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ORIGINAL ARTICLE

Antibacterial Susceptibility Patterns of *Staphylococcus species* to Common Antimicrobial Agents and Impact on Patients in Bayelsa State, Nigeria

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ABSTRACT

Antimicrobial resistance is a growing problem in Nigeria, increasing treatment costs and complicating care, particularly in Bayelsa State, where local data remain scarce. This study examined antibacterial susceptibility patterns of Staphylococcus species isolated from two tertiary hospitals and assessed the economic implications of common treatment options. We retrospectively reviewed 12,640 microbiology laboratory records over 36 months (2021–2023) and selected 2,070 bacterial isolates by systematic random sampling; 590 Staphylococcus isolates were tested for susceptibility using standard disk diffusion according to CLSI guidelines. A prospective economic evaluation from a societal perspective included direct and indirect costs. Cost-of-Illness and Cost-Effectiveness analyses were performed for ceftriaxone, cefpodoxime, and ciprofloxacin using prevailing hospital prices. Staphylococcus species accounted for 28.5% of isolates. Susceptibility rates (including intermediate) were highest for cefpodoxime (90.3%), followed by ceftriaxone (66.1%), gentamicin (60.6%), ciprofloxacin (51.1%), and cefuroxime (50.9%). High resistance was observed to co-trimoxazole (96%), tetracycline (75.8%), ceftazidime (72.9%), and co-amoxiclav (61%). Ceftriaxone had the highest cost per episode (NGN 21,311.79 or USD 66.60), while ciprofloxacin and cefpodoxime tablets were more cost-effective for susceptible isolates. National extrapolation for one million episodes estimated costs exceeding NGN 4.3 billion with ciprofloxacin and NGN 21.3 billion with ceftriaxone. Isolates showed good susceptibility to cefpodoxime and moderate susceptibility to other agents, but marked resistance to several commonly used drugs. Ciprofloxacin and cefpodoxime were more affordable options. Strengthening antibacterial stewardship, routine surveillance, and susceptibility-guided prescribing is essential to reduce the substantial economic burden of Staphylococcal infections in the region.

Keywords: Antibacterial resistance; Cost of illness; Cost-effectiveness analysis; Antibacterial efficacy.

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1.0 INTRODUCTION

Bacterial infections continue to cause significant illness and death worldwide despite the availability of antibiotics. These drugs have greatly reduced mortality associated with many infections, yet recurrent infections remain the leading causes of death globally (Iskandar et al., 2022; Mensa et al., 2021; Usman et al., 2026). A major contributor to this ongoing burden is the rapid spread of antimicrobial resistance (AMR), which complicates treatment and increases healthcare costs. Susceptibility testing of clinical isolates plays a vital role in guiding appropriate antibiotic selection and tracking resistance trends, thereby supporting effective patient care and infection control programmes (Baltekin et al., 2017). Among bacterial pathogens, *Staphylococcus aureus* stands out as a leading cause of both hospital- and community-acquired infections. It is responsible for a broad spectrum of conditions ranging from minor skin and soft tissue infections to life-threatening bacteremia and endocarditis (Tong et al., 2015; Gbotche et al., 2020). The organism's virulence is enhanced by its ability to produce various extracellular proteins and polysaccharides (Torres et al., 2021). The situation has become more challenging with the emergence and global spread of methicillin-resistant *S. aureus* (MRSA), which now accounts for a large proportion of *S. aureus* isolates in many healthcare facilities (Vena et al., 2023; Parsons et al., 2026). Known risk factors for hospital-acquired MRSA include recent hospitalisation, surgery, indwelling medical devices, and residence in long-term care facilities. However, community-acquired MRSA strains increasingly affect healthy individuals without typical risk factors (Al-lede et al., 2024; Chalmers & Wylam, 2020). In addition, the production of enzymes that neutralise antibiotics further raises the likelihood of treatment failure (Ahmad-Mansour et al., 2021; Suleiman et al., 2022). Antibacterial susceptibility patterns vary over time and differ markedly across geographic locations and even between hospitals within the same region (Keyal et al., 2020). This variability makes regular local surveillance essential for making informed decisions on empirical therapy. In Bayelsa State, Nigeria, however, consistent, up-to-date information on the susceptibility profiles of S. aureus and other staphylococci remains limited. The absence of reliable local data weakens antimicrobial stewardship efforts and infection control activities in the region (Suleiman et al., 2013).

