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Antimicrobial Susceptibility Patterns of Bacterial Isolates at Tertiary Hospital in Tanzania: A Retrospective Cross-Sectional Study

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ABSTRACT

Background: Antimicrobial resistance (AMR) has escalated significantly within healthcare facilities and community settings, presenting substantial challenges in the management of bacterial infections. Our research aimed to analyze three-year trends in antimicrobial susceptibility through the evaluation of AMR patterns in blood, urine, and wound swabs.

Methods: A retrospective cross sectional study was carried out at The Benjamin Mkapa Tertiary Hospital (BMH) in Dodoma, Tanzania. Researchers reviewed electronic medical records and laboratory results of patients from January 2020 to December 2022.

Results: The number of positive blood samples tested for antimicrobial susceptibility testing (AST) was 166 (2020). *Escherichia coli* showed resistance trends to ceftriaxone 100 (60%), meropenem 19 (12%), amikacin 21 (12%), and piperacillin-tazobactam 17 (10%). *Staphylococcus aureus* exhibited resistance trends of 89 (46%) for ciprofloxacin and 75 (45%) for levofloxacin, while those for gentamicin, vancomycin, and azithromycin were 30 (18%), 18 (11%), and 58 (35%), respectively. ASTs were performed on 65 positive wound/pus swabs in 2020. *Pseudomonas aeruginosa* showed fluctuating resistance patterns to ciprofloxacin, meropenem, and piperacillin-tazobactam over the years: 7 (11%), 17 (26%), and 19 (29%) in 2020. In 2020, 107 urine samples were tested for AST. *Escherichia coli* showed resistance to nine antimicrobials, including ceftazidime 20 (19%), meropenem 7 (7%), piperacillin-tazobactam 7 (32%), cefuroxime 9 (8%), amoxicillin-clavulanic acid 29 (27%), nitrofurantoin 7 (7%), and amikacin 8 (8%).

Conclusion: The findings underscore an increase in antimicrobial resistance (AMR) among priority pathogens, emphasising the importance of evidence-based antibiotic selection for direct treatment, empiric therapy, and surgical prophylaxis. We recommend future prospective, ward-specific, and outpatient-inpatient comparative AMR surveillance to address existing limitations and improve infection management strategies.

BACKGROUND

The significant escalation in resistant bacterial strains constrains the therapeutic options for treating infectious diseases, including febrile neutropenia, urinary tract infections, pneumonia, osteomyelitis, and device related bloodstream infections. Worldwide, the incidence of antimicrobial resistance among Gram negative bacteria is increasing faster than among Gram positive bacteria. Furthermore, there are currently no new antibiotics that demonstrate efficacy against Gram-negative bacteria in the near-term pipeline.[1, 2]

Surgical Site Infections (SSIs) account for 33% of all Healthcare Associated Infections (HAIs) in sub-Saharan Africa (SSA), caused by Gram negative organisms with a high level of Multidrug Resistance (MDR).[3] *Escherichia coli* is a well-known pathogenic bacterium associated with bloodstream infections (BSIs). This organism has demonstrated resistance to carbapenems and colistin, as documented in a tertiary hospital in South Africa.[4] *Pseudomonas aeruginosa* is a ubiquitous Gram-negative bacterium in South Africa and Ghana and is associated with causing up to 6% of Gram-negative BSIs among immunodeficient children.[5]

Prompt antimicrobial treatment is essential for the survival of patients with bacterial bloodstream infections infections.[6] Bloodstream infections are among the most lethal infections, with an estimated overall crude mortality rate of 15% 30%.[7] Antimicrobials should be administered promptly to individuals diagnosed with septicaemia, ideally within one hour of identification recognition.[8] A twelve per-cent increase in crude mortality is observed for each hour that antimicrobials are withheld from the initiation of septic shock. Furthermore, there is a 30% increase in mortality if appropriate treatment is not administered within the first twenty-four hours hours.[8] Urinary tract infections (UTIs) are the most prevalent infections worldwide, primarily caused by *Escherichia coli*.[9] Research conducted in Ethiopia and Uganda revealed that *Escherichia coli* and *Klebsiella pneumoniae* displayed multidrug resistance patterns, while *Acinetobacter baumannii* and *Pseudomonas aeruginosa* showed complete resistance to both ampicillin and piperacillin.[10, 11]

Understanding antimicrobial susceptibility patterns in hospitals is crucial for guiding antimicrobial procurement, conducting regular surveillance, and selecting appropriate treatments for empirical use, direct therapy, and surgical prophylaxis. Regular surveillance of antimicrobial resistance (AMR) provides the foundation for developing evidence-based prescribing policies and establishing benchmarks for antimicrobial stewardship programs.[12] At Benjamin Mkapa Hospital (BMH), it was noted that many patients were treated empirically for over 72 hours and received more than one day of surgical prophylactic antimicrobials.[13] This practice resulted in increased healthcare costs, prolonged hospital stays, higher morbidity and mortality rates, and faster development of resistance. Despite the availability of National Treatment Guidelines, there is still a pressing need for locally relevant guidelines. BMH prioritises evidence based monitoring of antimicrobial susceptibility trends to inform antibiotic testing, prescribing practices, and overall antibiotic use. Our retrospective study aims to evaluate antimicrobial resistance patterns among bacterial isolates from blood, urine, and wound swabs to better inform treatment decisions for bacterial infections and guide antibiotic susceptibility testing.

