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Bacterial profile and antibiogram of clinical isolates in a tertiary healthcare facility in northeast Nigeria: Initial steps towards developing local antibiotic guidelines and antimicrobial stewardship programme

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Abstract:

Background: Antibiograms and antibiotic guidelines are important tools for appropriate prescribing practices in combating the antimicrobial resistance (AMR) challenge. They serve as a prelude to an evidence-based Antimicrobial Stewardship (AMS) program, which is necessary for better Infection Prevention and Control (IPC) activities, especially in low-resource settings like Nigeria. This study determined the bacterial profile and antibiogram of clinical isolates in a tertiary healthcare facility in Gombe, northeastern Nigeria.
Methodology: This was a 4-year retrospective descriptive analysis of bacterial isolates from in and outpatient clinical specimens submitted to the Medical Microbiology Laboratory of the hospital between January 2019 to December 2022. Specimens were cultured for bacterial isolation and phenotypic identification using conventional techniques. Antibiotic susceptibility test was performed on each isolate by the Kirby Bauer disc diffusion method.
Results: A total of 15,457 bacteria were isolated over the 4-year period and include *Staphylococcus aureus* (6604, 42.72%), *Klebsiella* species (2382, 15.41%), *Escherichia coli* (2140, 13.84%), *Pseudomonas* species (1429, 9.25%), *Proteus* species (469, 3.03%) and *Enterococcus* species (215, 1.39%). The overall susceptibility (antibiogram) of all the bacterial isolates to commonly used antibiotics over the 4-year period was 59.0% for gentamicin, 54.5% for levofloxacin, 50.6% to ciprofloxacin, 48.5% to ceftriaxone, 48.5% to ceftazidime, and 41.9% to amoxicillin/clavulanate. Resistance rate was more than 50.0% for many of the tested antibiotics (ceftriaxone, ceftazidime, amoxicillin/clavulanate, and cefoxitin).
Conclusion: There was high level of resistance to many routinely used antibiotics tested in our facility. There is need for evidence-based AMS programmes hinged on local antibiotic guidelines for better patient safety and improved healthcare quality particularly in resource poor settings.

Keywords: Antibiogram; Antimicrobial Stewardship; Antibiotic Guidelines; Infection Prevention & Control

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Profil bactérien et antibiogramme d'isolats cliniques dans un établissement de soins de santé tertiaire dans le nord-est du Nigéria: premières étapes vers l'élaboration de directives locales sur les antibiotiques et d'un programme de gestion des antimicrobiens

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Résumé:

Contexte: Les antibiogrammes et les directives sur les antibiotiques sont des outils importants pour des pratiques de prescription appropriées dans la lutte contre le défi de la résistance aux antimicrobiens (RAM). Ils servent de prélude à un programme de gestion des antimicrobiens (GAM) fondé sur des données probantes, qui est nécessaire pour de meilleures activités de prévention et de contrôle des infections (PCI), en particulier dans les environnements à faibles ressources comme le Nigéria. Cette étude a déterminé le profil bactérien et l'antibiogramme des isolats cliniques dans un établissement de soins de santé tertiaire à Gombe, dans le nord-est du Nigéria.

Méthodologie: Il s'agissait d'une analyse descriptive rétrospective sur 4 ans des isolats bactériens provenant d'échantillons cliniques hospitaliers et ambulatoires soumis au laboratoire de microbiologie médicale de l'hôpital entre janvier 2019 et décembre 2022. Les échantillons ont été cultivés pour l'isolement bactérien et l'identification phénotypique à l'aide de techniques conventionnelles. Un test de sensibilité aux antibiotiques a été effectué sur chaque isolat par la méthode de diffusion sur disque de Kirby Bauer.

Résultats: Au total, 15 457 bactéries ont été isolées sur la période de 4 ans et comprennent *Staphylococcus aureus* (6604, 42,72%), des espèces de *Klebsiella* (2382, 15,41%), *Escherichia coli* (2140, 13,84%), des espèces de *Pseudomonas* (1429, 9,25%), des espèces de *Proteus* (469, 3,03%) et des espèces d'*Enterococcus* (215, 1,39%). La sensibilité globale (antibiogramme) de tous les isolats bactériens aux antibiotiques couramment utilisés sur la période de 4 ans était de 59,0% pour la gentamicine, 54,5% pour la lévofloxacine, 50,6% pour la ciprofloxacine, 48,5% pour la ceftriaxone, 48,5% pour la ceftazidime et 41,9% pour l'amoxicilline/clavulanate. Le taux de résistance était supérieur à 50,0 % pour de nombreux antibiotiques testés (ceftriaxone, ceftazidime, amoxicilline/clavulanate et céfoxitine).