In resource-constrained settings like ours, economic considerations are equally important when choosing treatment options. With limited healthcare budgets, evaluating both the clinical effectiveness and cost implications of antibiotics helps ensure better value for money (Planey, 2020; Suleiman et al., 2022). Economic evaluations that compare costs

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and outcomes of different interventions can provide hospital infection control committees with practical evidence to guide policy and promote rational antibiotic use (Elliott and Payne, 2005; Bhattacharjee et al., 2025; Trujillo Jara et al., 2026). Therefore, the present study combined antimicrobial susceptibility testing with pharmacoeconomic analysis to determine the resistance patterns of *Staphylococcus* species and assess the cost implications of selected treatment regimens in two tertiary hospitals in Bayelsa State, Nigeria. This approach seeks to fill the existing knowledge gap and provide actionable data for improved clinical practice and policy in the region

2.0 MATERIALS AND METHODS

2.1 Study setting
The study took place in two tertiary hospitals in Bayelsa State, Nigeria: Niger Delta University Teaching Hospital (NDUTH), Okolobiri, and Federal Medical Centre (FMC), Yenagoa. NDUTH is a state-owned teaching hospital located in Yenagoa Local Government Area. It serves as a major referral centre for public and private health facilities in Bayelsa and neighbouring parts of Delta and Rivers States, handling around 7,000 patients annually. FMC is a federal hospital situated in Ovom, Yenagoa, the state capital, with an annual patient turnover of approximately 10,000.

2.2 Study design
This research used a mixed-methods design. The retrospective component involved reviewing microbiology laboratory records from January 2012 to December 2014 to determine the pattern of bacterial isolates and their antibiotic susceptibility. Prospectively, we carried out time-and-motion studies to collect data for the economic evaluation of selected antimicrobial agents. This combined approach allowed us to link laboratory findings with real-world cost implications.

2.3 Participants and sampling
All patients who had microscopy, culture, and sensitivity tests requested at the two hospitals during the study period formed the retrospective population (12,420 records). We applied systematic random sampling with a six-interval to select isolates. This interval was chosen after considering the volume of records to ensure a representative and manageable sample. An average of 345 isolates per hospital per year were selected, giving a total of 2,070 isolates for detailed review. Of these, 590 were identified as *Staphylococcus aureus* and other staphylococcal species using standard laboratory techniques (Murray, 1999). These staphylococcal isolates were the main unit of analysis for both susceptibility patterns and economic evaluation. Susceptibility testing was performed by the Kirby-Bauer disk diffusion method following Clinical and Laboratory Standards Institute (CLSI) guidelines (2008).
The sample size calculation was based on a 95% confidence level and 5% margin of error for a large population, with the final number of staphylococcal isolates comfortably exceeding the minimum required (n=384).

2.4 Participants selection criteria
We included all bacterial isolates with complete susceptibility results from 2012 to 2014. Fungal isolates and records lacking susceptibility testing requests were excluded.

2.5 Ethical approval
Ethical approval was obtained from the Research and Ethics Committees of both hospitals (NDUTH/REC/0009/2015). All data were anonymized and kept strictly confidential. The study was conducted and reported in accordance with the STROBE guidelines for observational studies and the CHEERS statement for economic evaluations.

2.6 Data collection
Using a validated data extraction form, we collected patient age, sex, specimen source, isolated organism, and susceptibility results from laboratory records. For the economic analysis, drug prices were obtained from the hospital pharmacies, laboratory test costs from the microbiology department, and staff salaries from the accounts department. We also used structured observations and questionnaires on clinic days to record the time healthcare workers spent on consultation, sample processing, dispensing, and drug administration. Transport costs were verified with hospital drivers and officials of the Bayelsa State Union of Road Transport Workers. All costs were averaged using values current at the time of the study.

2.7 Data analysis
Data were entered into Microsoft Excel 2013. Susceptibility results were interpreted using standard CLSI criteria as susceptible (S), intermediate (I), or resistant (R). To give a more realistic picture of resistance in our setting, isolates reported as mildly sensitive were grouped with the resistant category. We calculated the percentage of susceptible isolates for each antibiotic and used the Chi-square test for trends to compare proportions ($p < 0.05$ significant). For the economic evaluation, we adopted a societal perspective and performed both Cost-of-Illness and Cost-Effectiveness Analyses. A decision table model was used, taking into account efficacy (based on average susceptibility rates from both hospitals), adherence potential, and humanistic outcomes (Suleiman et al., 2012). Incremental Cost-Effectiveness Ratios (ICERs) were calculated for the selected agents (ciprofloxacin, cefpodoxime, and ceftriaxone). One-way sensitivity analysis was conducted by varying key inputs such as drug costs, susceptibility rates, and personnel time to assess the robustness of the findings. Descriptive statistics were used to present the economic results.

3.0 RESULTS

3.1 Demographic characteristics and specimen sources
A total of 2,070 bacterial isolates were analysed from the two hospitals. These came from 820 male patients (39.6%) and 1,250 female patients (60.4%). *Staphylococcus* species accounted for 590 isolates, representing 28.5% of all isolates recovered during the study period. The most common specimen sources were wound swabs (38.6%) and urine (37.0%), followed by blood (12.4%) and stool (8.2%). Table 1 presents the distribution of isolates by gender, age group, and specimen source across the two hospitals.