METHODS

Study Design and Duration

A single-centre retrospective cross-sectional study was conducted at The Benjamin Mkapa Zonal Referral Hospital in Dodoma (BMH), Tanzania, from January 2020 to December 2022.

Study Area

The study was conducted at Benjamin Mkapa Hospital in Dodoma, Tanzania. The hospital is affiliated with the University of Dodoma and has a maximum capacity of 400 beds. The BMH Laboratory holds accreditation from the Southern African Development Community Accreditation Services (SADCAS) under ISO 15189:2012.[15] This laboratory adheres to standard operating procedures for sample analysis, employing conventional methods to detect bacterial infections. Results from antibiotic sensitivity tests are interpreted according to the guidelines established by the Clinical Laboratory Standards Institute (CLSI). Furthermore, the laboratory is recognised as a vital facility for monitoring antimicrobial resistance in Tanzania and serves as a training venue for students from the University of Dodoma.

Study Population

The study involved a review of electronic medical records and laboratory results for eligible patients meeting the inclusion criteria to analyse antimicrobial susceptibility trends in urine, wounds/pus swabs, and blood. All patient records from the Integrated Health Management Information System (IHMIS) were included in the study. Data on blood, pus, and urine sample growth patterns, and on samples with positive culture results, were assessed. The collected data included patient demographics (age and sex), wards, laboratory results (isolates and antimicrobial susceptibility results), and patient status (inpatient or outpatient). Subsequently, the data were exported to Microsoft Excel for cleaning and analysis.

Laboratory Procedures

Blood, Pus and Urine Sample Collection and Culture Procedures

Venous blood was aseptically collected from each patient. For pediatric patients, 2-5 ml of blood was drawn into BD BACTEC Plus™/F/F culture vials (Becton Dickinson and Company), while for adults, 8-10 ml was collected in BD BACTEC Plus Aerobic/F/F culture vials (Becton Dickinson and Company). The blood samples were promptly transported to the BMH laboratory at room temperature, where they were incubated in the BACTEC machine for further analysis. The blood samples were incubated in the BD BACTEC machine for up to 5 to 7 days. Positive blood cultures were subsequently inoculated onto Blood agar, Chocolate agar, and MacConkey agar, which were then incubated for 18 to 24 hours at 37°C. Standard microbiological techniques were utilised to identify the bacteria, incorporating evaluations of colony morphology, Gram staining, and various biochemical tests (Oxoid, UK). Gram positive cocci were identified based on their Gram reaction and the results of catalase and coagulase tests. Gram negative rods were identified through biochemical tests, including Kligler Iron Agar (KIA), Simon's citrate agar, Indole, urea, and motility assessments.[16, 17]

A pus sample was collected from the discharge area of the wound. The swab was carefully taken from the centre of the wound, ensuring that the surrounding skin margins were avoided to prevent contamination. The swab was gently rotated to allow thorough absorption of the pus, then immediately placed into a sterile container for testing. Subsequently, a primary Gram stain of the pus sample was performed based on average observations from 10 fields. This process was undertaken to characterise and quantify polymorphonuclear cells (PMNCs) and microorganisms. A moderate presence (2–10 PMNCs and microorganisms) or a high presence (>10 PMNCs and microorganisms) per oil immersion field at 100× magnification was deemed positive, and those samples were subjected to culture. Each sample that met these criteria was cultured under aerobic conditions on blood agar (Oxoid, UK) and MacConkey agar (Oxoid, UK). Following growth, biochemical identification tests were systematically performed for Gram-positive bacteria, utilising hemolysis on blood agar, as well as tests for catalase, coagulase/Staphlex/DNase, bile esculin, optochin, and bacitracin.

For Gram-negative bacteria, identification tests included lactose fermentation on MacConkey agar, alongside oxidase testing, triple sugar iron agar (TSI), sulfur-indole-motility (SIM), urease, and citrate tests (Oxoid, UK).[17, 18]

Urine samples were collected using the midstream urine method, and the clean-catch method was used for children. Participants were instructed to collect urine samples in two separate sterile containers. These samples were immediately stored at 4°C in a refrigerator, and cultures were performed within 24 hours of collection. To isolate microorganisms, urine samples were plated on cysteine lactose electrolyte deficient (CLED) agar. A calibrated loop delivering approximately 0.001 mL was used to inoculate CLED agar plates, which were then incubated aerobically at 37°C for 24 hours. The growth of a single type of organism at a concentration greater than 10^5 colony forming units was considered indicative of bacteriuria. Clinical isolates were identified and confirmed biochemically following standard laboratory procedures. The confirmed bacterial isolates were suspended in nutrient broth supplemented with 16% glycerol and stored at -80°C. These isolated bacterial samples were subsequently used for antimicrobial susceptibility testing.[17, 19]

Sample Size Estimation and Sampling Techniques

The development of antibiograms requires collecting a minimum of 30 isolates for each reported bacterial species, which is essential for ensuring the reliability of cumulative antibiograms that reflect antimicrobial susceptibility trends. In this process, only final and verified results from antimicrobial susceptibility testing (AST) were used for assessment, analysis, and the establishment of trends related to antimicrobial resistance (AMR). The antibiotics evaluated were categorised according to the World Health Organisation's AWaRe classification, which includes Access, Watch, and Reserve. The findings from this analysis were presented as percentages indicating susceptibility levels among the tested isolates.[20] To accurately interpret the results of antibiotic susceptibility tests, the Clinical Laboratory Standards Institute (CLSI) guidelines were strictly followed. All pertinent data were meticulously collected and entered into a Microsoft Excel spreadsheet, where they underwent a thorough cleaning process to ensure accuracy prior to analysis.

