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Antibiotic Resistance Indices of Methicillin-Resistant *Staphylococcus aureus* isolates at a Tertiary Healthcare Facility in Calabar, Nigeria.

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Abstract

Staphylococcus aureus is a common nosocomial and community acquired pathogen associated with remarkable antibiotic resistance, high morbidity and prolonged hospitalization. This study investigated the prevalence and antibiotic-resistance patterns of methicillin-resistant *S. aureus* (MRSA) isolated from clinical specimens in University of Calabar Teaching Hospital (UCTH), Calabar, Nigeria. A total of 98 isolates of *S. aureus were* collected from UCTH Microbiology Laboratory, identified by *conventional bacteriological methods, and* subjected to MRSA screening and antibiotics susceptibility testing using *Kirby-Bauer disc-diffusion method*. Multiple antibiotics resistance (MAR) index of each isolate was evaluated. The prevalence of MRSA was 53.1%, with the highest proportion of the pathogen (34.6%) obtained from urine specimens. The MRSA strains showed 96.2% susceptibility to amoxicillin-clavulanate, but exhibited high resistance to kanamycin (88.5%), erythromycin (80.7%) and gentamicin (69.2%), while 10 (19.2%) showed complete resistance to vancomycin and 30 (57.7%) were multidrug resistant strains. The MAR indices were greater than 0.2 for 92.3% of the isolates. The high MAR values of the isolates may suggest indiscriminate use of antibiotics, with likelihood for treatment failures and escalation of drug resistance in the population. Antibacterial interventions based on antibiotics susceptibility tests reports would likely enhance good clinical outcomes and prevent further escalation of drug-resistant strains in the population. The high activity of amoxicillin-clavulanate against the MRSA strains may suggest a predominance of beta-lactamase producing staphylococcal strains in this study setting, making a case for further studies to determine the drug resistance determinants of the pathogen in the population.

Keywords: *Staphylococcus aureus*, methicillin-resistance, vancomycin-resistance, multidrug resistance, multiple antibiotics resistant index.

Introduction

Staphylococcus aureus is a common opportunistic human pathogen associated with remarkable antibiotic resistance, high morbidity and mortality rates that pose enormous public health challenges globally (Vysakh and Jeya, 2013). The organism can cause a variety of illnesses ranging from mild skin and soft tissue infections to more severe systemic conditions especially in young children, older adults and people with weakened immunity (Tong *et al*., 2015). However, *S. aureus* is a transient normal flora of the human skin and mucosal surfaces in 20-90% of healthy populations (Rasigade and Vandenesch, 2014). An estimated 25-30% of healthy individuals are long term carriers of *S. aureus*, presumed to be an important source of spread of the pathogen among individuals (Miller and Diep, 2008). Various host factors, including loss of the normal skin barrier, presence of underlying diseases such as diabetes and acquired immune deficiency syndrome (AIDS) or defects in neutrophil functions predispose humans to staphylococcal infections (Chambers and DeLeo, 2009).

In spite of substantial efforts to control staphylococcal infections in many clinical

settings, *S. aureus* pathogens have persisted as a leading cause of both hospital and community acquired infections worldwide. In hospital setting alone, the pathogen is responsible for one million serious infections per year globally (Chambers and DeLeo, 2009) and has remained even more challenging in the public health space due to the rising prevalence of methicillin-resistant *S. aureus* (MRSA) strains (Taylor and Unakal, 2021). MRSA strains are characteristically multidrug resistant and account for a large proportion of hospital-associated staphylococcal infections with significant morbidity and mortality (Boucher and Corey, 2008; Kundu & Biswas, 2012). Apparently, the virulence and pathogenicity of the pathogen seemed to have assumed additional impetus with the emergence of community-associated MRSA, capable of causing infections in otherwise healthy individuals outside of healthcare settings (Li *et al*., 2009; Udo, 2013). In recent years, the threat of MRSA has been further complicated with the mounting prevalence of strains completely resistant to vancomycin, a first line anti-MRSA drug for treatment of serious staphylococcal infections (Yanguang *et al*., 2020).