Table **1.** Distribution of isolates by demographic characteristics and specimen source

Variables	NDUTH n (%)	FMC n (%)	Total n (%)
Gender			
Male	406 (39.2)	414 (40.0)	820 (39.6)
Female	629 (60.8)	621 (60.0)	1,250 (60.4)
Age Group (years)			
0–10	275 (26.6)	300 (29.0)	575 (27.8)
11–20	68 (6.7)	55 (5.3)	123 (5.9)
21–30	264 (25.5)	245 (23.7)	509 (24.6)
31–40	124 (12.0)	134 (12.9)	258 (12.5)
41–50	128 (12.4)	116 (11.2)	244 (11.8)
51–60	84 (8.1)	77 (7.4)	161 (7.8)
61–70	39 (3.8)	54 (5.2)	93 (4.5)
71–80	30 (2.9)	41 (4.0)	71 (3.4)
81–90	22 (2.1)	9 (0.9)	31 (1.5)
91–100	1 (0.1)	4 (0.4)	5 (0.2)
Specimen Source			
Swabs	489 (47.2)	391 (37.8)	880 (42.5)
Urine	388 (37.5)	377 (36.4)	765 (37.0)
Blood	53 (5.1)	203 (19.6)	256 (12.4)
Stool	105 (10.1)	64 (6.2)	169 (8.2)

3.2 Antimicrobial susceptibility patterns
Staphylococcus isolates showed high resistance to several commonly used antibiotics: co-trimoxazole (96.0%), tetracycline (75.8%), ceftazidime (72.9%), and co-amoxiclav (61.0%). Notable intermediate susceptibility was observed for cefpodoxime (36.1%), gentamicin (31.6%), and ceftriaxone (26.7%). On the other hand, higher sensitivity was recorded for nitrofurantoin (70.2%), cefpodoxime (54.2%), ceftriaxone (39.4%), ciprofloxacin (37.5%), gentamicin (29.0%), and cefuroxime (28.3%). When intermediate results were combined with full susceptibility, the overall susceptibility rates were: cefpodoxime 90.3%, ceftriaxone 66.1%, gentamicin 60.6%, ciprofloxacin 51.1%, and cefuroxime 50.9%. Multidrug resistance (MDR), defined here as resistance to three or more classes of antibiotics, was common, particularly involving co-trimoxazole, tetracycline, and ceftazidime. Detailed susceptibility patterns are shown in Table 2.

Table **2:** Antibiotic susceptibility patterns of *Staphylococcus* isolates

Drug	Sensitive n (%)	Intermediate n (%)	Resistant n (%)	Total n (%)
Ciprofloxacin	33 (37.5)	12 (13.6)	43 (48.9)	88 (100)
Co-amoxiclav	124 (24.2)	86 (16.8)	313 (61.0)	513 (100)
Ceftriaxone	121 (39.4)	82 (26.7)	104 (33.9)	307 (100)
Cefuroxime	130 (28.3)	104 (22.6)	226 (49.1)	460 (100)
Ceftazidime	55 (14.7)	46 (12.3)	272 (72.9)	373 (100)
Cefpodoxime	39 (54.2)	26 (36.1)	7 (9.7)	72 (100)
Gentamicin	146 (29.0)	159 (31.6)	198 (39.4)	503 (100)
Cotrimoxazole	4 (4.0)	0 (0.0)	97 (96.0)	101 (100)
Tetracycline	9 (13.6)	7 (10.6)	50 (75.8)	66 (100)
Nitrofurantoin	47 (70.2)	8 (11.9)	12 (17.9)	67 (100)

$\chi^2 = 379.70$, df = 18, $p < 0.0001$ (testing for significant differences in susceptibility patterns across antibiotics).

3.3 Economic impact analysis on individuals

Three agents (ciprofloxacin tablets, ceftriaxone injection, and cefpodoxime tablets) were selected for economic analysis because they were the most commonly prescribed in the study hospitals. Effectiveness ratings were derived from a composite score that included measured susceptibility (efficacy), likely patient adherence, and reported tolerability/adverse effects. Cefpodoxime had the highest composite effectiveness rating (0.8393), followed by ceftriaxone (0.6785) and ciprofloxacin (0.6465). From a societal perspective, the average cost per treatment episode was lowest for ciprofloxacin tablets (NGN 4,324.83 / USD 13.51), followed by cefpodoxime tablets (NGN 6,284.83 / USD 19.64), and highest for ceftriaxone injection (NGN 21,311.79 / USD 66.60). Cost-effectiveness analysis showed ciprofloxacin as the most cost-effective option, with a cost-effectiveness ratio of NGN 6,688.32 (USD 20.90) per unit of effectiveness. Cefpodoxime followed at NGN 7,488.18 (USD 23.40). The incremental cost-effectiveness ratio (ICER) for using cefpodoxime instead of ciprofloxacin was NGN 61,275.93 (USD 191.48) per additional unit of effectiveness gained. Sensitivity analysis confirmed that these rankings remained stable even when key costs were varied substantially. Extrapolating to a hypothetical national level of one million staphylococcal infection episodes (based on available infection rate estimates) suggests a potential cost range of approximately NGN 4.32 billion using ciprofloxacin to NGN 21.31 billion using ceftriaxone. These figures should be interpreted with caution as they depend on several assumptions regarding prevalence and treatment practices.