Once the data were cleaned, a comprehensive analysis was performed to extract vital demographic information, trends in sample growth, the specific wards from which samples were taken, and overall patterns in antimicrobial susceptibility. Antibiograms serve as valuable tools, illustrating the shifting patterns of bacterial susceptibility to various antibiotics over time. To effectively summarise the essential characteristics of the patient population, the bacterial isolates, and the antimicrobial susceptibility results, descriptive statistics were employed, providing a clearer understanding of the data collected.

Inclusion Criteria

Urine, wound/pus swab, and blood samples collected between 2020 and 2022 were analysed to identify growth, no growth, and mixed/contaminated growth. Samples with growth isolates were further tested for antimicrobial susceptibilities to determine if they were susceptible, resistant, or had intermediate results. When developing antimicrobial susceptibility trends, we used the total number of isolates as the denominator, and the numbers of susceptible, intermediate, and resistant isolates as the numerators. The ppriority isolates from urine samples were *Escherichia coli* and *Klebsiella pneumoniae*, which were tested for several antibiotics according to the guidelines. Surveillance of AMR in wound/pus swabs was *Escherichia coli*, *Acinetobacter baumannii*, *Pseudomonas*, *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Streptococcus pneumoniae*. *Escherichia coli*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Streptococcus pneumoniae* were isolated from the blood sample.[21]

Exclusion Criteria

We excluded records with incomplete or missing data. According to the National AMR surveillance guidelines, isolates from stool, urethral, cervical swabs, and cerebrospinal fluid specimens were not included in our surveillance[21]. In line with the Tanzania AMR surveillance framework, we also excluded non-priority pathogens from both Gram-negative and Gram-positive bacteria.

Data Processing, Analysis and Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was performed on Mueller-Hinton agar (Oxoid, UK) using the conventional disc diffusion method, as previously described by the Clinical Laboratory Standards Institute (CLSI), with the respective antibiotic disks for Gram positive and Gram negative bacteria. Respective disks for Gram-positive bacteria included were penicillin G (10µg), erythromycin (15µg), clindamycin (2µg), ciprofloxacin (5µg), gentamicin (10µg), gentamicin (120µg–high level for *Enterococcus spp*), trimethoprim-sulfamethoxazole (1.25µg/ 23.7µg), and chloramphenicol (30µg). Antibiotic discs for Gram-negative bacteria included were ampicillin (10µg), ciprofloxacin (5µg), gentamicin (10µg), amikacin (30µg), ceftriaxone (30µg), ceftazidime (10µg), and cefepime (10µg), trimethoprim/sulfamethoxazole (1.25µg/23.7µg), piperacillin/tazobactam (100/10µg), and meropenem (10µg). After incubating the plates at 37°C for 18–24 hours, the diameter (nearest whole mm) of the inhibition zones for each antibiotic was measured.[16, 18, 19] The breakpoint interpretations were based on whether the bacterium was susceptible (S), intermediate (I), or resistant (R) to the tested drugs, according to the CLSI recommendations.[17] The choice of antibiotics varied depending on the range available to the laboratory.

Ethical Approval

The National Institute for Medical Research (NIMR) and the National Health Research Ethics Review Committee (NatHREC) provided ethical clearance for the study under reference number NIMR/HQ/R. 8a/Vol. IX/4260, with the decision date recorded as March 31, 2023. Additionally, the BMH authority authorised the research to be conducted within the hospital. Robust measures for data storage and confidentiality were implemented, including password-protected access. All patient identifiers were removed prior to data extraction, and the data were stored securely.

RESULTS

Demographic and Collected Priority Samples

Between 2020 and 2022, a substantial number of samples were collected from adult outpatients, the majority of whom were over 46 years of age. Female patients predominantly contributed urine samples, whereas male patients primarily contributed pus/wound swabs and blood samples, as detailed in tables 1 to 3.

The number of positive blood samples tested for ASTs was 166 (2020), 191 (2021), and 247 (2022), (Table 1). The data in Figures I to 3 and Table 1 illustrate the antimicrobial susceptibility patterns of bacterial isolates from blood samples. In 2020, *Escherichia coli* showed resistance trends to ceftriaxone 100 (60%), cefepime 102 (61%), meropenem 19 (12%), gentamicin 55 (33%), amikacin 21 (12%), and piperacillin-tazobactam 17 (10%). However, in 2021, *Escherichia coli* resistance trends were to ceftriaxone 125 (65%), cefepime 98 (51%), meropenem 38 (19%), gentamicin 43 (23%), amikacin 23 (12%), and piperacillin-tazobactam 81 (42%). By 2022, *Escherichia coli* demonstrated resistance trends to ceftriaxone 183 (74%), cefepime 170 (69%), meropenem 27 (11%), gentamicin 79 (32%), amikacin 36 (15%), and piperacillin-tazobactam 92 (37%).