Although *S. aureus* is naturally susceptible to virtually every antibiotic, it has a remarkable ability and ease of developing drug-resistance, often by horizontal genes transfer, chromosomal mutation, or selective pressures arising from indiscriminate antibiotics usage (Chambers and DeLeo, 2009). Efforts targeted at preventing further escalation of staphylococcal drug-resistance would certainly require continued surveillance of MRSA infections in different epidemiological settings, with the aim of tracking multidrug resistant strains and susceptibility patterns for informed therapeutic options.

Methodology

Study site.

This study was carried out in the University of Calabar Teaching Hospital (UCTH), a tertiary healthcare facility located in Calabar- a coastal city and metropolitan capital of Cross River State, Nigeria. Calabar has an area of 406 square kilometers, with an estimated population of 605,000 as at the 2021 (United Nations, 2021).

Collection and characterization of *S. aureus* isolates

A total of 98 *S. aureus isolates from various clinical specimens were collected from the* Microbiology Laboratory of UCTH, Calabar. Patients' information including age, gender, clinical departments and specimens obtained, admission status etc. were noted. The isolates were sub-cultured on Mannitol salt agar and incubated at 37ºC for 12-16 hours. The identity of *S. aureus* isolates was re-confirmed by a combination of colonial and Gram's morphology, and biochemical tests including catalase and tube coagulase tests.

Antimicrobial susceptibility test

Antibiotic susceptibility testing of the isolates was done using the agar-disc diffusion method. The antibiotics discs used were Cefoxitin (30µg), Ciprofloxacin (30µg), Vancomycin (30µg), Erythromycin (15µg), Gentamicin (10µg), Azithromycin (30µg), Levofloxacin (5µg), Ceftriaxone (3µg), and Amoxicillin-clavulanic acid (30µg). Three to five pure colonies of each isolate were picked and transferred to a tube containing 5 ml of normal saline. The preparation was mixed thoroughly to make the suspension homogeneous. The turbidity of the suspension was adjusted to a 0.5 McFarland turbidity standard. Using a sterile swab, the bacterial suspension was inoculated uniformly onto the entire surface of Muller Hinton agar (MHA) plates and allowed to dry for about 15–30 minutes**.** With the aid of sterile forceps, antibiotics-impregnated disks were placed- at least 24 mm away from each other- on the inoculated plates to avoid overlapping zones of inhibition. The plates were left on the bench for 30 minutes to enhance antibiotics diffusion into the media before incubation; following incubation at 37°C for 24 hours, the plates were examined for zones of inhibition. The zones of inhibition were measured and reported as 'Susceptible, Intermediate, or Resistant', according to the Clinical and Laboratory Standards Institute guidelines (CLSI, 2021).

Detection of MRSA

The MRSA isolates were identified phenotypically using cefoxitin (30µg) discs. Isolates with zone of inhibition equal to or above 22mm were reported as

methicillin sensitive *S. aureus* (MSSA), whereas isolates that produced zone diameters equal to or less than 21mm were reported as methicillin resistant *S. aureus* (CLSI, 2021).

Multiple antibiotics resistance (MAR) index
Multiple antibiotics resistance (MAR) index for each isolate was calculated as a ratio of the number of antibiotics which an isolate showed resistance to the total number of antibiotics used for susceptibility testing against the isolate (Cockerill *et al*., 2012).

Determination of Multidrug Resistance
Multidrug resistance (MDR) was reported by resistance of an isolate to three or more classes of antibiotics tested against the isolate (Parssakthi, *et al*., 2000; Jombo *et al*., 2010).

Statistical analysis
Proportions obtained in this study were analyzed using descriptive statistics and chi-square in SPSS version 20 for Windows. P-values ≤ 0.05 were considered significant at 95% confidence interval.