Conclusion: Il y avait un niveau élevé de résistance à de nombreux antibiotiques couramment utilisés testés dans notre établissement. Il est nécessaire de mettre en place des programmes de gestion des antibiotiques fondés sur des données probantes et s'appuyant sur des directives locales en matière d'antibiotiques pour améliorer la sécurité des patients et la qualité des soins de santé, en particulier dans les milieux pauvres en ressources.

Mots-clés: Antibiogramme; Gestion des antimicrobiens; Directives sur les antibiotiques; Prévention et contrôle des infections

Introduction:

Overuse of empirical broad-spectrum antibiotics and inadequate antimicrobial stewardship (AMS) programs at all levels have significantly contributed to the emergence and spread of multidrug-resistant organisms (MDROs) (1). The global impact of MDROs has detrimentally affected worldwide infection prevention and control (IPC) efforts, patient safety, and healthcare quality with severe repercussions particularly in low-resource settings, manifesting in significant healthcare challenges. Availability of bacterial profiles and their antibiograms from clinical isolates is necessary for the control of resistance to antimicrobial agents especially in developing countries (2,3).

Apart from being a component of the AMS programme, the antibiogram provides important information about the sensitivity/ resistance pattern in particular settings, enabling an evidence-based empirical use of antibiotics. This is especially important in many low-and-middle-income-countries (LMICs) where patients are unable to afford payment for routine microbiological investigations or the facilities for such are not available (4,5). Results of studies on antibiotic stewardship programmes in Africa revealed lack of institutional annual antibiograms as one deficiency in many countries (6,7).

Antimicrobial Resistance (AMR) commonly results from their misuse and abuse across human, agricultural/environmental and veterinary healthcare in addition to poor AMS programmes/strategies including inadequate surveillance and policies/guidelines (8-10). Resistance to clinically important Gram-positive bacteria such as *Staphylococcus aureus* including methicillin resistant *S. aureus* (MRSA), *Streptococcus pneumoniae*, *Enterococcus* spp, *Corynebacterium* spp and *Streptococcus agalactiae*, and Gram-negative bacteria such as *Escherichia coli, Klebsiella* spp, *Pseudomonas, Acinetobacter* spp, *Proteus, Morganella, Citrobacter* spp, *Enterobacter* spp, *Salmonella* spp, and *Shigella* spp to commonly available antibiotics have been widely reported in sub-Saharan African countries (11-13). This constitutes a major public health challenge with heavy financial burden on both patients and healthcare providers (14,15).

In some developed countries, deployment of effective IPC measures has led to reduction in the prevalence of key MDROs such as MRSA in contrast to sub-Saharan Africa where the burden of infectious diseases is still unacceptably high (16,17). In Nigeria, a 2.3-fold increase in MRSA prevalence was reported in association with several infections including osteomyelitis, bloodstream, skin/soft tissue/wound, surgical sites, respiratory, and urinary tract infections over a five-year period (18). Antibiograms play a key role in improving the appropriateness of empirical antibiotic therapy and reducing the emergence and spread of AMR in any given society or institution (19). This study presents a four-year review of bacterial profiles and antibiogram of clinical isolates in Federal Teaching Hospital Gombe, as a prelude to development of local antibiotic policy for evidence-based AMS programme in the hospital.

Materials and method:

Study area:

This study was conducted in a 555-bed Federal Teaching Hospital Gombe (FTHG), a tertiary health facility in northeastern Nigeria. Gombe State is located at the centre of northeastern Nigeria and FTHG receives and manages patients from all neighbouring states and beyond. The hospital enjoys the complement of virtually all common medical/surgical specialties.

Ethical consideration:

This study used existing laboratory records (secondary data), hence, there was no risk of physical harm to the patients. The data were de-identified for confidentiality and privacy of patients. Ethical approval was obtained from the Research and Ethics Committee of FTHG, before the commencement of the study.

Clinical isolates analysed from routine specimens:

Routine clinical specimens (urine, sputum, blood, aspirates, swabs, and biopsies) collected from all in and outpatients of all age groups with suspected clinical infections and processed in the Medical Microbiology laboratory of FTHG from January 2019 to December 2022, yielded the isolates analysed in this study.

Culture isolation and identification:

The specimens were routinely collected according to standard procedures in appropriate specimen containers, timely transported to the laboratory and processed immediately by conventional culture isolation methods. All urine specimens were inoculated on Cysteine Lactose Electrolyte Deficient (CLED) and Blood Agar (BA) plates, while sputum, blood, seminal fluid and swabs/aspirates/biopsies were all inoculated on MacConkey, Blood and Chocolate agar plates. All plates were incubated aerobically at 37^{o}C for 16-24 hours. Isolates were identified by colonial morphology, Gram-reaction and conventional biochemical test schemes.