Staphylococcus aureus, a grampositive bacterium, exhibited decreasing susceptibility trends from 2020 to 2022. In 2020, the resistance rates for ciprofloxacin and levofloxacin were 89 (46%) and 75 (45%), respectively, while those for gentamicin, vancomycin, and azithromycin were 30 (18%), 18 (11%), and 58 (35%), respectively. In 2021, the resistance rates for ciprofloxacin and levofloxacin were 37 (19%) and 63 (33%), respectively, with resistance rates of 47 (25%), 37 (19%), and 35 (18%) for gentamycin, vancomycin, and azithromycin, respectively. However, in 2022, the resistance rates for ciprofloxacin and levofloxacin increased to 62 (25%) and 92 (37%), respectively, while resistance rates for gentamycin, vancomycin, and azithromycin were 100 (41%), 16 (6%), and 69 (28%), respectively.

The ASTs of 65 positive wound/pus swabs were tested in 2020, 197 in 2021, and 326 in 2022, see supplementary table 2, supplementary Table 1 and Figures 4 to 5 illustrate the antimicrobial susceptibility trends of bacteria isolates from wound/pus swabs. *Pseudomonas aeruginosa* show fluctuating resistance patterns to ciprofloxacin, meropenem, and piperacillin-tazobactam over the years: 7 (11%), 17 (26%), and 19 (29%) in 2020; 67 (34%), 30 (15%), and 49 (25%) in 2021; and 63 (19%), 47 (14%), and 49 (15%) in 2022, respectively.

Acinetobacter baumannii isolates were assessed for antibiotic resistance patterns over the years. In 2020, the bacteria exhibited susceptibility to sulfamethoxazole trimethoprim 23(35%), ciprofloxacin 25 (39%), imipenem 14 (22%), gentamycin 22 (34%), and amikacin 8(12%). The resistance pattern rates in 2021 were sulfamethoxazole trimethoprim 40 (20%), ciprofloxacin 62 (32%), imipenem 32 (16%), gentamicin 58 (29%), and amikacin 15 (8%). Subsequently, in 2022, the resistance pattern further increased to sulfamethoxazole trimethoprim 80 (25%), ciprofloxacin 77 (24%), imipenem 36 (11%), gentamicin 49 (15%), and amikacin 21 (6%). The number of positive urine samples tested for ASTs was 107 in 2020, 306 in 2021, and 407 in 2022, see Table 3 and supplementary Table 1. The antimicrobial resistance pattern of bacterial isolates from urine is illustrated in Figure 7.

Two bacteria, *Escherichia coli* and *Klebsiella pneumoniae*, were tested for resistance patterns across several antimicrobials. Escherichia coli in 2020 showed resistance to nine antimicrobials, including ceftazidime 20 (19%), cefepime 37 (35%), imipenem 5 (5%), meropenem 7 (7%), piperacillin-tazobactam 7 (32%), cefuroxime 9 (8%), amoxicillin-clavulanic acid 29 (27%), nitrofurantoin 7 (7%), and amikacin 8 (8%). Klebsiella pneumoniae in 2020 also showed resistance to nine antimicrobials, including ceftazidime 21 (20%), cefepime 38 (36%), imipenem 8 (8%), meropenem 4 (4%), piperacillin-tazobactam 8 (8%), cefuroxime 10 (9%), amoxicillin-clavulanic acid 24 (22%), nitrofurantoin 5 (5%), and amikacin 7 (7%). More detailed data for the years 2021 and 2022 are provided in supplementary table 1.

AMK-amikacin, AMC-amoxicillin-clavulanic, AMP-ampicillin, AMX-amoxicillin, CAZ-ceftazidime, CFZ-cefazolin, CHF-chloramphenicol, CIP-ciprofloxacin, CLI-clindamycin, CRO-ceftriaxone, CTX-cefotaxime, CXM-cefuroxime, ERY-erythromycin, FEP-cefepime, GEN- gentamicin, IPM-imipenem, LVX-levofloxacin, MEM- meropenem, MEM-meropenem, NIT-nitrofurantoin, OX-oxacillin, PEN-penicillin, PIP-piperacillin, PTZ-piperacillin-tazobactam, SXT-sulfamethoxazole-trimethoprim, TET- tetracycline, TOB-tobramycin and VAN-vancomycin.

TABLE 1: Descriptions of blood sample and demographic

Variables	2020 (N=345)	2021 (N=906)	2022 (N=3240)
Age (Mean ± SD)	27.3±24.7	29.2±26.2	21.0±24.6
Age groups	Number (%)	Number (%)	Number (%)
<2 years old	1(0.29)	12(1.32)	321(9.91)
3-5 years old	66(19.13)	164(18.10)	422(13.02)