Results
Prevalence and distribution of MRSA isolates
Out of 98 *S. aureus* isolates characterized in this study, 52 (53.1%) were found to be MRSA strains, while only 46 (46.9%) were MSSA (Table 1). Distribution of the MRSA strains into clinical sources showed that the highest proportion was obtained from urine specimens (34.6%), followed in decreasing order by wound/exudates (30.7%), high vaginal swab (21.2%), sputum (9.6%), and blood (3.8%) [Table 2]. There was no significant association between the isolation rates of the pathogen and the clinical specimens (P= 0.619).

Distribution of MRSA by age of patients
Distribution of MRSA by age of patients showed the highest percentage of the pathogen was obtained among those aged 1-10 years (21.2%), followed by 21-30 years age bracket (19.2%),

Table 1: Prevalence of MRSA

S. aureus isolates	Number	Prevalence (%)
MRSA	52	53.1
MSSA	46	46.9
Total	98	100

Table 2: Distribution of MRSA from clinical specimens

Clinical specimen	No. of *S. aureus* isolates	MRSA (%) [n=52]	P-value
Urine	34	18 (34.6)	0.619
Wound/exudates	30	16 (30.7)	
High vaginal swab	21	11 (21.2)	
Sputum	9	5 (9.6)	
Blood	4	2 (3.8)	

while the lowest proportion was found in those aged 41-50 (9.6%) [Table 3] Association between prevalence of MRSA and age of the patients was not statistically significant (P = 0.707).

Resistance of MRSA Strains to vancomycin and other antibiotics

A total of 16 (30.7%) of 52 MRSA strains showed resistance to vancomycin, with 10 (19.2%) of the isolates showing complete resistance, while 6 (11.5%) exhibited intermediate resistance to the drug. In descending order, resistance rates of 88.5%, 80.7%, 69.2%, 53.8%, 46.2%, 42.3% and 38.5% were found for kanamycin, erythromycin, gentamicin, levofloxacin, azithromycin, ceftriaxone and ciprofloxacin, respectively. Similarly, intermediate resistance of the isolates to erythromycin, azithromycin, gentamicin, levofloxacin, ciprofloxacin and ceftriaxone was 15.4%, 11.5%, 5.8%, 3.9%, 3.8% and 1.9%, respectively. Remarkably, MRSA isolates showed high susceptibility to amoxicillin-clavulanate (96.2%), while sensitivity to ciprofloxacin (57.7%) and ceftriaxone (55.8%) were modest.

Multiple antibiotics resistance index of MRSA

The MAR index analysis showed that 48 (92.3%) of 52 MRSA strains had values ranging from 0.3 to 0.9, while only 4 (7.6%) of the isolates had indices less than or equal to 0.2. No isolate was found with an index equal to 1 (Table 5).

Multidrug resistant MRSA

Thirty (57.7%) of MRSA in this study were identified as MDR strains based on resistance to 3 or more classes of antibiotics. Only 9 (30.0%) of 30 MDR strains were resistant to 3 classes of antibiotics, while 15 (50.0 %), 4 (13.3%), and 2 (6.7%) showed resistance to 4, 5 and 6 classes of antibiotics, respectively (Table 6).

Table 3: Distribution of MRSA by age of patients

Age (years)	No of *S. aureus* isolates	MRSA (%) [n=52]	P- value
1-10	21	11 (21.2)	0.707
11-20	15	8 (15.4)	
21-30	19	10 (19.2)	
31-40	17	9 (17.3)	
41-50	9	5 (9.6)	
>50	17	9 (17.3)	

Table 4: Antibiotic resistance pattern of MRSA to selected antibiotics

MRSA Status	Number of isolates (%)								
	*CPX	VN	E	CN	KN	LEV	AZM	CRO	AMC
Susceptible	30(57.7)	36(69.2)	2 (3.8)	13(25.0)	6(11.5)	22(42.3)	24(46.2)	29(55.8)	50(96.2)
Intermediate	2(3.8)	6(11.5)	8(15.4)	3(5.8)	0 (0)	2(3.9)	4(7.7)	1(1.9)	0 (0)
Resistant	20(38.5)	10(19.2)	42(80.7)	36(69.2)	46(88.5)	28(53.8)	24(46.2)	22(42.3)	2(3.8)

*Antibiotics: CPX- Ciprofloxacin 30µg, VN- Vancomycin 30µg, E- Erythromycin 15µg, CN- Gentamicin 10µg, KN- Kanamycin 30µg, LEV- Levofloxacin 5µg, CRO- Ceftriaxone 3µg, AMC- Amoxicillin-clavulanic acid 30µg.