Antibiotic susceptibility testing:

Antibiotic susceptibility testing (AST) of the isolates was done using modified Kirby-Bauer disc diffusion method on Mueller-Hinton (MH) agar plates and results were interpreted according to the 2019 Clinical and Laboratory Standard Institutes (CLS1) guidelines (16). The antibiotic discs (Oxoid UK) include amoxicillin/clavulanate (20/10 µg), ceftriaxone (30µg), ceftazidime (30µg), cefoxitin (30µg), gentamicin (10µg), levofloxacin (5µg), ciprofloxacin (5µg), and erythromycin (15µg).

Results:

Bacterial profiles:

A total of 15,457 bacteria were isolated over the 4-year period of the study; 2019 (n=4,025), 2020 (n=3,978), 2021 (n=3,885) and 2022 (n=3,569). Majority were from urine (9,504, 61.49%), aspirates/swabs/biopsies (3,727, 24.11%), blood (1238, 8.01%) and sputum (988, 6.39%). The commonly isolated bacteria are *S. aureus* (6,604, 42.72%), *Klebsiella* spp (2,382, 15.41%), *Escherichia coli* (2,140, 13.84%), *Pseudomonas* spp (1,429, 9.25%), *Proteus* spp (469, 3.03%) and *Enterococcus* spp (215; 1.39%). Other Gram-negative and Gram-positive bacteria constituted 1,330 (8.60%), and 897 (5.80%) respectively. The distributions of the isolates by year of identification and specimens of origin is highlighted in Table 1.

Antibiogram:

The overall susceptibility to common antibiotics tested on all the bacteria could be summarised as gentamicin (59.0%), levofloxacin (54.5%), ciprofloxacin (50.6%), ceftriaxone (48.5%), ceftazidime (48.5%), and amoxicillin/clavulanate (41.9%). The susceptibility of all *S. aureus* isolates to cefoxitin was 44.5%, indicating 55.5% MRSA rate. Of all the Gram-positive bacteria tested, only 36.9% were susceptible to erythromycin.

Table 1: Distributions of isolates by year of identification and specimens of origin

Specimen	Organism	2019	2020	2021	2022	Total (%)
Urine	*Staphylococcus aureus*	888	1013	1214	973	4088 (43.01)
	Escherichia coli	388	519	288	425	1620 (17.04)
	Klebsiella species	347	352	534	356	1589 (16.71)
	Other Gram negatives	273	171	216	165	825 (8.68)
	Pseudomonas species	206	148	259	183	796 (8.38)
	Other Gram positives	69	64	48	56	237 (2.49)
	Enterococcus species	55	39	47	24	165 (1.74)
	Proteus species	54	63	19	48	184 (1.94)
		2280	2369	2625	2230	9504 (100.0)
Swabs/ Aspirates/ Biopsies	*Staphylococcus aureus*	457	543	357	343	1700 (45.61)
	Klebsiella species	132	97	55	095	379 (10.17)
	Pseudomonas species	127	108	117	126	478 (12.82)
	Other Gram positives	107	90	41	55	338 (9.07)
	Proteus species	82	89	18	70	259 (6.95)
	Escherichia coli	76	128	76	75	355 (9.53)
	Other Gram negatives	76	37	35	71	219 (5.88)
	Enterococcus species	20	7	1	16	44 (1.18)
		1077	1099	700	851	3727 (100)
Blood	*Staphylococcus aureus*	269	136	197	171	773 (62.44)
	Other Gram positives	31	10	24	26	91 (7.35)
	Klebsiella species	11	15	17	10	53 (4.28)
	Proteus species	6	6	1	0	13 (1.05)
	Escherichia coli	4	4	19	23	50 (4.04)
	Other Gram negatives	2	31	65	7	175 (14.14)
	Enterococcus species	0	1	2	2	5 (0.40)
		337	227	365	309	1238 (100.0)
Sputum	*Klebsiella* species	132	133	042	54	361 (36.54)
	Other gram positives	76	79	71	50	276 (27.93)
	Pseudomonas species	42	15	20	0	77 (7.79)
	Other Gram negatives	39	14	17	41	111 (11.23)
	Escherichia coli	26	26	30	33	115 (11.64)
	Staphylococcus aureus	15	12	15	1	43 (4.35)
	Enterococcus species	1	0	0	0	1 (0.10)
	Proteus species	0	4	0	0	4 (0.40)
		331	283	195	179	988 (100.0)

The distribution of isolates and their percentage susceptibility to common antibiotics and year of isolation is highlighted in Table 2 and Fig 1. The trend in susceptibility to the common antibiotics for *E. coli*, showed that about 70% were susceptible to gentamicin in 2019. But in the subsequent years (2020, 2021 and 2022), the susceptibility dropped to 51%, 47.7% and 50.5% respectively. Susceptibility of *E. coli* to ceftriaxone was 64.2% in 2019, 35.4% in 2020, 43.6% in 2021 and 33.3% in 2022. However, the susceptibility of the bacterium to ciprofloxacin over the years was 49.7% (2019), 34.4% (2020), 28.1% (2021) and 42.8 (2022).