Continue

TABLE 1: Continued

Variables	2020 (N=345)	2021 (N=906)	2022 (N=3240)
6-14 years old	90(26.09)	176(19.43)	385(11.88)
15-20 years old	11(3.19)	29(3.20)	40(1.23)
21-45 years old	77(22.32)	202(22.30)	341(10.52)
>46 years old	100(28.99)	323(35.65)	480(14.81)
Patient type			
Outpatient	269(77.97)	633(69.87)	2426(74.88)
Inpatients	76(22.03)	273(30.13)	814(25.12)
Type of ward			
Unspecified ward name	159(46.09)	593(65.45)	1701(52.50)
Paediatric	73(21.16)	74(8.17)	436(13.46)
Private	41(11.88)	104(11.48)	230(7.10)
Surgical	10(2.90)	28(3.09)	224(6.91)
Orthopaedics	5(1.45)	0(0.00)	146(4.51)
Medical ward	3(0.87)	8(0.88)	142(4.38)
Cardiology	11(3.19)	30(3.31)	131(4.04)
ICU	27(7.83)	26(2.87)	107(3.30)
Obstetrics and Gynaecology	2(0.58)	18(1.99)	105(3.24)
Urology	7(2.03)	4(0.44)	10(0.31)
Mortuary	3(0.87)	0(0.00)	8(0.25)
Nephrology	0(0.00)	8(0.88)	0(0.00)
Oncology	4(1.16)	9(0.99)	0(0.00)
Ophthalmology	0(0.00)	4(0.44)	0(0.00)
Sex			
Male	173(50.14)	499(55.08)	1831(56.51)
Female	172(49.86)	407(44.92)	1409(43.49)
Sample growth patterns			
Samples with no growth	141(40.87)	690(76.16)	2591(79.97)
Samples with positive growth	166(48.12)	191(21.08)	247(7.62)
Samples with mixed growth/contamination	38(11.01)	25(2.76)	402(12.41)

Blood samples demonstrated positive growth rates of 48.12% (166 out of 345) in 2020, 21.08% (191 out of 906) in 2021, and 7.62% (247 out of 3240) in 2022

TABLE 2: Descriptions of Pus/Wound Sample and Demographic Data

Variables	2020 (N=82)	2021 (N=237)	2022 (N=451)
Age (Mean ± SD)	44.9±22.5	40.3±21.5	41.3±21.7
Age groups	Number (%)	Number (%)	Number (%)
<2 years old	0(0.00)	4(1.69)	19(4.21)
3-5 years old	3(3.66)	5(2.11)	4(0.89)
6-14 years old	3(3.66)	14(5.91)	27(5.99)
15-20 years old	1(1.22)	12(5.06)	20(4.43)
21-45 years old	29(35.37)	107(45.15)	186(41.24)
>46 years old	46(56.10)	95(40.08)	195(43.24)
Patient type			
Inpatients	44(53.66)	108(45.57)	263(58.31)
Outpatient	38(46.34)	129(54.43)	188(41.69)
Type of ward			
Unspecified ward name	51(62.20)	138(58.23)	187(41.46)
Surgical	11(13.41)	43(18.14)	114(25.28)
Private	2(2.44)	12(5.06)	61(13.53)
Paediatric	7(8.54)	10(4.22)	26(5.76)

Continue

TABLE 2: Continued

Variables	2020 (N=82)	2021 (N=237)	2022 (N=451)
Urology	2(2.44)	17(7.17)	22(4.88)
Obstetrics and gynaecology	0(0.00)	4(1.69)	14(3.10)
Cardiology	2(2.44)	1(0.42)	7(1.55)
ICU	1(1.22)	5(2.11)	6(1.33)
Mortuary	0(0.00)	0(0.00)	5(1.11)
Medical ward	0(0.00)	2(0.84)	4(0.89)
Orthopaedics	0(0.00)	0(0.00)	4(0.89)
Nephrology	0(0.00)	3(1.27)	1(0.22)
Oncology	6(7.32)	2(0.84)	0(0.00)
Sex			
Male	49(59.76)	152(64.14)	297(65.85)
Female	33(40.24)	85(35.86)	154(34.15)
Sample growth patterns			
Samples with no growth	17(20.73)	36(15.19)	41(9.09)
Samples with positive growth	65(79.27)	197(83.12)	326(72.28)
Samples with mixed growth/contamination	0(0.00)	4(1.69)	84(18.63)

Pus/wound swabs showed positive growth rates of 79.27% (65 out of 82) in 2020, 83.12% (197 out of 237) in 2021, and 72.28% (326 out of 451) in 2022

TABLE 3: Descriptions of Urine Samples and Demographic Data

Variable	2020 (N=680)	2021 (N=1327)	2022 (N=2596)
Mean ± SD	26.75±22.01	30.42±21.57	27.81±21.90
Age groups	Number (%)	Number (%)	number (%)
<2 years old	0(0.00)	7(0.53)	78(3.00)
3-5 years old	55(8.09)	100(7.54)	296(11.40)
6-14 years old	170(25.00)	248(18.69	489(18.84)
15-20 years old	8(1.18)	33(2.49)	44(1.69)
21-45 years old	157(23.09)	623(46.95)	1083(41.72)
>46 years old	290(42.65)	316(23.81)	606(23.34)
Patient type			
Outpatient	92(13.53)	1194(89.98)	2394(92.22)
Inpatients	588(86.47)	133(10.02)	202(7.78)
Type of ward			
Unspecified ward name	543(79.85)	1199(90.35)	2457(94.65)
Paediatric	30(4.41)	47(3.54)	72(2.77)
Private	29(4.26)	23(1.73)	23(0.89)
ICU	14(2.06)	8(0.60)	18(0.69)
Urology	9(1.32)	6(0.45)	8(0.31)
Surgical	10(1.47)	9(0.68)	6(0.23)
Cardiology	10(1.47)	16(1.21)	4(0.15)
Medical ward	7(1.03)	3(0.23)	3(0.12)
Obstetrics and gynaecology	8(1.18)	7(0.53)	3(0.12)
Mortuary	1(0.15)	0(0.00)	2(0.08)
Nephrology	6(0.88)	5(0.38)	0(0.00)
Oncology	4(0.59)	2(0.15)	0(0.00)
Ophthalmology	9(1.32)	2(0.15)	0(0.00)