Table 5: Multiple antibiotic resistant index of MRSA isolates (N=52)

No. of antibiotics resistance by isolates	MAR index	No. (%) of isolates
1	0.1	2 (3.8)
2	0.2	2 (3.8)
3	0.3	5 (9.6)
4	0.4	7 (13.4)
5	0.5	9 (17.3)
6	0.6	10 (19.2)
7	0.7	9 (17.3)
8	0.8	7 (13.4)

Table 6: Multidrug resistant MRSA strains (N=52)

[a] Classes of antibiotics	No. (%) of MDR strains	[b] MDR %
R6: CPX VN E KN CN LEV CRO AZM AMC	2 (3.8)	6.7
R5: CFX VAN ERY KAN CN LEV CRO AZM	4 (7.7)	13.3
R4: CFX ERY CN KAN LEV CRO AZM	7 (13.5)	23.3
R4: ERY CN KAN CRO LEV AZM	8 (15.4)	26.7
R3: ERY KAN CN LEV AZM	9 (17.3)	30.0
Total	30 (57.7)	100

[a] R6, R5, R4 and R3 were used to symbolize resistance to six, five, four and three classes of antibiotics, respectively.

[b] MDR was defined using six classes of antibiotics: Fluorouinolones (CFX- ciprofloxacin, LEV-Levofloxacin), Glycopeptide (VAN- vancomycin), Macrolides (ERY- erythromycin, AZM-Azithromycin), Aminoglycosides (CN- Gentamicin, KN- kanamycin), Cephalosporin (CRO-ceftriaxone), Penicillin (AMC- Amoxicillin-clavulanate).

Discussion

S. aureus is the leading cause of wound and soft tissue infections in many clinical settings (Chambers and DeLeo, 2009). This study, however, found the highest proportion of *S. aureus* isolates from urine specimens, ahead of wounds/exudates, while blood specimens contributed the least among other clinical sources. This finding varied slightly with that of a study conducted in south-east Nigeria which, although similarly reported the least recovery of *S. aureus* from blood specimens, found the highest isolation rate of the pathogen from wounds (Nsofor *et al*., 2016). Considering that *S. aureus* is a relatively uncommon cause of urinary tract infections in the general population (Yousefi *et al*., 2016), the high proportion of the pathogen obtained from urinary sources in this study could have been enhanced by hospital-acquired urogenital infections, particularly in children. This study obtained the highest number of *S. aureus* isolates from clinical specimens of children aged 1 to 10 years old. Although this finding contrasts sharply with the report of a previous study in north-west Nigeria which found the highest prevalence of urogenital staphylococcal infections in young adults aged 20-25 years (Adeiza *et al*., 2020), it may be consistent with the fact that children are often more liable to acquiring urinary tract infections due to lack of appropriate immunity and hygiene.

