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Research Article

Assessment of Antibiotics Resistance from Isolates Responsible for UTI in Four Regional Referral Hospitals in Tanzania

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Abstract

The global impact of antimicrobial resistance (AMR) includes increased morbidity and mortality rates and healthcare costs, particularly in low- and middle-income countries (LMICs), and it has dire economic and security implications. This study assessed the resistance of clinical isolates responsible for urinary tract infections (UTI) to antibacterial agents for treating UTIs in selected healthcare facilities in Tanzania. A total of 151 clinical isolates of *E. coli* and *S. aureus* isolated from urine samples in selected health facilities were analyzed for antimicrobial susceptibility to establish the presence of individual and multi-drug resistance (MDR). The results revealed that *E. Coli* displayed a significant difference in resistance (χ^2 =12.808, p =0.002) across the selected antibiotics, in which *E. coli* showed the highest resistance to amoxicillin (AML) and the least resistance to meropenem (p <0.005). In contrast, *S. aureus isolates* showed a significant difference. (χ^2=53.627, p-value<0.001) in resistance across the selected antibiotics, in which *S. aureus* showed the highest resistance to AML, peaking at more than 91%, and least resistant (4%) to nitrofurantoin (NIT) (4%). When p-value<0.005, both *E. coli* and *S. aureus* demonstrated MDR against selected antibiotics in all health facilities under study, in which Morogoro Regional Referral Hospital showed the highest (65.4%) for *E. coli* and Benjamin Mkapa Hospital showed the highest (83.3%) for *S. aureus.* Similarly, Maweni Regional Referral Hospital demonstrated the lowest MDR for *E. coli* (23%) and *S. aureus* (13%). Finding suggest that some antibiotics are still in used in clinical practice despite of the evidence of emerging resistance against them hence it call for effective regular AMR surveillance and antimicrobial stewardship implementation to optimize antibiotics use in clinical practice and exclude less efficacious ones.

Keywords

Antimicrobial Resistance, Clinical Isolates, Urinary Tract Infections, *E. coli* and *S. aureus*, Tanzania Healthcare Facilities

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1. Introduction

Antibacterial agents are compounds that kill or immobilize bacteria and are used to treat and manage bacterial infections and perioperative procedures [1]. These are further categorized based on their activity against different bacterial agents as either broad-spectrum, which acts on a wide range of gram-positive and gram-negative bacteria, or narrow-spectrum, which works on either gram-positive or gram-negative bacteria [2].

Despite the importance of these antibiotics in treatment, there have been reports of a significant increase in unsuccessful treatments owing to emerging antimicrobial resistance (AMR) [3]. When AMR occurs, microorganisms persist or grow in the presence of antibiotics designed to inhibit or kill them [4]. Several related factors, including poor hygiene and sanitation, infection control, overprescription, lack of treatment completion, antibiotic overuse in farming, and lack of development of novel antibiotics, have been identified as drivers of emerging AMR [5, 6]. Additionally, substandard medicines are another major factor driving the development of antimicrobial resistance. For instance, a 2020 report by the Tanzania Medicines and Medical Devices Authority (TMDA) recorded nine substandard and falsified medicines, including antibiotics, circulating in the market [7].

The global effects of AMR include increased morbidity and mortality rates, increased healthcare costs, particularly in low- and middle-income countries (LMICs), and dire economic and security implications [8]. Numerous studies conducted in Tanzania over the past ten years reveal that AMR continues to rise despite various intervention efforts [9, 10]. To combat AMR, the World Health Organization (WHO), by partnering with different countries, including Tanzania, initiated antimicrobial stewardship programs to promote the optimal use of antimicrobials at all levels of healthcare facilities [11, 12]. Tanzania continues implementing its National Action Plan on Antimicrobial Resistance (NAP–AMR), the first release implemented for 2017-2022 and the second in 2023-2028. NAP-AMR intends to minimize AMR delinquency and contribute to AMR global data [13, 14].

The prevalence of urinary tract infections (UTI) in Tanzania has been reported to range from 16% in children to 38-41% in adults [15-17]. Typical human body flora under favorable conditions can cause infections such as UTI, abscesses, furuncles, cellulitis, traveler's diarrhea, bacteremia, pneumonia, and neonatal meningitis [18]. The occurrence of infectious diseases in Tanzania may be due to poor water and hygiene sanitation (WASH) and antibiotic misuse [14]. Among the most frequently diagnosed bacterial infections in healthcare facilities at different levels are *E. coli* and *Staphylococcus aureus* [19]. Emerging AMR among these bacteria can contribute to the spread of AMR and transmit it to other bacteria, including pathogenic ones. Thus, we selected representative microbial agents to determine changes in AMR or susceptibility patterns of clinical isolates due to ongoing interventions against AMR.