Continue

TABLE 3: Descriptions of Urine Samples and Demographic Data

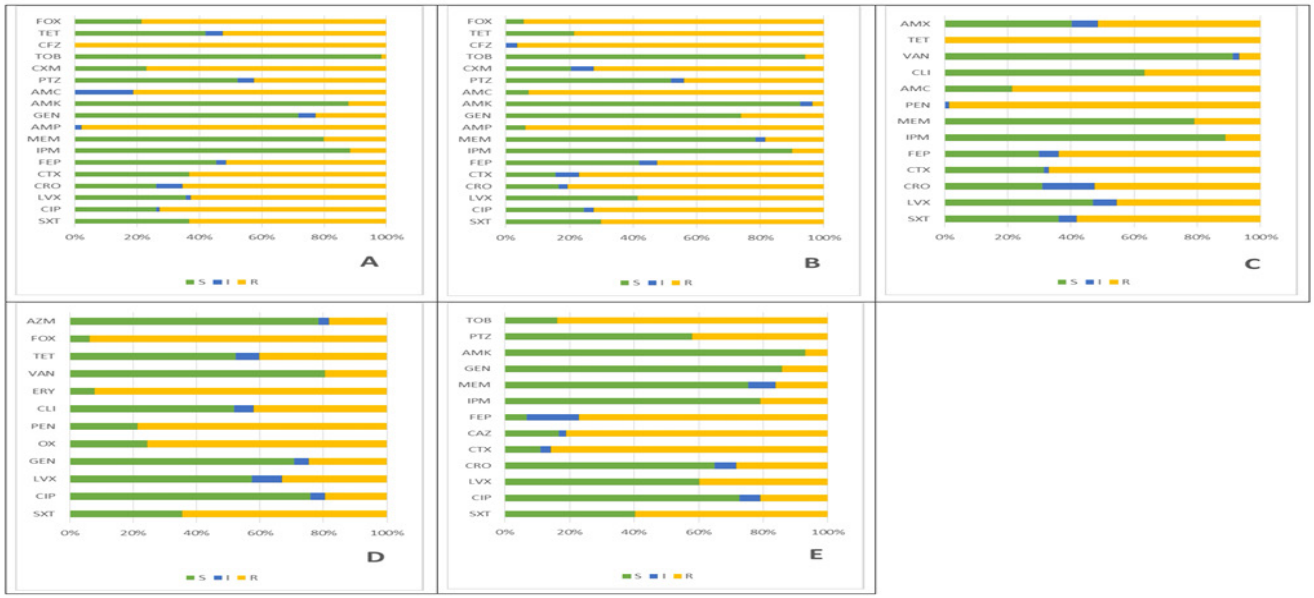
Variable	2020 (N=680)	2021 (N=1327)	2022 (N=2596)
Sex			
Male	284(41.76)	560(42.20)	1407(54.20)
Female	396(58.24)	767(57.80)	1189(45.80)
Sample growth patterns			
Samples with no growth	544(80.00)	965(72.72)	2049(78.93)
Samples with positive growth	107(15.74)	306(23.06)	407(15.68)
Samples with mixed growth/contamination	29(4.26)	56(4.22)	140(5.39)

Urine samples displayed a positive growth pattern of 15.74% (107 out of 680) in 2020, 23.06% (306 out of 1327) in 2021, and 15.68% (407 out of 2596) in 2022

FIGURE 1: Antimicrobial Susceptibility Patterns of Bacteria Isolates From Blood Samples, 2020

Note: E*scherichia coli, A; Streptococcus pneumoniae, B; Klebsiella pneumoniae, C; Staphylococcus aureus, D; Acinetobacter baumannii, E*

FIGURE 2: Antimicrobial Susceptibility Patterns of Bacteria Isolates from Blood Samples, 2021



Note: Escherichia coli, A; Streptococcus pneumoniae, B; Klebsiella pneumoniae, C; Staphylococcus aureus, D; Acinetobacter baumannii, E

FIGURE 3: Antimicrobial Susceptibility Patterns of Bacteria Isolates From Blood Samples, 2022

Note: *Escherichia coli, A; Streptococcus pneumoniae, B; Klebsiella pneumoniae, C; Staphylococcus aureus, D; Acinetobacter baumannii, E*