The susceptibility *of Pseudomonas* spp to commonly used antibiotics were; 53.9% (2019), 83.3% (2020), 22.2% (2021), and 38.9% (2022) for ceftazidime; and 63.5% (2019), 50.3% (2020), 50.0% (2021), and 48.4% (2022) for gentamicin, while for ciprofloxacin, the susceptibility was 70.3% (2019) 52.7% (2020), 49.7% (2021) and 45.4% (2022).

Staphylococcus aureus isolates in the study was steadily susceptible to gentamicin for the 4-year period, while for ciprofloxacin, susceptibility of 38.9%, 24.6%, 40.1% and 52.8% were observed in 2019, 2020, 2021 and 2022 respectively. The trends in susceptibility to other antibiotics were as shown in Figs 2, 3 and 4.

Table 2: Antibiogram (Percentage susceptibility) of the bacterial isolates to common antibiotics based on years

Year	**Bacteria**	**Number**	**Percentage (%)**							
			CN	**AMC**	**FOX**	**CRO**	**CIP**	**LEV**	**CAZ**	**E**
2019	*Staphylococcus aureus*	1629	66.5	NA	51.0	NA	38.1	33.2	NA	32
	Klebsiella pneumoniae	622	62.0	45.5	NT	55.4	62.5	29.4	NT	NA
	Escherichia coli	494	69.5	45.1	NT	64.2	49.7	25.4	NT	NA
	Proteus spp	142	63.2	48.9	NT	76.4	68.3	100	NT	NA
	Pseudomonas aeruginosa	389	63.5	NA	NA	NA	70.3	57.3	53.9	NA
	Enterococcus spp	076	NA	AN	NT	NA	68.8	45.7	NA	50.0
	Other Gram negatives	390	78.8	48.5	NT	76.6	71.2	54.2	NT	NA
	Other Gram positives	283	73.0	NT	NT	NT	65.4	45.7	NT	46.2
2020	*Staphylococcus aureus*	1704	59.5	NA	42.0	NA	24.6	28.4	NA	21.7
	Klebsiella pneumoniae	597	53.8	36.8	NT	38.8	53.5	37.0	NT	NA
	Escherichia coli	677	51.2	22.1	NT	35.4	34.4	14.5	NT	NA
	Proteus spp	162	66.1	59.1	NT	63.6	53.1	50.5	NT	NA
	Pseudomonas spp	295	50.3	NA	NA	NA	52.7	45.1	83.3	NA
	Enterococcus spp	047	NA	NA	NA	NA	63.2	70.4	NA	33.3
	Other Gram negatives	253	73.8	57.3	NT	66.0	71.7	66.8	NT	NA
	Other Gram positives	243	68.2	78.5	NT	NT	68.6	72.5	NT	53.2
2021	*Staphylococcus aureus*	1783	57.8	NA	37.3	NA	40.1	36.6	NA	26.6
	Klebsiella spp	648	46.6	43.7	NT	23.1	45.4	41.6	NT	NA
	Pseudomonas spp	436	50.0	NA	NA	NA	49.7	53.0	22.2	NA
	Escherichia coli	413	47.7	33.8	NT	43.6	28.1	57.1	NT	NA
	Enterococcus spp	050	NA	NA	NA	NA	44.0	45.4	NA	30.7
	Proteus spp	038	63.6	25.0	NT	38.7	40.0	55.5	NT	NA
	Other Gram-negatives	333	54.8	32.8	NT	39.2	48.6	56.4	NT	NA
	Other Gram-positives	184	60.0	50.0	NT	NT	43.3	51.9	NT	22.2
2022	*Staphylococcus aureus*	1488	61.5	NA	47.6	NA	46.8	52.8	NA	34.5
	Escherichia coli	556	50.5	25.0	NT	33.3	42.8	46.1	NT	NA
	Klebsiella spp	515	52.2	27.6	NT	36.1	41.5	47.8	NT	NA
	Pseudomonas spp	309	48.4	NA	NA	NA	35.9	45.4	38.9	NA
	Proteus spp	118	40.9	39.9	NT	45.0	34.2	45.6	NT	NA
	Enterococcus spp	042	NT	NA	NA	NA	56.7	76.2	NA	49.9
	Other Gram-negatives	354	55.3	37.8	NT	40.1	49.2	60.8	NT	NA
	Other Gram-positives	187	51.9	NT	NT	NT	56.3	61.0	NT	47.5
		15457	**58.6**	**41.9**	**44.5**	**48.5**	**50.6**	**54.5**	**49.6**	**36.9**