As a medicine regulator in Tanzania, TMDA has a direct role in ensuring the quality and safety of medicines by utilizing different strategies in registration, inspection, pharmacovigilance, and post-market surveillance to support the National Action Plan on Antimicrobial Resistance (NAP–AMR) together with the National Strategic Health Plan in line with Sustainable Development Goals (SDG) 2030 [20]. Therefore, this study aimed to assess the susceptibility of *E. coli* and *S. aureus* clinical isolates to selected antibiotics according to standard treatment guidelines (STG) to establish the magnitude of their AMR in four major referral regional hospitals in Tanzania.

2. Methodology

2.1. Study Location

The study was conducted in three zones of the country involving four referral hospitals, namely Western Zone (Maweni Regional Referral Hospital), Central Zone (Benjamin Mkapa Hospital and Morogoro Regional Hospital), and Eastern Zone (Temeke Referral Hospital).

2.2. Study Design and Sampling Strategy

A cross-sectional study design and purposive sampling were used (Kothari 2004). Individual hospitals were selected based on their capacity to perform bacterial cultures, isolation, and identification. Bacterial isolates of *E. coli* and *S. aureus* responsible for UTI were collected from hospital laboratories in selected hospitals. Samples were cultured and identified to obtain isolates, which were used to assess the prevalence of antibiotic resistance recommended in Tanzania's Standard Treatment Guideline 2022.

2.3. Sample Size Determination

The sample size was computed using a calculator developed by Statistics Kingdom (https://www.statskingdom.com/sample_size_chi2.html). The sample size computation followed a 95% Confidence Interval (CI) and a marginal error of 5%. Based on this calculation, 174 isolates were expected to be collected from the selected health facilities.

2.4. Sample Collection, Inclusion and Exclusion Criteria

2.4.1. Sample Collection

Positive *E. coli* and *S. aureus* isolates responsible for UTIs

were collected from respective health facility laboratories responsible for UTI cases between February and March 2023 for subsequent analyses.

2.4.2. Inclusion and Exclusion Criteria

All positive clinical isolates responsible for UTI in the healthcare facilities laboratory were included in this study.

2.5. Sample Isolation

Isolates responsible for UTI were collected and subcultured for colony identification of *S. aureus* and *E. coli*, Isolates were grown on cystine lactose electrolyte-deficient (CLED) (Oxoid) and MacConkey Agar (MCA) (Oxoid), respectively [21]. Gram Staining was performed to identify gram-positive and gram-negative bacteria [22]. For *S. aureus*, colonies with deep yellow colonies and gram-positive bacteria were selected and submitted to biochemical tests (Shields and Tsang, 2006) [23]. A total of hundred three (103) isolates of *E. coli* were collected from different regions based on the hospital's capacity to perform bacterial culture, isolation, and identification as follows 30 (29%) from Benjamin Mkapa Hospital, 12 (12%) from Temeke Regional Referral Hospital, 29 (28%) from Morogoro Regional Referral Hospital, and 32 (31%) from Maweni Regional Referral Hospital. A total of eighty four (84) isolates of *S. aureus* were collected from the four regions. 31(37%) were recruited from Morogoro Referral Hospital, 32(38%) from Maweni Hospital, 8(10%) from Benjamin Mkapa Hospital, and 13(15%) from Temeke Hospital. All isolates were transported to the TMDA Microbiology Laboratory in double-strength tryptic soy broth (TSB) at room temperature to the TMDA Microbiology Laboratory.

2.6. Laboratory Analysis

2.6.1. Biochemical Identification of *S. aureus*

Colonies with a deep yellow color on Cystine, lactose, electrolyte-deficient (CLED) Agar and positive Gram staining were collected for biochemical identification of *S. aureus*. Catalase and coagulase were used, as described by Ali et al. (2019) [24].

2.6.2. Biochemical Identification of *E. coli*

Red colonies on MacConkey agar (Oxoid) with negative gram staining were selected and subjected to biochemical tests. Oxidase, Sulfur Indole Motility (SIM), triple sugar iron (TSI), and urease tests were performed according to the procedures described by Ali (2019 and Brink, 2010) [24].

2.6.3. Recovery of Isolates from Transport Media (TSB)

Using the Streak method, 151 out of 187 isolates were recovered on selective media (mannitol salt agar and MacConkey Agar) after 24 h of incubation at 37 ℃. Fifty-five (55) isolates of *S. aureus* and 96 isolates of *E. coli* were recovered. Pure cultures were subcultured in their respective culture media and incubated at 37 ℃ for 18-24 hours and the pure colonies were used for subsequent experiments.