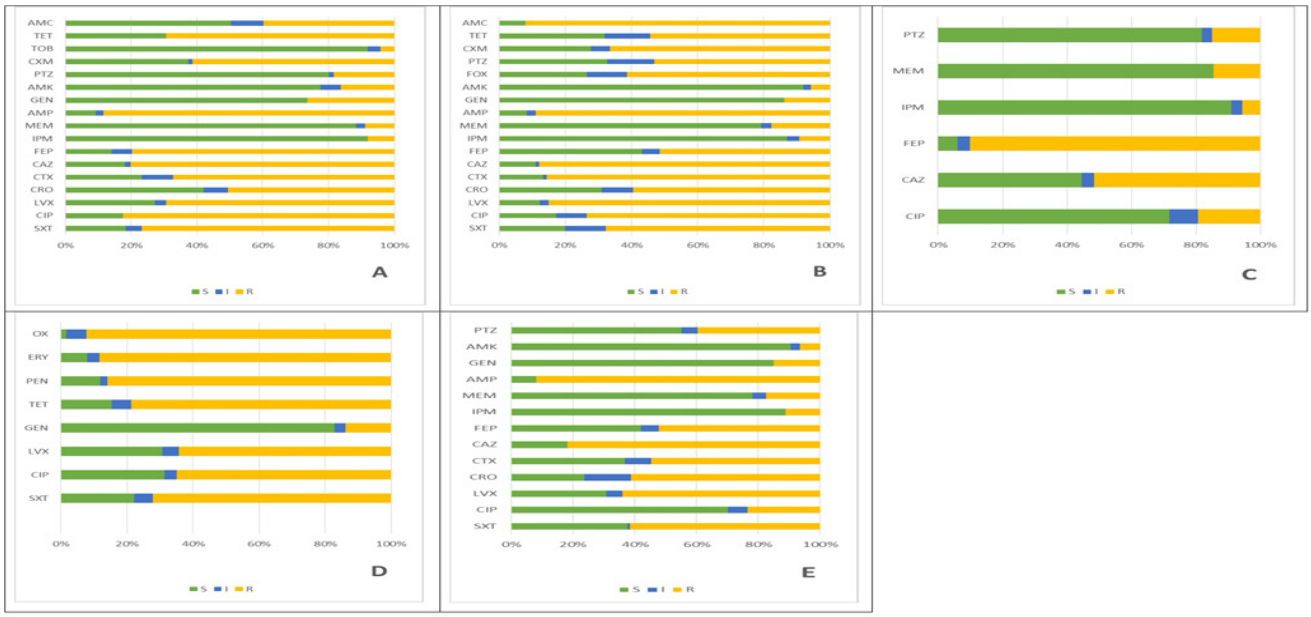
FIGURE 4: Antimicrobial Susceptibility Trends of Bacteria Isolates from Wound/Pus Swabs, 2020

Note: Escherichia coli, A; Pseudomonas aeruginosa, B; Klebsiella pneumoniae, C; Staphylococcus aureus, D; Acinetobacter baumannii, E

FIGURE 5: Antimicrobial Susceptibility Trends of Bacteria Isolates From Wound/Pus Swabs, 2021

Note: *Escherichia coli, A; Pseudomonas aeruginosa, B; Klebsiella pneumoniae, C; Staphylococcus aureus, D; Acinetobacter baumannii, E*

FIGURE 6: Antimicrobial Susceptibility Trends of Bacteria Isolates from Wound/Pus Swabs, 2022



Note: Escherichia coli, A; Pseudomonas aeruginosa, B; Klebsiella pneumoniae, C; Staphylococcus aureus, D; Acinetobacter baumannii, E

FIGURE 7: Antimicrobial Susceptibilities Pattern of Bacteria Isolates from Urine, 2020, 2021 and 2022

Note: *Escherichia coli, A; Klebsiella pneumoniae, B*

DISCUSSION

The ongoing monitoring of antimicrobial resistance (AMR) at BMH has provided valuable insights into the effectiveness of Antimicrobial Susceptibility Testing (AST). By gathering a wide array of clinical samples, we found that only a small percentage showed clinically significant bacterial growth. Among these, wound and pus swabs were major players, with a culture positivity rate of 59.6%. This figure not only surpasses results from earlier studies in Uganda but also closely mirrors previous findings on surgical site infections (SSIs)[22], highlighting the importance of these sample types for identifying infectious agents. In contrast, urine and blood samples showed inconsistent growth rates, often leading to contamination or insufficient growth for AST. This inconsistency aligns with trends observed in Malawi based research, emphasizing the ongoing challenges in effective microbial analysis.[23] The high bacterial load in wound swabs likely stems from a polymicrobial environment, often rich in nutrients.[23, 24]

Bloodstream infections (BSIs) pose a significant clinical challenge, especially when caused by Gram negative bacteria. Data from Muhimbili National Hospital reveal that these organisms account for 74% of BSI cases, with nearly 70.5% classified as multidrug resistant (MDR).[24] At BMH, we are particularly focused on two key pathogens: *Escherichia coli* and *Klebsiella pneumoniae*. These bacteria have shown a concerning increase in AMR from 2020 to 2022, particularly against crucial antibiotics like ceftriaxone and cefepime. Fortunately, both remain highly susceptible to carbapenems, aminoglycosides, amikacin, and piperacillin tazobactam, with around 70% effectiveness. Another significant player in this landscape is *Staphylococcus aureus*, which has shown a decrease in antimicrobial resistance over three years. By 2022, its effectiveness was only notable for a limited number of antibiotics, with gentamicin at 82%, vancomycin at 89%, and azithromycin at 58%. This decline in sensitivity could hinder the selection of suitable antimicrobials for treating conditions such as febrile neutropenia and septicemia, limiting treatment options at BMH. Our findings emphasise the importance of accurate empirical treatment and the need to utilise antibiograms to select appropriate antibiotics in these cases.

In Nigeria, concerning resistance levels have also been found in wound swab isolates, particularly among *Acinetobacter spp*., *Klebsiella spp*., *Pseudomonas spp*., and *Escherichia coli*.[25] This aligns with our findings at BMH, where *Acinetobacter baumannii* showed increased susceptibility to imipenem, gentamicin, and amikacin between 2020 and 2022. However, *Pseudomonas aeruginosa* displayed fluctuating susceptibility to vital antibiotics, including ciprofloxacin, carbapenems, and piperacillin-tazobactam, during the same period, reflecting resistance trends observed in previous studies from Malawi and Ethiopia.[26, 27] Moreover, *Escherichia coli* and *Klebsiella pneumoniae* are demonstrating increasing resistance to commonly prescribed antibiotics such as ampicillin and cefepime, though they remain effective against alternatives such as ciprofloxacin and gentamicin.[28, 29] The association of these bacteria with SSIs and surgical site skin infections (SSSIs) underscores the challenges in treating wound infections and emphasises the critical need to effectively utilise antibiograms to select the right antibiotics for surgical prophylaxis and targeted wound infection therapy.

