several studies have reported similar findings where *E. coli* was the predominant cause of UTIs (Agbugui et al. 2016; Asafo-Adjei et al. 2018; Mishra et al. 2016). In addition, the current study recovered non-fermentative GNBs such as *P. aeruginosa*, *A. baumanii*, and *B. cepacia*, which have been highly associated with hospital-acquired infections (Ángeles-Garay et al. 2017; Hrbacek et al. 2021; Jiménez-Guerra et al. 2018). Furthermore, *S. aureus* was the prevalent Gram-positive bacteria causing UTI, similar to reports in other studies (Agbugui et al. 2016; Mishra et al. 2016; Odoki et al. 2019).

Our study demonstrated a high overall resistance rate towards amoxicillin-clavulanic acid, ciprofloxacin, and nitrofurantoin, the recommended antibiotics for UTI in our setting. The findings are consistent with reports in Ethiopia and Ghana (Asafo-Adjei et al. 2018; Seifu and Gebissa 2018). On the contrary, a study at Bugando hospital, Northwest Tanzania, reported a lower resistance rate towards ciprofloxacin (31–51%) and nitrofurantoin (35–42%) (Ndomba et al. 2022). The varying resistance rate could be due to differences in hospital antibiotic policy, prescribing practices across the hospitals, and the characteristics of patients. In addition, the easy availability of these antibiotics over the counter and affordability for managing UTI in Tanzania may explain the high resistance rate (Raphael et al. 2021). Amikacin and meropenem had a low resistance rate against GNB, which were predominant pathogens; hence could be used

Table 3 Comparison of antimicrobial resistance rate between ESBL and non-ESBL bacterial pathogens causing UTI among men with prostate enlargement at Muhimbili National Hospital, Dar es Salaam-Tanzania

Antimicrobial agent	Bacterial resistant patterns		*p* value
	ESBL producers ($N = 98$), *n* (%)	Non-ESBL producers ($N = 41$), *n* (%)	
Amikacin	38 (38.8)	9 (22.0)	0.008
Amoxicillin/clavulanic acid	91 (92.9)	35 (85.4)	< 0.001
Ceftazidime	90 (91.8)	31 (75.6)	< 0.001
Ceftriaxone	89 (90.8)	31 (63.3)	< 0.001
Ciprofloxacin	84 (85.7)	39 (95.1)	0.110
Gentamicin	67 (68.4)	25 (61.0)	0.016
Meropenem	23 (23.5)	16 (39.0)	0.297
Nitrofurantoin	57 (58.2)	28 (68.3)	0.686
Trimethoprim/Sulfamethoxazole	89 (90.8)	39 (95.1)	0.005

as empirical therapy while awaiting AST results. However, great caution should be taken with amikacin due to its adverse effects, especially among the elderly, who may suffer nephrotoxic complications (Ipekci et al. 2014).

The proportion of MDR strains among patients with prostate enlargement was remarkably higher than reports from other studies conducted among men with BPH, hospitalized patients, and old patients with community-acquired UTI (Gashaw et al. 2018; Madrazo et al. 2021b; Mishra et al. 2016). The current findings are also higher than reports from studies in Tanzania on UTI in the population of women, children, people with an indwelling urinary catheter, and people living with HIV (PLWHIV) (Ndomba et al. 2022; Ngowi et al. 2021; Raphael et al. 2021; Schmider et al. 2022). Several factors may contribute to this study's high rate of MDR strains, as reported in other studies (Kalluru et al. 2018; Nicolle 2005). Advanced age among this studied population is one of the risk factors for acquiring infections caused by MDR pathogens (Guclu et al. 2021). Additionally, studies have shown that most patients with prostate enlargement require catheterization to relieve urine retention, which predisposes them to infection with MDR strains (Kalluru et al. 2018). Further, these patients have a high hospital attendance rate, thus predisposing them to colonization or infections with MDR strains (Perez and van Duin 2013; Safdar and Maki 2002). Repeated use of antibiotics to treat recurrent UTI may be one of the attributes for the emergence of MDR strains due to selection pressure (Holmes et al. 2016; Serlin et al. 2018). A high proportion of MDR strains among uropathogens in the studied population calls for implementing an antimicrobial stewardship program and AMR surveillance in urology. Unfortunately, there are limited choices for oral antibiotic therapies against MDR strains causing UTI. Therefore, there is a need to implement routine culture and AST to direct the choice of antibiotic. However, fosfomycin, not tested in this study, has been reported to be effective in treating UTIs caused by MDR GNB (Giancola et al. 2017; Pullukcu et al. 2007).

In the current study, we observed around three-quarters of *S. aureus* being MRSA, higher than reported studies conducted in Ethiopia (43.4%), Nigeria (13.1%), Iran (55.6%), and India (43%) in the adult population (Mitiku et al. 2021; Mofolorunsho et al. 2015; Yousefi et al. 2017). Our study's high proportion of MRSA infection may be attributed to several factors, as reported in other studies, including improper antibiotic use (McHugh and Riley 2004; Porto et al. 2013), surgical interventions and catheterization (Loftus et al. 2018) and recent hospitalization (Drapeau et al. 2007). Clindamycin has been preferred to treat infections by MRSA (Goudarzi et al. 2020), but the development of inducible clindamycin resistance may curb the efficacy of this antibiotic (Coello et al. 1997; Siberry et al. 2003). In this study, the proportion of inducible clindamycin resistance among *S. aureus* strains was 45.5%. Several studies have reported similar findings whereby the proportion of inducible clindamycin resistance ranged from 2.9% to 44.0% in Africa (Assefa 2022). The proportion of inducible clindamycin resistance was reported to be 10% in Egypt (Abdelmawgoud et al. 2021), 35.8% in Libya (Zorgani et al. 2009), and 33.3% in Uganda (Mwambi et al. 2014). On the contrary, a low prevalence of inducible clindamycin resistance was reported in Iran (7.5% to 21.7%) (Goudarzi et al. 2020).