2.6.4. Antibiotics and Reference Microorganisms

The selection of antibiotics used in this study was based on the current recommendations of the Tanzania Standard Treatment Guide for treating all types of tract infections. Selected antibiotics are listed in table 1.

Table 1. *List and details of Antibiotic agents used.*

Class	Antibiotic	Batch No.	Date of expire
Penicillin	Amox/Clav (AMC 20/10 µg), Piperacillin – tazobactam (TZP 100/10µg), Amoxicillin (AML 10 µg)	3294941	2024/05/30
Aminoglycosides	Gentamicin (CN 10)	3261708	2024/03/17
Quinolones	Ciprofloxacin (CIP 5 µg)	3552317	2025/09/21
Cephalosporins	Ceftriaxone + sulbactam (CSE30 µg)		
	Ceftriaxone (CRO 30 µg)	3545371	2025/09/4
Nitrofurans	Nitrofurantoin (NIT 300 µg)	3538222	2025/08/18
Carbapenem	Meropenem (MEM 10µg)	3524471	2023/07/19

2.6.5. Standard Control Microorganism

This study used two controls reference standard microorganisms as shown in table 2.

Table 2. List of reference bacteria used.

No.	Microorganism	Ref Number	Batch	Expire date
1	E. coli	ATCC 25922	Lot: 362251	28/03/2023
2	S. aureus	ATCC 25923	Lot: 421086	27/06/2023

2.6.6. Antimicrobial Susceptibility Test

Pure overnight *E. coli* and *S. aureus* colonies were tested for antibiotic susceptibility on Muller Hilton agar using the Kirby-Bauer method [26]. The disk diffusion method was employed according to the Clinical and Laboratory Standard Institute (CLSI) guidelines (32nd edition 2022). Fresh colonies of each isolate were cultured on Nutrient Agar (NA). They were standardized in phosphate-buffered saline (PBS) to make a suspension equivalent to 0.5 McFarland, approximately 1.0×10^8 CFU/mL. Suspensions were uniformly spread on Mueller-Hinton agar (MHA) using a sterile swab. Antibiotic discs (Oxoid) containing ceftriaxone, amoxicillin/clavulanic acid, amoxicillin, meropenem, gentamycin, nitrofurantoin, ciprofloxacin, piperacin/tazobactam, or ceftriaxone/sulbactam were used. Nine discs were used for each isolate, and no more than five discs were placed on a single MHA plate at a distance of 24 mm [27]. The plates were incubated aerobic at 35 ℃ ± and 2 ℃ for 16–18 h. A calibrated Vernier caliper was used to measure the zone of inhibition, and the results were interpreted as resistance (R), intermediate (I), or susceptible (S) according to the CLSI guideline 2022. *Staphylococcus aureus ATCC 25923* and *Escherichia coli ATCC 25922* were the controls.

2.7. Data Analysis

Data were captured in Microsoft Excel and analyzed using the Statistical Package for Social Sciences (SPSS) for Windows version 23. Categorical variables were summarized as proportions, and comparisons between groups were estimated using Pearson's chi-square test. Fisher's exact test was used when the total score was less than 20 ($n \leq 20$) or when the total score was less than five (5). Intermediate-sensitive isolates were considered fully sensitive during analysis. Odds ratios with their respective 95% confidence intervals (CI) were calculated to measure the strength of associations. A two-sided p-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Sample Size and Response Rate

Determination of The sample size per hospital was determined by Mugenda and Mugenda (2003), who considered that a response rate of 50% is appropriate for analysis and reporting, a rate of 60% is reasonable, and a rate of 70% or more is excellent. A total of 151 clinical isolates were collected to register a response rate of 87.8% (Table 3). Response rates were considered excellent and accurate for statistical analysis.

Table 3. Hospital facilities response rate.

Hospital facility	Target	Actual	Response Rate (%)
BMH	43	35	81.4
MRH	43	53	123.3
MHK	43	45	104.7
TRH	43	18	41.9
Total	172	151	87.8

3.2. Sample Collection

A total of 151 clinical isolates were collected from four health facilities. The isolates comprised 96 (63.6%) *E. coli* and 55 (36.4%) *S. aureus*. Morogoro Regional Referral Hospital showed the highest number of isolates (n = 53), while Temeke (n = 18) had the lowest number of isolates (Figure 1)

and (Table 4).