NA (Not Applicable), NT (Not Tested), AMC (Amoxicillin/Clavulanate), CRO (Ceftriaxone), CAZ (Ceftazidime), FOX (cefoxitin), CN (Gentamycin), LEV (Levofloxacin), CIP (Ciprofloxacin), and E (Erythromycin); Other Gram-negatives: *Citrobacter* species, *Enterobacter* species, *Serratia* species, *Salmonella* species, *Acinetobacter* species, *Providentia, Morganella, Yersinia, Achromobacter, Moraxella and Stenotrophomonas* species. Other Gram-positives: *Streptococcus* species, *Bacillus* species and Diphtheroids

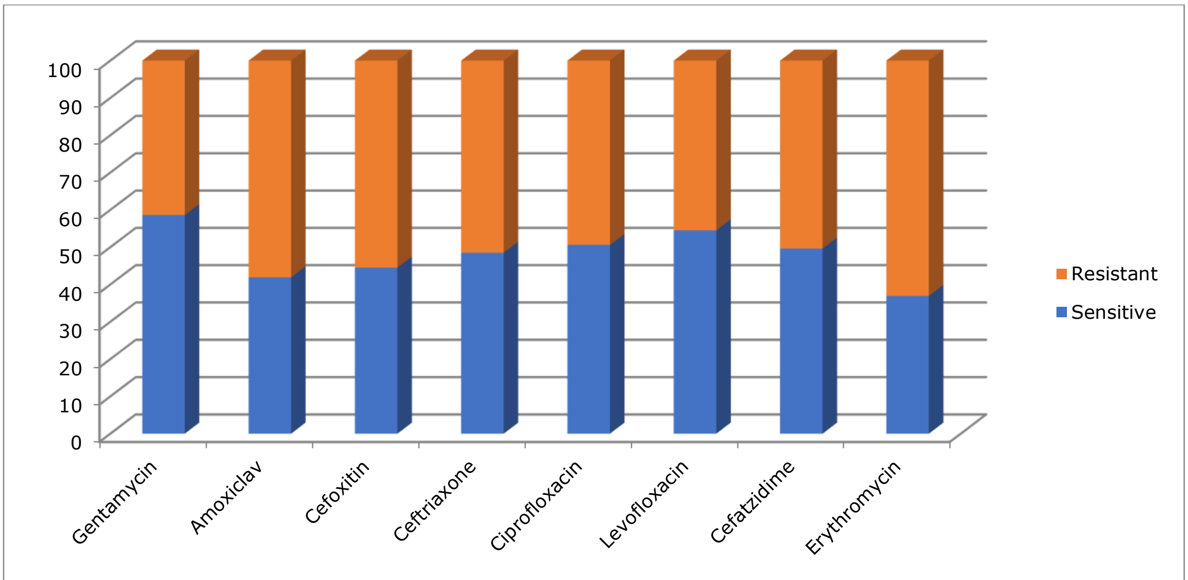

Fig 1: Overall percentage susceptibility (antibiogram) of the bacterial isolates to common first line antibiotics in the 4-year study period