Although MSSA strains remain a prime cause of several human infections, MRSA has gained much notoriety due to the high morbidity and therapeutic difficulties associated with its infections. MRSA infections are characteristically multidrug resistant and very difficult to treat, often resulting in prolonged hospitalization with huge cost implications (Kundu & Biswas, 2012). This study found a slightly higher proportion of MRSA (53.1%) than MSSA (46.9%). The MRSA strains showed a high level of resistance to erythromycin, kanamycin, gentamicin and levofloxacin, while exhibiting modest resistance to ciprofloxacin and ceftriaxone. The resistance rates of MRSA to commonly used antibiotics in this study are consistent with the rates reported for the pathogen by similar studies in south-east Nigeria (Nworie *et al*., 2013; Ariom *et al*., 2017; Anowai *et al*., 2018). Significantly, about a third of the MRSA strains in this study were found to exhibit varying levels of vancomycin resistance, although only 19.2% were completely resistant to the drug. Comparatively, this vancomycin-resistance rate, although similar to 22.6% reported for a study in Abakaliki, Nigeria (Ariom *et al*., 2017), was not consistent with the rates found in some other parts of the country (Olayinka *et al*., 2004; Bamigboye *et al*. 2018; Olufunmiso *et al*., 2018). Whereas vancomycin is a first line anti-staphylococcal agent used for treatment of MRSA infections, increasing resistance of the pathogen to the drug has been reported in many countries (Whitener *et al*., 2004; Menezes *et al*., 2008; Shariati *et al*., 2020). Curiously, lower prevalence rates of VRSA have been reported in developed nations compared with many developing countries (Shariati *et al*., 2020), the latter lacking the strict drug policies that control the prescription, sales, and use of antibiotics. Even within Nigeria, there are sharp dissimilarities in the prevalence rates of staphylococcal vancomycin-resistance due to disparities in the levels of antibiotic abuse in different parts of the country.

The MAR indexing of bacterial pathogens provides a simple and convenient method of assessing antibiotic abuse in a population. The evaluation of MAR index of isolates in this study revealed values greater than 0.2 for an overwhelming majority of the MRSA strains. These findings represent widespread abuse of antibiotics in the population, with potentials for treatment failures and escalation of staphylococcal drug-resistance. Generally, MAR indices greater than 0.2 are known to be effective indicators of bacterial pathogens acquired from highly contaminated environments associated with indiscriminate use of antibiotics, whereas values less than or equal to 0.2 would indicate bacteria from sources with less antibiotic usage (Sandhu *et al*., 2016).

This study found an MDR-prevalence of 57.7% among the MRSA strains. Nevertheless, a very high percentage of the MRSA strains were susceptible to amoxicillin-clavulanate. This finding was similar to an earlier report in this epidemiological setting which found a high activity of the drug against

common ear pathogens, including *S. aureus* (Umoh *et al*., 2023). In discordance, however, high resistance rates of the pathogen to amoxicillin-clavulanate have been reported in many parts of Nigeria (Ikeh, 2003; Taiwo *et al*., 2004; Onwubiko & Sadiq, 2011).

Conclusion

This study found relatively high prevalence rates of 53.1% and 19.2% for MRSA and VRSA, respectively. The high MAR indices of the study isolates may highlight indiscriminate use of common antibacterial drugs, with potentials for treatment failures and escalation of drug-resistance in the population. The excellent activity of amoxicillin-clavulanate against the MRSA isolates may suggest, first, its potential efficacy for treatment of serious staphylococcal infections; and secondly, a predominance of beta-lactamase producing staphylococcal strains in the population, making a case for further evaluation of drug-resistance determinants of the pathogens in the locality.

Limitations

Regrettably, this study did not investigate the environmental and genetic determinants of staphylococcal drug resistance in this setting. Inclusion of such investigations would likely have boosted the epidemiological data required for prevention and control of antibacterial drug resistance in the population. Further studies on the antibacterial drug resistance profiles of pathogens in the population should include evaluation of genetic and environmental dynamics of the drug resistance.

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References

Adeiza, S.S., Onaolapo, J.A. & Olayinka, B.O. (2020). Prevalence, risk-factors, and antimicrobial susceptibility profile of methicillin-resistant *Staphylococcus aureus* (MRSA) obtained from nares of patients and staff of Sokoto state-owned hospitals in Nigeria. *GMS Hygiene and Infection Control*; **15**: Doc25. doi: 10.3205/dgkh000360.

Anowai, C. O., Agarry, O. O. & Akin-Osanaiye, B. C. (2018). Antibiotics Susceptibility Profile of *Staphylococcus aureus* Isolated from Clinical Patients in Abuja, Nigeria. *Direct Research Journal of Health and Pharmacology*; **6(3)**: 19-26.