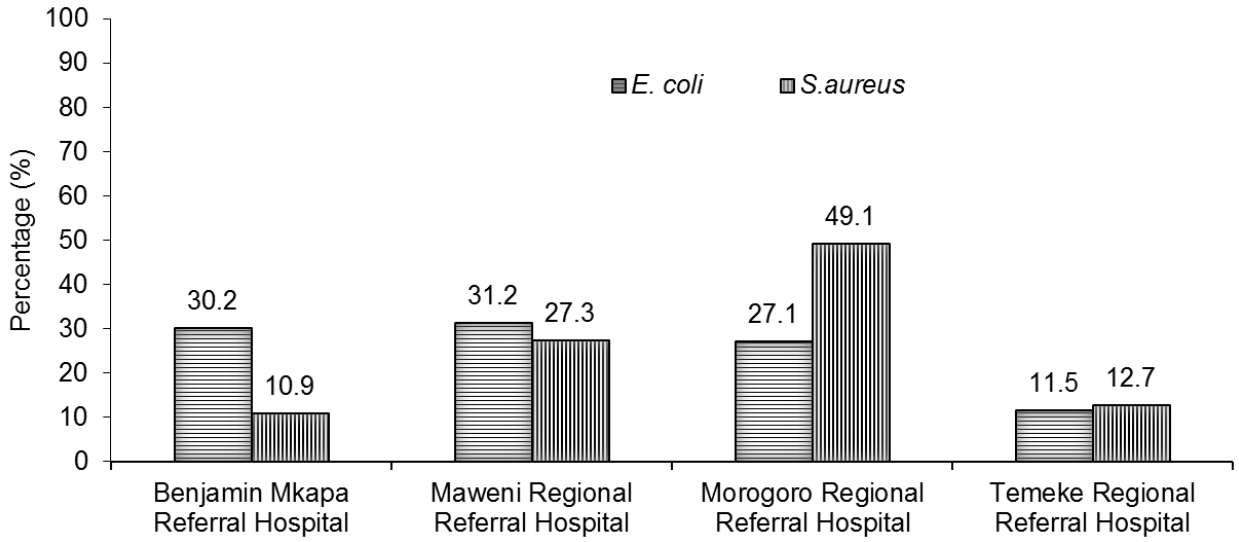

Figure 1. *Bacterial isolates from four health facilities (n= 151).*

Table 4. *Distribution of collected bacterial isolates in relation to health facilities.*

Health Facility	Isolates for *E. coli* n (%)	Isolates for *S. aureus* n (%)	Total isolates collected n (%)
BMH	29 (30.2)	6 (10.9)	35 (100)
MHK	30 (31.2)	15 (27.3)	45 (100)
MRH	26 (27.1)	27 (49.1)	53 (100)
TRH	11 (11.5)	7 (12.7)	18 (100)
Total	96 (63.6)	55 (36.4)	151 (100)

Key: BMH = Benjamin Mkapa Referral Hospital, MHK = Maweni Regional Referral Hospital, MRH = Morogoro Regional Referral Hospital, TRH = Temeke Regional Referral Hospital.

3.3. Isolation and Purification

The collected clinical isolates were identified and purified using biochemical tests; only pure isolates were used in subsequent studies.

3.4. Control Data for Standard Microorganism (Positive Control)

The results of quality control for susceptibility testing of reference microorganisms against selected antibiotics was performed using standard microorganism *Escherichia coli* ATCC 95222 and *Staphyloccocus aureus* ATCC 25923 against all antibiotics in this study indicated susceptibility of the control organism.

3.5. Prevalence of Antimicrobial Resistance

3.5.1. Prevalence of Antimicrobial Resistance Among *E. coli* Isolates

Findings revealed that *E. coli* showed varying resistance levels to all antibiotics. *E. coli* showed the highest resistance to amoxicillin (AML), peaking at 93%, whereas the lowest resistance, 1% was observed in meropenem (MEM), (Figure 2) where antimicrobial resistance patterns of *E. coli* isolates against the nine (9) antibiotics is illustrated.