The present study observed that most Enterobacterales (70.5%) were ESBL-PE, accounting for the high resistance observed towards third-generation cephalosporins. The findings were comparable with another study in the same hospital, which showed a high prevalence of ESBL-PE (Moyo et al. 2010). Another study in Mwanza, Tanzania, reported a prevalence of 50.6% for ESBL-PE, slightly lower than this study (Ndomba et al. 2022). ESBL is carried in the plasmid, which carries other resistance genes that can be easily transferred among the Enterobacterales. The transfer of ESBL genes through plasmid may justify significant resistance towards other antibiotics, including ciprofloxacin, gentamicin, and trimethoprim/sulfamethoxazole (Schwaber et al. 2005). Further, cefepime was used to detect the presence of AmpC since it is less affected by AmpC β-lactamases (Sasirekha and Shivakumar 2012). Four bacteria strains (*E. cloacae*, *K. pneumoniae*, *P. stuartii* and *E. coli*) had class C β-lactamase enzymes. AmpC β-lactamases can be chromosomal or plasmid-encoded and can be induced in frequent exposure to β-lactam antibiotics (Jacoby 2009; Mohamudha et al. 2010; Philippon et al. 2002; Rodríguez-Baño et al. 2012).

Our study found a comparatively higher rate of carbapenem resistance than the study in Mwanza, Tanzania (Ndomba et al. 2022) but lower than the findings in Ethiopia (Gashaw et al. 2018). The carbapenem class of antibiotics is usually prescribed for treating UTIs caused by MDR bacteria, including ESBL-producing and AmpC-producing Enterobacterales (Cerceo et al. 2016; Rodríguez-Baño et al. 2018). One of the main mechanisms of carbapenem resistance in GNB is carbapenemase enzyme production which hydrolyses these antibiotics (Hasan et al. 2021). Our study found that the proportion of carbapenemase-producing organisms (CPO) among GNB was higher than in Asia and Europe (Braun et al. 2018; Zhao et al. 2021). A high proportion of carbapenem resistance in the current study was observed among *P. aeruginosa* (50%), followed by *P. mirabilis* (33.3%) and *E. cloacae* (26.7%). Another study also showed similar findings with a high rate of carbapenem resistance in

P. aeruginosa (78.4%), *K. pneumoniae* (31.6%), *E. cloacae* (25.2%), and *E. coli* (24.3%) (Zhao et al. 2021). The observed variations in carbapenem resistance rate could be due to differences in geographic location, study population, and infection prevention and control measures across countries (Braun et al. 2018; Zhao et al. 2021). In preceding studies, catheterization, antibiotic use, and hospital admission have been reported as the risk factor for infection with CPO (Kim et al. 2020).

We should have followed up on patients to determine their outcomes, which was one of our study's limitations. This study recommends whole genome sequencing to unveil novel virulence and AMR genes.

Conclusions

We observed a high proportion of MDR strains of uropathogenic bacteria in symptomatic patients with prostate enlargement. Furthermore, these strains were resistant to more than four antibiotic classes, which are routinely prescribed, thus limiting the available options for UTI treatments. These results support the need for routine culture and AST in place of empirical therapy. In keeping with the findings from this study, we recommend revising UTI treatment guidelines and substituting ineffective antibiotics with effective ones.

Abbreviations

AMR	Antimicrobial resistance
AST	Antimicrobial susceptibility testing
BPH	Benign prostate hyperplasia
CLSI	Clinical and Laboratory Standards Institute
CPO	Carbapenemase-producing organisms
ESBL	Extended-spectrum beta-lactamases
ESBL-PE	Extended-spectrum beta-lactamases producing Enterobacterales
GNB	Gram-negative bacteria
MDR	Multidrug resistant
MDRGNB	Multidrug-resistant Gram-negative bacteria
MNH	Muhimbili National Hospital
MUHAS	Muhimbili University of Health and Allied Sciences
UTI	Urinary tract infection

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42269-023-01030-z.

Additional file 1. Fig. S2A: A flowchart showing bacterial isolation and identification for Gram-negative bacteria isolated from urine specimens. **Fig. S2B**: A flowchart showing bacterial isolation and identification for Gram-positive bacteria isolated from urine specimens.

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Author contributions

EMN and AJ conceptualized the work and developed the methodology. EMN and MM did the data analysis. EMN carried out the laboratory work. Writing the original draft was done by EMN. AM, AS, JM, FM, MIM, MM, and AJ did the manuscript's final review and edit. All authors read and approved the final manuscript.

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Availability of data and materials

All graphs and tables generated in this study are included in this manuscript.

Declarations

Ethics approval and consent to participate

The study attained ethical clearance from the Senate Research and Publications Committee of the Muhimbili University of Health and Allied Sciences (MUHAS) with reference number MUHAS-REC-06-2021-697. As a result, the MNH administration granted permission to conduct the study. In addition, participants were requested to sign informed consent before enrolment in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interest.

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