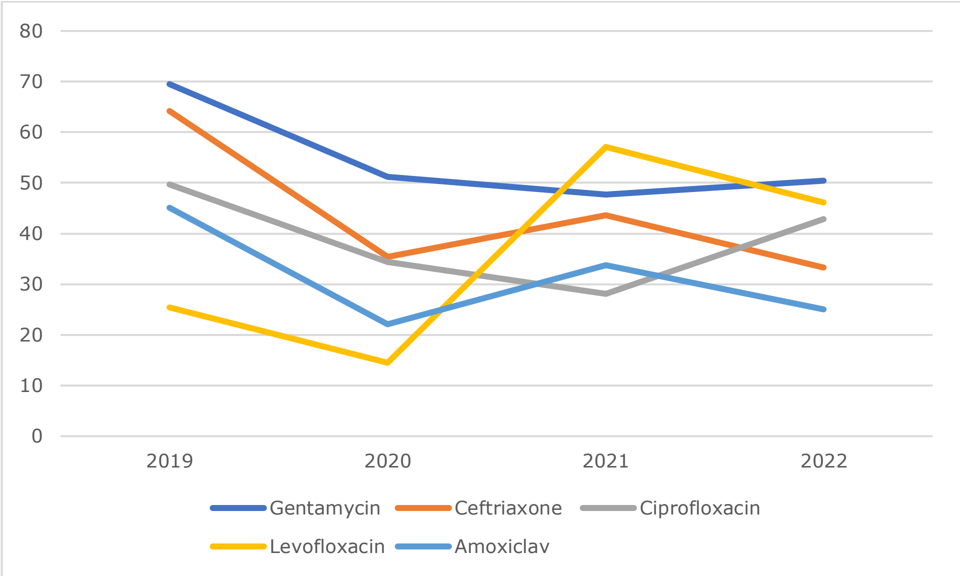

Fig 2: Trend of *Escherichia coli* isolates susceptibility to common antibiotics

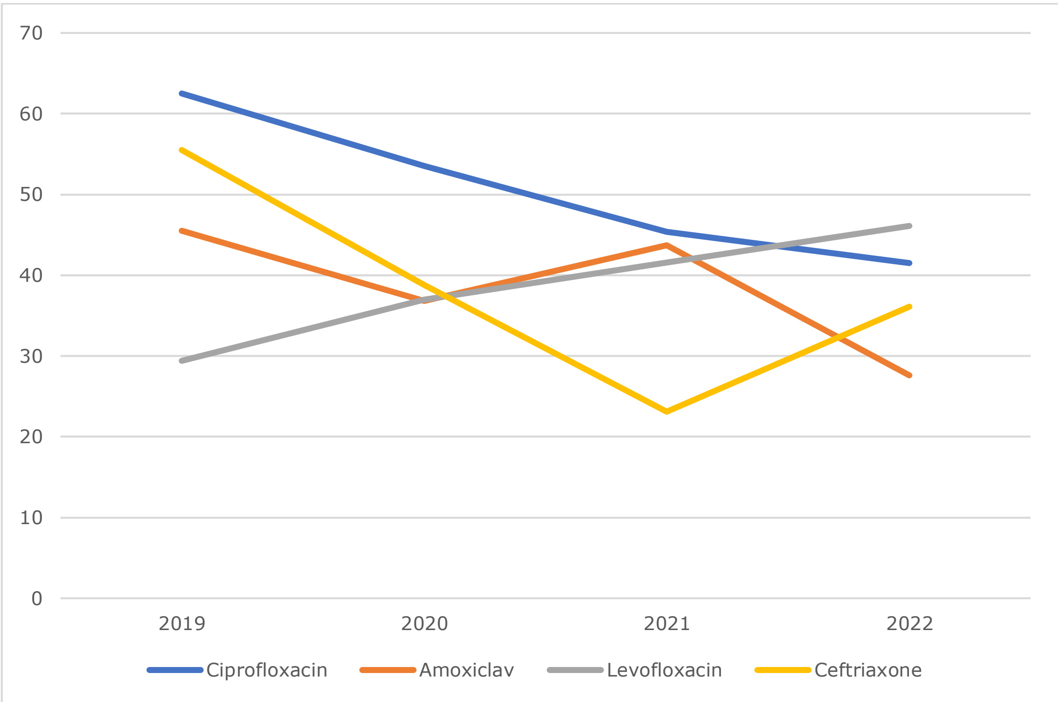

Fig 3: Trend of *Klebsiella* spp isolates susceptibility to common antibiotics

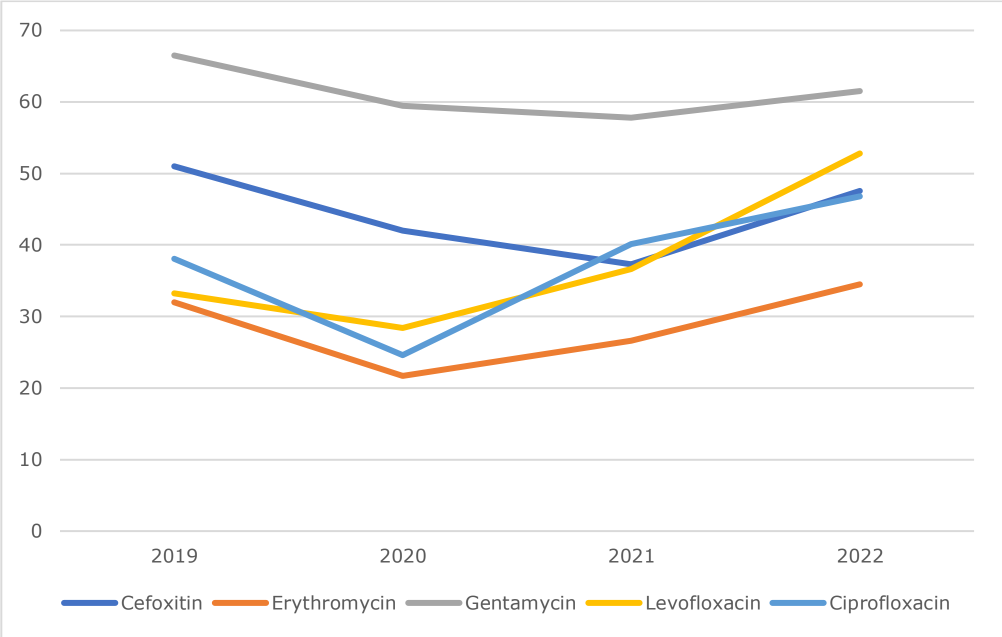

Fig 4: Trend of *Staphylococcus aureus* isolates susceptibility to common antibiotics

Discussion:

This study identified the most common bacterial isolates from clinical samples collected from patients with suspected clinical infections over a four-year period in our facility and their percentage susceptibility (antibiogram) to commonly used antibiotics. Urine (61.49%) and aspirates/swabs/biopsies (24.11%) contributed the highest number of bacterial isolates highlighting a similarity with the findings of an earlier report from the same centre which identified urine and aspirates/swabs/ biopsies as the specimens with highest yield of bacteria (17). Similar study carried out in Iraq, also showed that a significant proportion of the isolates (67.1%) and (19.6%) were respectively reported from urine and swabs/aspirates (18). Findings from a recent study conducted in Ghana were in keeping with this trend (19). Urinary tract infections are among the most common infectious diseases which reflect the isolates from urine being most predominant in most bacteriology laboratories (20).

The most isolated bacterium in this study was *S. aureus* (42.72%), which reflects the fact that staphylococci generally are associated with variety of infections and are equally common cause of infections in low-and-middle-income-countries (21). Among the first line antibiotics tested, *S. aureus* was most susceptible to gentamicin (61.3%) and least to erythromycin (28.7%). The susceptibility of *S. aureus* to erythromycin from a recent meta-analysis of studies conducted in Nigeria was about 53% (22). High prevalence of resistance to erythromycin in our study may be explained by the constitutive nature of the resistance expressed by staphylococci to erythromycin as previously reported in Gombe (23). Susceptibility to these antibiotics was low compared to that of a study in Asia that reported high susceptibility to gentamicin (86.2%) and erythromycin (83.3%) by staphylococci (24). A similar study in Algeria reported significantly high susceptibility to gentamicin of 92.3% by staphylococci isolated from clinical specimens (25). These variations in findings might not be unconnected with the openly observed rampant misuse and abuse of such antibiotics in our settings.