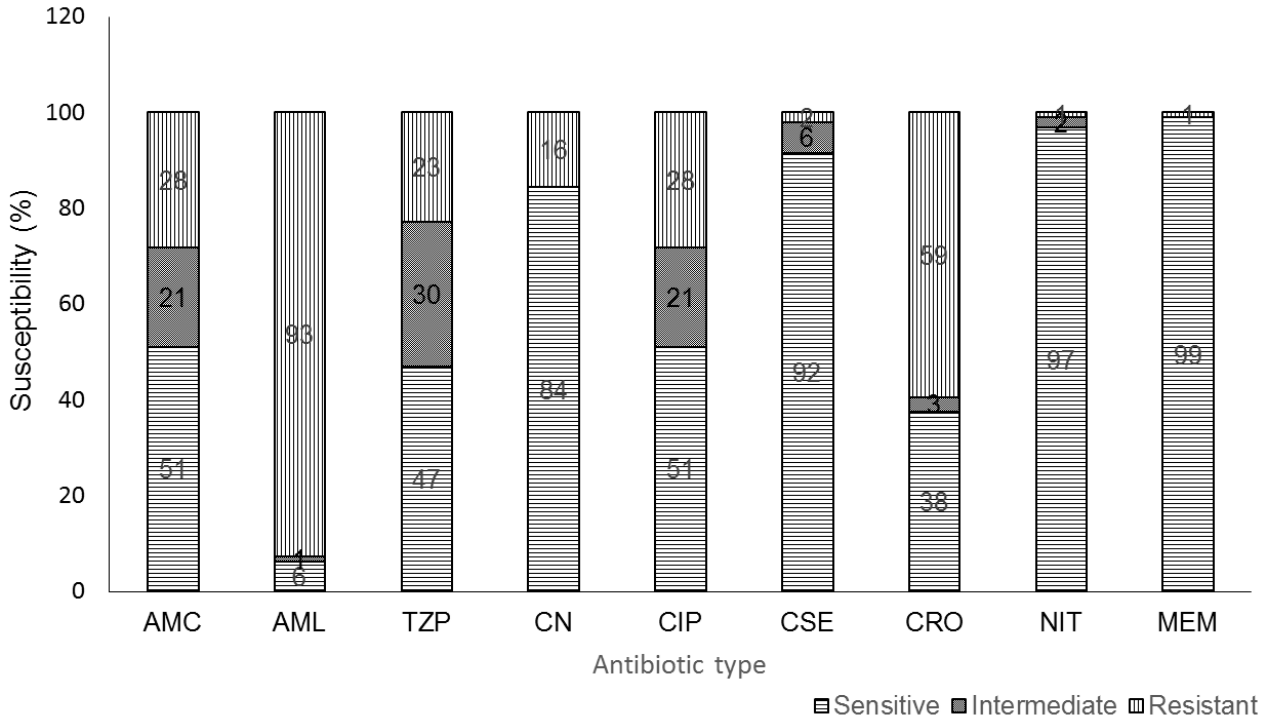

Figure 2. *Overall resistance pattern of E. coli against nine antimicrobial agents (n=96).*

3.5.2. Antimicrobial Resistance Pattern of *E. coli*

This study found a significant difference (X^2=12.808: p-value=0.002) in resistance across the selected antibiotics observed in which *E. coli* showed the highest resistance to amoxicillin (AML) and least resistance to meropenem where p-value<0.005 (Table 5).

Table 5. *Antimicrobial resistance pattern of E. coil isolates across nine antibiotics.*

Antibiotic	Sensitive n (%)	Intermediate n (%)	Resistant n (%)	X^2	p-value
Amoxicillin clavulanic acid	49 (51.0)	20 (10.8)	27 (28.2)		
Amoxicillin	6 (6.3)	1 (1.0)	89 (92.7)		
Piperacillin tazobactam	45 (46.9)	29 (30.2)	22 (22.9)		
Gentamycin	81 (84.4)	0.(0)	15 (15.6)		
Ciprofloxacin	49 (51.0)	20 (20.8)	27 (28.2)	12.808	0.002
Ceftriaxone sulbactam	88 (91.7)	6 (6.3)	2 (2.1)		
Ceftriaxone	36 (37.5)	3 (3.1)	57 (59.4)		
Nitrofurantoin	93 (96.9)	2 (2.1)	1 (1.0)		
Meropenem	95 (99.0)	0 (0)	(1.0)		

3.5.3. Antimicrobial Resistance Among *S. aureus* Isolates

Resistance to *S. aureus* was observed for all five (5) selected antibiotics. *S. aureus* demonstrated the highest resistance against amoxicillin (AML), peaking at more than 91%, followed by ciprofloxacin (CIP) at 47.3%. Nitrofurantoin (NIT) demonstrated the highest efficacy, with least resistance (4%) (Figure 3).