Ariom, T., Iroha, I. R., Nwuzo, A.C. *et al*. (2017). Molecular characterization and antibiogram of methicillin and vancomycin resistant staphylococcus aureus. International Journal of Current Research; **9(7)**: 53534-53541.

Bamigboye, B.T., Olugbeng, A.O. & Samuel S. T. (2018). "Phenotypic and molecular identification of vancomycin resistance in clinical Staphylococcus aureus isolates in Osogbo, Nigeria. *European Journal of Microbiology and Immunology;* **8(1)**: 25-30.

Boucher, H.W., & Corey, G.R. (2008). Epidemiology of methicillin-resistant *Staphylococcus aureus*. *Clinical Infectious Diseases*; ***46*(5)**: S344-S349.

Chambers, H.F. & DeLeo, F.R. (2009). Waves of resistance: *Staphylococcus aureus* in the antibiotic era. *Nature Review of Microbiology*; ***7* (9):** 629–641.

Clinical and Laboratory Standards Institute (2021). Performance Standards for Antimicrobial Susceptibility Testing. 31st ed. CLSI supplement M100.Clinical and Laboratory Standards Institute; 2021.

Cockerill, Franlin R., *et al*. (2012). Methods for Dilution Antimicrobial Susceptibility Tests for Bacteria That Grow Aerobically: Approved Standard-Ninth Edition. CLSI, 2012; 12. ISBN 1-56238-784-7.

Ikeh, E. I. (2003). Methicillin resistant *Staphylococcus aureus* at Jos University Teaching Hospital (JUTH). *African Journal of Clinical and Experimental Microbiology*; **4(1)**:52-55.

Jombo, G.T., Akpan, S. S., Epoke, J. *et al*. (2010). Antimicrobial susceptibility profile of community acquired and nosocomial isolates of *Escherichia coli* from clinical blood culture specimens at a Nigerian university teaching hospital. *Asian Pacific Journal of Tropical Medicine*; **3(8)**: 662-665.

Kundu, G.K.R. & Biswas, S. (2012). Methicillin-resistant *Staphylococcus aureus*: A brief review. *International Research Journal of Biological Science*; **1**:65–71.

Li, M., Diep, B., Villaruz, A. *et al*. (2009). Evolution of virulence in epidemic community associated *Staphylococcus aureus*. *Proceedings of the National Academy of Science,* USA; 106: 5883-5888.

Menezes, G.A., Harish, B.N. Sujatha, S. *et al*. (2008). Emergence of vancomycin-intermediate *Staphylococcus* species in southern India. *Journal of Medical Microbiology*; ***57*(7)**: 911–912. https://doi.org/10.1099/jmm.0.47829-0

Miller, L.G. & Diep, B.A. (2008). Colonization, Fomites, and Virulence: Rethinking the Pathogenesis of Community-Associated Methicillin-Resistant *Staphylococcus aureus* Infection. *Clinical Infectious Diseases*; ***46*(5)**: 752–760. https://doi.org/10.1086/526773.

Nsofor, C.A., Nwokenkwo, V.N. & Ohale, C.U. (2016). Prevalence and Antibiotic Susceptibility Pattern of *Staphylococcus aureus* Isolated from Various Clinical Specimens in South East Nigeria. *MedCrave Online Journal of Cell Science and Report:* https://doi.org/10.15406/mojcsr.2016.03.00054.

Nworie, A., Azi, S.O., Ibiam, G.A. *et al*. (2013). Nasal carriage of methicillin resistant *Staphylococcus aureus* amongst meat sellers in Abakaliki metropolis, Ebonyi State, Nigeria. *Microbiological Research Journal International*; **1(3)**: 48-53.

Olayinka, B., Olayinka A. & Onaolapo J. (2004). Pattern of resistance to vancomycin and other antimicrobial agents in staphylococcal isolates in a university teaching hospital. *African Journal of Clinical and Experimental Microbiology*; ***6*(1)**: https://doi.org/ 10.4314/ajcem. v6i1.7395

Olufunmiso, O., Tolulope, I. & Roger, C. (2017). Multidrug and vancomycin resistance among clinical isolates of *Staphylococcus aureus* from different teaching hospitals in Nigeria. *African Health Sciences*; ***17*(3)**: 797. https://doi.org/10.4314/ahs.v17i3.23.