The situation is particularly challenging regarding urinary tract infections (UTIs) linked to bacterial isolates of *Escherichia coli* and *Klebsiella pneumoniae*.[30] Data indicate a downward trend in susceptibility from 2020 to 2022, with similar resistance patterns against third-generation cephalosporins and penicillins noted in studies from Sierra Leone and Ethiopia. Still, carbapenems, piperacillin-tazobactam, and amikacin maintain their efficacy against these pathogens.[9, 31, 32] The widespread, often inappropriate, empirical use of antibiotics may contributed to rising resistance levels, especially among drugs such as sulfamethoxazole-trimethoprim, amoxicillin/clavulanic acid, and ceftriaxone, all of which saw increased consumption during the COVID-19 pandemic.[13, 32] Interestingly, the less frequent use of antibiotics such as nitrofurantoin has allowed it to retain its effectiveness against *Escherichia coli* and *Klebsiella pneumoniae*, making it a potentially valuable option going forward.

This study revealed that bacterial isolates obtained from blood, urine, and wound swabs have demonstrated alarming resistance to a wide range of antimicrobials, complicating the management of common bacterial infections. Moreover, our findings highlight significant concerns regarding the effectiveness of current therapeutic strategies for managing bacterial infections, including septicemia, febrile neutropenia, surgical site infections, and urinary tract infections. Consequently, healthcare professionals may face increasingly limited options when selecting antimicrobial treatments that are both effective and affordable. This troubling trend is particularly pronounced in well-known pathogens such as *Escherichia coli*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*. As these resistant bacteria continue to proliferate, the difficulty in managing widespread infections becomes more pronounced, highlighting the critical necessity for innovative strategies in antimicrobial therapy, enhanced infection prevention and control measures, and the advancement of evidence-based antimicrobial procurement guided by antibiograms, alongside sustainable antimicrobial stewardship programs.

Study Strengths and Limitations

This study offers valuable insights into antimicrobial resistance patterns at BMH, a prominent tertiary hospital in Tanzania. Presenting localised data has significant implications for clinical decision-making and the development of tailored antibiograms. The methodology is comprehensive, encompassing various sample types such as blood, urine, and swabs from wounds or pus, thereby enabling comparative analysis across different infection sites. Additionally, it addresses the years of the COVID-19 pandemic, enhancing our understanding of shifts in antibiotic prescribing practices and resistance profiles. This effort aligns well with Tanzania's National AMR Action Plan and the WHO's frameworks.

Conversely, the retrospective design of the study limits our ability to establish causal relationships, underscoring the need for future research to emphasise data completeness

and address potential laboratory bias. As a cross-sectional study conducted at a single centre, it restricts subgroup comparisons, particularly between inpatient and outpatient populations. Although certain trends in antimicrobial resistance over the three-year period have been observed, these should be interpreted with caution due to possible inaccuracies in routine data collection. Furthermore, the findings may lack generalisability to other hospitals across Tanzania, and the retrospective nature of the study precludes real-time monitoring of resistance trends. To attain a more comprehensive understanding of antimicrobial resistance, future research should consider adopting multi-centre, prospective methodologies.

CONCLUSION

Our studies indicate a concerning trend of escalating antimicrobial resistance (AMR) among bacterial strains in Tanzania. This situation underscores the critical importance of responsible antibiotic utilisation in both medical treatments and surgical procedures. At Benjamin Mkapa Hospital, assessments have revealed alarmingly high levels of multidrug-resistant (MDR) bacteria, particularly in blood, urine, and wound specimens, rendering many commonly prescribed antibiotics significantly less effective. A substantial contributing factor to this issue is the lack of local antibiograms in numerous healthcare facilities, resulting in inappropriate prescribing practices that exacerbate resistance rates. The data derived from wound samples are particularly alarming and underscore the urgent need for enhanced infection control measures. To effectively address AMR, Tanzania must prioritise the development of specific antibiograms and establish a national monitoring system. Such initiatives would furnish essential, current resistance data, which is vital for safeguarding vulnerable populations.

RECOMMENDATIONS

Regularly update facility-specific antibiograms to enhance antimicrobial prescribing. Promote the careful use of reserve antimicrobials for multidrug-resistant infections. Enforce policies to limit the use of broad-spectrum antimicrobials, conduct clinical auditing, and implement surveillance of use and consumption. Strengthen measures against surgical site infections and improve wound care. Develop a real-time surveillance system to enable timely intervention. Enhance clinical sample collection practices to reduce contamination. Conduct studies across Tanzania to gain insights into AMR trends. We recommend a prospective cohort study with a set number of participants to provide a comparative sample size and bacterial isolates. This approach will help address the variability in antimicrobial resistance trends observed over three years and reduce inaccuracies in routine data collection. These recommendations focus on optimising the management of antimicrobial resistance (AMR) to achieve improved healthcare outcomes.

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