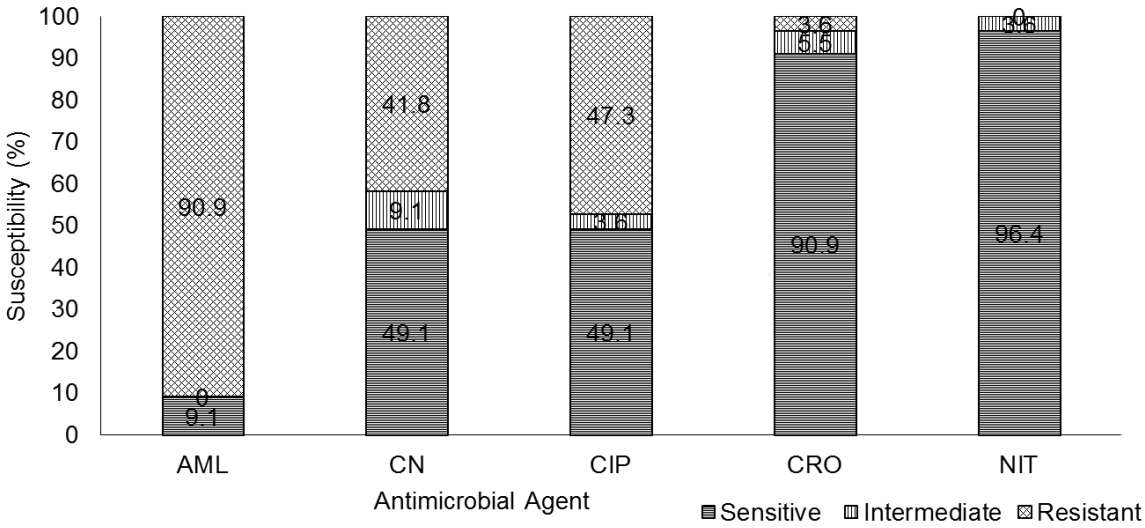

Figure 3. *Overall susceptibility pattern of S. aureus against five antibiotics.*

3.5.4. Antimicrobial Resistance Pattern of *S. aureus*

The analysis of the chi-square test indicated a significant difference (x^2=53.627, p <0.001) in resistance across the selected antibiotics, in which *S. aureus* showed the highest resistance to amoxicillin (AML) and the least resistance to nitrofurantoin (NIT), where p <0.005 (Table 6).

Table 6. *Antimicrobial resistance pattern of S. aureus isolates across five antibiotics.*

Antimicrobial agent	Sensitive n (%)	Intermediate n (%)	Resistant n (%)	x^2	p-value
Amoxicillin	5(9.1)	0	50(90.9)		
Gentamycin	27(49.1)	5(9.1)	23(41.8)		
Ciprofloxacin	28(49.1)	2(3.6)	25(47.3)	53.627	<0.001
Ceftriaxone	50(90.9)	3(5.5)	2(3.6)		
Nitrofurantoin	53(96.4)	2(3.6)	0		

3.6. Multi-drug Resistance Among Isolates

Findings from this study showed that both *E. coli* and *S. aureus* isolates demonstrated multi-drug resistance (MDR) against selected antibiotics in all health facilities under study, in which isolates from Morogoro Regional Referral Hospital showed the highest (65.4%) MDR for *E. coli* and Benjamin Mkapa Hospital showed the highest (83.3%) for *S. aureus.* Similarly, Maweni Regional Referral Hospital demonstrated the lowest multi-drug resistance for *E. coli* (23%) and *S. aureus* (13%) (Figure 4).

A chi-square (χ^2) test for independence was performed to determine whether there was any difference in MDR across the four health facilities. These findings demonstrate that the differences in MDR status across health facilities were statistically significant for *E. coli* (χ^2 = 10.301; p = 0.016) and *S. aureus* (χ^2 = 11.673; p = 0.006). Regarding MDR among *E. coli*, isolates Morogoro Regional Referral Hospital showed the highest (65.4%) and, Maweni Regional Referral Hospital demonstrated the lowest multi-drug resistance (23%) and Benjamin Mkapa Hospital showed the highest MDR in *S. aureus* (83.3%). Maweni Regional Referral Hospital demonstrated the lowest multi-drug resistance for *E. coli* (23%) and *S. aureus* (13%) (Table 7).