In this study, only 44.5% of the *S. aureus* was susceptible to cefoxitin, indicating that more than half of the *S. aureus* isolates were MRSA. Similar studies from different parts of Nigeria have reported varying figures on phenotypic MRSA prevalence of 65.4% and 22.6% (26,27). These variations may be due to genetic, environmental, methodology, and other factors. The prevalence of MRSA was 80% and 56.2% in studies conducted in Cameroon and Afghanistan respectively (28,29). The observed trend of susceptibility among isolated staphylococci showed that there was a steady increase in susceptibility to cefoxitin, gentamicin and ciprofloxacin in 2022.

Enterococcus spp, another Gram-positive bacteria, were observed to be most commonly susceptible to levofloxacin (59.4%), which is at variance with the results of a South Korean study where *Enterococcus* spp were highly sensitive (90.4%) to levofloxacin (30). This may be associated with the high carriage of multidrug resistant *Enterococcus* spp among individuals in Nigeria with levofloxacin resistance being up to 34% in a study in south-western part of the country (31).

Klebsiella species were the second most prevalent bacteria isolated and the most common among the Enterobacterales in this study, but with overall low susceptibility to the commonly tested antibiotics. *Klebsiella* spp was identified as the second most common Gram-negative bacterial pathogen in a similar study conducted in Nigeria (32) while it was ranked first in another study from Ghana (33). The highest susceptibility of 53.7% was recorded for gentamicin and the least of 38.4% to amoxicillin/clavulanate by the *Klebsiella* isolates. These results are in keeping with reports from a study conducted in northwest Nigeria with susceptibility rates of 64.5% and 22.3% for *Klebsiella* spp to gentamicin and amoxicillin/clavulanate respectively (32). On the contrary, a study conducted in Taiwan reported susceptibility of *Klebsiella* spp to gentamicin and amoxicillin/clavulanate to be 84.8% and 89.1% respectively (34). In our study, *Klebsiella* spp demonstrated a continuous decline in susceptibility to ciprofloxacin from 2019 to 2022, while steep decrease to ceftriaxone from 2019 to 2021, stabilized and began to increase in susceptibility in 2022, with intermittent decline and increase in susceptibility to amoxicillin/clavulanate over the years under review.