Onwubiko, N. & Sadiq, N. (2011). Antibiotic sensitivity pattern of *Staphylococcus aureus* from clinical isolates in a tertiary health institution in Kano, Northwestern Nigeria. *Pan African Medical Journal;* ***8*(1)**: https://doi.org/10.4314/pamj.v8i1.71050.

Parssakthi, N., Vadivelu, J., Ariffin, H. *et al*. (2000). Epidemiology and characterization of nosocomially transmitted multidrug-resistant *Klebsiella pneumoniae*. *International Journal Infectious Disease*; **4(3)**: 123-8. Doi: 10:1016/s1201-9712(00)90072-9.

Rasigade, J.P. & Vandenesch, F. (2014). *Staphylococcus aureus:* a pathogen with still unresolved issues. *Infections Genetic and Evolution*; ***21:*** 510-514.

Sandhu, R., Dahiya, S. & Sayal, P. (2016). Evaluation of multiple antibiotic resistance (MAR) index and Doxycycline susceptibility of *Acinetobacter* species among inpatients. *Indian Journal of Microbiology Research*; **3(3)**: 299-304.

Shariati, A., Dadashi, M.., Moghadam, M.T. *et al*. (2020). Global prevalence and distribution of vancomycin resistant, vancomycin intermediate and heterogeneously vancomycin intermediate *Staphylococcus aureus* clinical isolates: a systematic review and meta-analysis. *Scientific Reports;* **10**: 12689. https://doi.org/10.1038/s41598-020-69058-z.

Taiwo, S.S., Bamidele, M., Omonigbehin, E.A. *et al*. (2005). Molecular epidemiology of methicillin resistant *Staphylococcus aureus* in Ilorin, Nigeria. *West African Journal of Medicine; **24(2)***:100-106.

Taylor, T.A., & Unakal, C.G. (2021). Staphylococcus aureus. In *StatPearls [Internet]*. StatPearls Publishing.

Tong, S.Y., Davis, J.S., Eichenberger, E. *et al*. (2015). *Staphylococcus aureus* infections: epidemiology, pathophysiology, clinical manifestations, and management. *Clinical Microbiology Reviews*; ***28*(3)**: 603-661.

Udo, E. E. (2013). Community-acquired methicillin-resistant *Staphylococcus aureus*: The new face of an old foe *Medical Principles and Practice; **22***: 20-29.

Umoh, N.O., Osibu, B.E., Eyo, A. *et al*. (2023). Prevalence and antibiotic-resistance indices of bacterial pathogens of otitis media among patients attending a Tertiary hospital in

Calabar, Nigeria. *International Journal of Tropical Disease and Health*; **44(12)**: 16-23.

United Nations (2022). UN World Urbanization Prospects 2022. Accessed online: https://worldpopulationreview.com/world-cities/calabar-population.

Vysakh, P. R. & Jeya, M. (2013). A comparative analysis of community acquired, and hospital acquired methicillin resistant *Staphylococcus aureus*. *Journal of clinical and diagnostic research: Journal of Clinical and Diagnostic Research*; *7***(7)**: 1339.

Whitener, C.J., Park, S.Y., Browne, F.A. *et al*. (2004). Vancomycin Resistant *Staphylococcus aureus* in the Absence of Vancomycin Exposure. *Clinical Infectious Diseases*; ***38*(8)**: 1049–1055. https://doi.org/10.1086/382357.

Yanguang, C., Sijin, Y. & Xiancai, R. (2020). Vancomycin resistant *Staphylococcus aureus* infections: A review of case updating and clinical features. *Journal of Advanced Research*; **21**: 169-176.

Yousefi M., Pourmand M.R., Fallah F. *et al*. (2016). Characterization of *Staphylococcus aureus* biofilm formation in urinary tract infection. *Iran Journal of Public Health*; **45(4)**: 485-493.

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