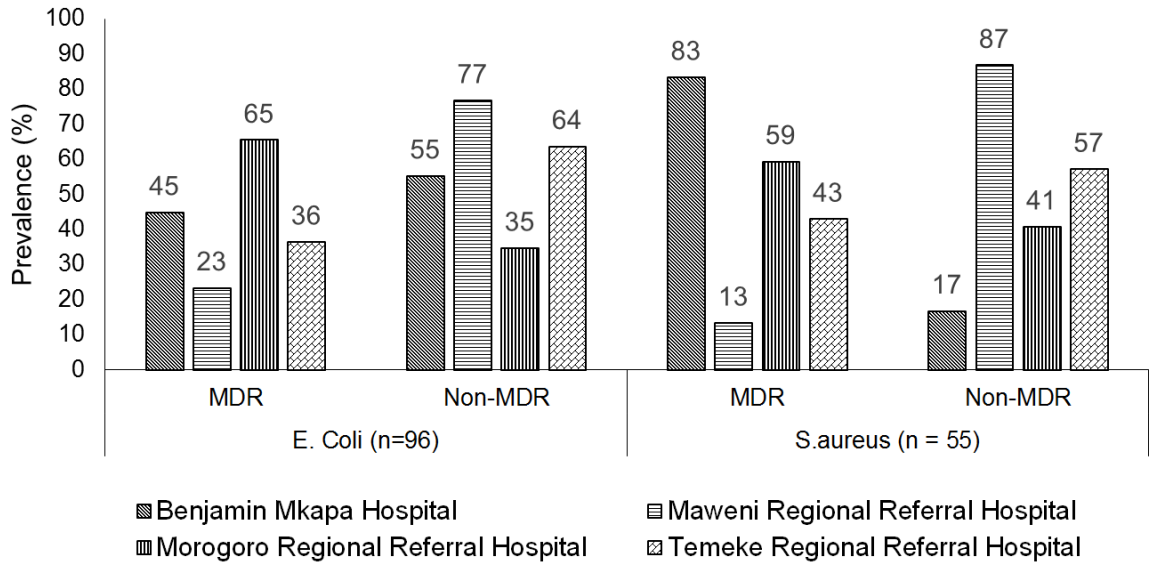

Figure 4. *Prevalence of multi-drug resistance across selected health facilities.*

Table 7. *Multidrug-resistant patterns of isolated E. coli and S. aureus across health facilities.*

Health facility	*E. coli*				*S. aureus* (%)			
	MDR Status n (%)		X^2	P - value	MDR Status n (%)		X^2	P- value
	Yes	No			Yes	No		
Benjamin Mkapa Hospital	13 (44.8)	16 (55.2)			5 (83.3)	1 (16.7)		
Maweni	7 (23.3)	23 (76.7)			2 (13.3)	13 (86.7)		
Morogoro Regional Referral Hospital	17 (65.4)	9 (34.6)	10.301	0.016	16 (59.3)	11 (40.7)	11.673	0.006
Temeke Regional Referral Hospital	4 (36.4)	7 (63.6)			3 (42.9)	4 (57.1)		
Total	41 (42.7)	55 (57.3)			26 (47.3)	(52.7)		

4. Discussion

This study assessed AMR among *E. coli* and *S. aureus* isolates from the urine of patients in selected health facilities against nine recommended antibiotics for treating UTI, according to the Standard Treatment Guidelines in Tanzania. Of the isolates (n=151) obtained, 96 (63.6%) and 55 (36.4%) were *E. coli* and *S. aureus*. respectively. This agrees with observations from other studies conducted in this locality and Sub-Saharan Africa, where *E. coli* was the predominant causative agent of UTIs [28]. *S. aureus* is not a commonly known causative agent of UTI. However, these bacteria cause ascending UTIs in patients with indwelling catheters or urinary tract instrumentation or patients who have recently undergone diagnostic cystoscopy and may experience transient bacteremia [29].

Of the six (6) antibiotic classes tested, the carbapenem showed the highest efficacy against *E. coli* (meropenem 99%), followed by nitrofuran (nitrofurantoin 96.9%) and cephalosporin (ceftriaxone sulbactam 91.7%) where p-value<0.005. These findings are consistent with those reported previously [19].

In the cephalosporin class, ceftriaxone was shown to be less effective (37.5%) against *E. coli* compared to ceftriaxone sulbactam (91.7%), this difference in efficacy can be attributed to the action of sulbactam which prevents the β-lactamase activity of *E. coli*.

E. coli isolates showed the highest resistance to antibiotics belonging to the penicillin class (amoxicillin, 92.7%) and marked resistance to amoxicillin-clavulanic acid (28.2%). These findings are consistent with those of other studies [30]. The difference in resistance between amoxicillin 92.7%) and amoxicillin-clavulanic acid 28.2%, the same phenomenon has

been reported by others [31], who attributed the increased efficacy of AMC against *E. coli* to the inhibitory effect of clavulanic acid on β-lactamase in *E. coli*.

All isolates were highly susceptible to nitrofurantoin (96.4%) followed by ceftriaxone (90.9%). The high efficacy of nitrofurantoin is attributed to its multiple drug target sites that evade antimicrobial resistance. *S. aureus* showed high resistance to amoxicillin (90.9%). Followed by ciprofloxacin 47.2% and gentamycin 41.8%). Resistance to quinolone ciprofloxacin may be attributed to chromosome-mediated resistance from overprescribing quinolone antibiotics for treating bacterial infections [32].

Overall, multi-drug resistance, i.e., resistance by one species to antibiotics from at least three classes of antibiotics, was observed, *E. coli* (42.7%) and *S. aureus* (47.3%), respectively. A similar pattern was reported previously [9]. Resistance in *S. aureus* has been documented to be mediated by the synthesis of Beta-Lactamases, Penicillin Binding Proteins (PBP2A), and Mutation-Dependent Modification of PBP Proteins [33].