Escherichia coli was the second most prevalent member of the order Enterobacterales in this study. This is not surprising as this pathogen is a known common causative agent of urinary tract infections and urinary isolates were the majority from the samples processed in the study. The highest susceptibility rate of 54.7% was recorded for gentamicin while a low rate of 31.5% was to amoxicillin/clavulanate. The low susceptibility of *E. coli* to amoxicillin/clavulanate may be due to widespread and non-rational use (availability to purchase without prescription) of this antibiotic commonly observed in our communities. A study assessing susceptibility of uropathogens in Africa reported a rate of 48% and 45% for *E. coli* to gentamicin and amoxicillin/clavulanate respectively (35). The susceptibility of *E. coli* to amoxicillin/clavulanate was 25.5% in a study conducted in Saudi Arabia (36). The overall trend of susceptibility of *E. coli* to the commonly used antibiotics showed a considerably high susceptibility to gentamicin, ceftriaxone, and ciprofloxacin in 2019, followed by steep decline in 2020/2021 and stabilizing in 2022. This may be linked to the overuse of these antibiotics for prophylaxis and empiric therapy, leading with the associated widespread resistance in the community and the hospital.

Pseudomonas spp showed similar susceptibility rates to all tested antibiotics; 53.1% to gentamicin, 52.2% to ciprofloxacin, 50.2% to levofloxacin and 49.6% to ceftazidime. The susceptibility rate to gentamicin has similarity to that reported in a study conducted in Saudi Arabia of 56.7% (37). However, susceptibility rates to ceftazidime (83.3%), levofloxacin (70.0%) and ciprofloxacin (76.7%) in the Saudi Arabia study were comparatively higher than the rates reported in our study. The overall trend of susceptibility to gentamicin continued to reduce steadily while the susceptibility to ceftazidime increased in 2020, this was immediately followed by a drastic decrease in 2021 and 2022. There was also associated decrease and increase in susceptibility to ciprofloxacin creating a zigzag pattern every year. This may not be unconnected to the difference in potency of the antibiotics used in these patients. The low susceptibility of *Pseudomonas* spp to these antibiotics may be due to their frequent use for empiric therapy and for prophylactic purposes in our facility. However, in a study conducted at Antwerp University Hospital (UZA), 91.4% sensitivity of *Pseudomonas* spp was reported to piperacillin/tazobactam (which we did not test in our study) and ceftazidime (38).

We had earlier reported a high level of antibiotic prescribing and over-reliance on empirical antibiotic therapy among healthcare practitioners in our centre and this region of the country (39,40). These were considered major drivers of AMR and threats to patient safety which require urgent attention in form of AMS programmes based on local evidence and policies/guidelines. Our study established a baseline profile of bacterial isolates and their antibiogram over a four-year period to serve as a prelude for an evidence-based hospital antibiotic policy. This will strengthen the AMS programme in the hospital and pave way for better IPC practices and improved patient safety and healthcare quality.

Our study is not without some limitations. It is a single centre study and cannot be generalized for the entire country. Additionally, manual biochemical methods were used for the identification of the bacteria. As such, it was impossible to completely identify and discountenance all duplicate isolates in the study as the data were retrospectively obtained from routine clinical isolates.

Conclusion:

Bacterial profiles and antibiogram of clinical isolates are important pre-requisites for evidence-based local antibiotic guidelines which are necessary for better antimicrobial stewardship programmes especially in low-resource settings. Findings from this study revealed a relatively high level and increasing trend of resistance to commonly used antibiotics by most of the tested bacteria. There is need to develop functional country-wide and hospital-based antibiotic guidelines that can streamline empiric antibiotic therapy to reduce antimicrobial resistance and improve patient safety and healthcare quality.

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Contributions of authors:

MMM, MI, and GBG were involved in the study conception and design; MM, MWA, IEW, MIG, and MSC were involved in data collection and analysis; MM, JOF, MSC, HUF, and IEW were involved in interpretation of results; MM, JOF, and MI were involved in drafting of manuscript; and IEW, MWA, MI, and MSC were involved in revision of intellectual content. All authors reviewed and approved the final version of the manuscript submitted for publication.

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