4.0 DISCUSSION

The study found that *Staphylococcus* isolates accounted for 28.5% of all bacterial isolates recovered from the two hospitals. These organisms showed moderate to good susceptibility to cefpodoxime, ceftriaxone, gentamicin, ciprofloxacin, and cefuroxime, while demonstrating high resistance to co-trimoxazole (96%), tetracycline (75.8%), ceftazidime (72.9%), and co-amoxiclav (61%). This pattern of resistance is consistent with several previous reports from Nigeria and other low-resource settings, where overuse of readily available older antibiotics has contributed to rising resistance levels (Adamu et al., 2021; Ibrahim et al, 2024). The relatively high recovery of staphylococci may be explained by the large proportion of wound swabs and urine samples processed in the laboratories. As noted by Bierowiec et al. (2019), staphylococcal species commonly colonise the skin and mucous membranes, while Swaney et al. (2020) highlighted their dual role as commensals that help maintain skin homeostasis and potential pathogens in susceptible hosts. The predominance of cases among children aged 0–10 years in our study aligns with the understanding that immature immune systems make young children more vulnerable to infections (Ygberg & Nilsson, 2012; Walker et al., 2013). Interestingly, we observed more isolates from female patients, which contrasts with some earlier findings that reported higher infection rates in males (Cerdeira and Brigagão, 2023), though gender differences in healthcare-seeking behaviour may also play a role. From a clinical perspective, these susceptibility patterns have important implications for empirical therapy. Although ciprofloxacin performed well in the cost-effectiveness analysis, its restriction in paediatric populations — a major demographic in our data — means alternatives such as cefpodoxime or cefuroxime are often more suitable. For critically ill patients, the higher cost of injectable ceftriaxone may be justified. The frequent multidrug resistance observed also underscores the need for improved laboratory support to identify MRSA and guide targeted therapy, especially as resistance to even newer agents continues to emerge (David & Daum, 2017). Economically, cefpodoxime recorded the highest composite effectiveness rating, but ciprofloxacin offered the best cost per unit of effectiveness for susceptible isolates. Ceftriaxone was substantially more expensive. These findings reinforce that treatment cost remains a critical barrier to effective care in resource-limited environments (Ayé et al., 2010; Suleiman et al., 2012). While our national cost projections illustrate the potential scale of the burden, they are based on assumptions and should be viewed as illustrative rather than precise forecasts. Strengths and Limitations Strengths of this study include the use of data from two tertiary hospitals within the same state and the integration of susceptibility testing with pharmacoeconomic evaluation. However, important limitations exist. The data were collected between 2012 and 2014, so resistance patterns may have shifted since then. The sample size for some antibiotics was modest, and we did not distinguish between methicillin-resistant and susceptible strains. Our effectiveness ratings, though based on predefined criteria, still involve some subjectivity. In addition, in-vitro susceptibility results do not always translate directly to clinical outcomes. These limitations reduce the generalisability of our findings and emphasise the need for more recent, prospective studies that include patient outcomes.

5.0 Conclusion

Staphylococcus isolates in the two Bayelsa State tertiary hospitals showed relatively good susceptibility to cefpodoxime, ceftriaxone, gentamicin, ciprofloxacin, and cefuroxime, but high levels of resistance to co-trimoxazole, tetracycline, ceftazidime, and co-amoxiclav. Cefpodoxime demonstrated the highest overall effectiveness rating, while ciprofloxacin and cefpodoxime proved the most cost-effective options for susceptible isolates from a societal perspective. These findings highlight the substantial economic burden of staphylococcal infections and the urgent need for context-specific antimicrobial stewardship. Local surveillance should be strengthened and regularly updated to guide empirical therapy and hospital formularies. Where possible, clinicians should prioritize affordable, susceptibility-supported agents such as ciprofloxacin or cefpodoxime, while considering patient age and clinical severity. Greater investment in laboratory capacity, rational antibiotic use, and exploration of drug repurposing will be essential to curb resistance and reduce treatment costs in resource-limited settings like ours.

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7.0 Conflict of interest

In this research, no competing interests were recorded. No external funding was received for this work, and none of the authors has any financial or non-financial relationships that could be perceived as influencing the results or interpretation of the study.

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