Resistance in *E. coli* is caused by bacterial influx pumps, beta-lactamase production, drug target modification, and antibiotic molecule modification [31]. The development of multi-drug antimicrobial resistance in both bacterial species may be driven by factors such as misuse of antibiotics in human health care due to improper prescription practices, as reported by [34] self-medication mediated by a shorter perceived distance to drug outlets and higher medical consultation fees, as documented by [34].

This study revealed *E. coli* as an MDR etiological agent for UTI, with a prevalence rate of n=41 (42.7%). Similar findings were reported [35] with a slight variation in the percentage prevalence. Antibiotic resistance in *E. coli* is caused by the bacterial influx pump, *Beta-lactamase* production, drug target modification, and antibiotic molecule modification [31].

This study revealed *S. aureus* as an MDR etiological agent for UTI, with a prevalence rate of n=26 (47.3%). This observation correlates with other findings from studies on the status of multi-drug resistance in *S. aureus* conducted in different parts of the world, with slight differences in prevalence [19, 24, 25, 36].

Escherichia coli isolates showed MDR to commonly used antibiotics among the selected, with Morogoro Regional referral hospital being the highest with 65.4%). In comparison, the least was Maweni Regional Referral Hospital, with 7% of all health facilities.

This study revealed that *S aureus* isolates showed MDR as a commonly used antibiotic. Benjamin Mkapa Hospital had the highest rate at 83.3% and the lowest at Maweni Regional Referral Hospital at 7% in all health facility studies. This result indicates that the multi-drug resistance is vivid. This finding is consistent with those of other studies that showed a similar behavior of *S. aureus* against different classes of antibiotics.

5. Conclusion

This study found the existence of resistant and MDR isolates of *E. coli* and *S. aureus* to some antibiotics recommended in the Tanzania Standard Treatment Guidelines. Our findings call for continuous surveillance of AMR and implementation of antimicrobial stewardship at all hospital levels to identify and optimize antibiotic use against less-efficacious antibiotics still used in clinical practice. It also recommends a broader study on antibiotics currently in use to identify microorganisms that are highly resistant to and recommend their exclusion from treatment.

Abbreviations

CFU	Colony Forming Unit
AMR	Antimicrobial Resistance
LMICs	Low- and Middle-income Countries
UTI	Urinary Tract Infections
MDR	Multi-drug Resistance
AML	Amoxicillin
NIT	Nitrofurantoin
CIP	Ciprofloxacin
CN	Gentamicin
CSE	Ceftriaxone + Sulbactam
CRO	Ceftriaxone
MEM	Meropenem
TMDA	Tanzania Medicines and Medical Devices Authority
WHO	World Health Organization
NAP–AMR	National Action Plan on Antimicrobial Resistance
WASH	Water and Hygiene Sanitation
BMH	Benjamin Mkapa Hospital
MHK	Maweni Regional Referral Hospital
MRH	Morogoro Regional Referrel Hospital
TRH	Temeke Regional Referral Hospital
SDG	Sustainable Development Goals
STG	Standard Treatment Guidelines
CLED	Cystine Lactose Electrolyte-deficient
MCA	MacConkey Agar
TSB	Tryptic Soy Broth
SIM	Sulfur Indole Motility
NA	Nutrient Agar
PBS	Phosphate-buffered Saline
CLSI	Clinical and Laboratory Standard Institute
ATCC	American Type Culture Collection

Author Contributions

Adelard Bartholomew Mtenga: Conceptualization, Formal Analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing

Adam Fimbo: Supervision, Writing – review & editing

Danstan Hipolite: Project administration, Writing – review & editing

Revocatus Makonope: Data curation, Investigation, Methodology

Saxon Mwambene: Data curation, Investigation, Methodology, Software

Yonah Hebron: Validation, Writing – review & editing

Kissa Mwamwitwa: Supervision, Validation, Writing – review & editing

Raphael Zozimus Sangeda: Supervision, Validation, Writing – review & editing

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Ethical Compliance

All procedures performed in studies did not involve human or animals and thus for this kind of research work ethical clearance was not reuired.

Data Summary

Research data for this publication is available for any kind of use, all data used to draw conclusion are provided in the manuscript as required.

Transparency Declaration

As the lead author on behalf of all authors, I confirm that the manuscript was developed based on the research data obtained from a genuine research work conducted and all information provided in this manuscript is honest, sincere and transparent account of the research to the best of our knowledge. Authors take fully responsibility of the information presented in this publication. All authors have none to declare.

Conflicts of Interest

The authors declare no conflicts of interest.

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