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Comparative Microbial Contamination Profiles of Radiology Imaging Equipment in Public and Private Facilities in Abia State, Nigeria

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ABSTRACT

This cross-sectional study compared microbial contamination profiles on radiology imaging equipment in public and private facilities in Abia State, Nigeria, to establish baseline data for enhancing infection prevention and control measures in resource-limited settings. Between January and June 2025, 360 surface samples were collected from high-touch sites on X-ray machines, ultrasound units, and computed tomography scanners across three purposively selected public hospitals and three private diagnostic centres, using sterile swabs pre-moistened with saline, followed by culture on selective media, biochemical identification, antibiotic susceptibility testing, and log-transformed colony-forming unit quantification with statistical analysis using independent t-tests and chi-square tests. Microbial contamination was detected on 92% of surfaces, with significantly higher mean log-transformed colony-forming units per square centimetre in public facilities (1.69±0.28) compared to private ones (1.46±0.22; p<0.001), particularly on computed tomography scanners (public: 1.80±0.29; private: 1.54±0.23); predominant isolates included Staphylococcus aureus (35% public, 25% private), coagulase-negative staphylococci (25% public, 30% private), and Klebsiella species (20% public, 15% private), with multidrug-resistant strains affecting 45% of public isolates versus 25% in private settings, correlating positively with patient volumes (r=0.62, p<0.01) and inversely with cleaning frequency (r= -0.58, p<0.01). These findings highlight elevated healthcare-associated infection risks in public facilities due to resource constraints and operational burdens and the need for facility-specific decontamination protocols, routine microbial audits, and policy-driven resource reallocation to mitigate nosocomial transmission and foster equitable diagnostic safety.

INTRODUCTION

Radiological imaging equipment is indispensable in modern healthcare for accurate diagnosis and patient management, yet these devices frequently harbour microbial pathogens, posing substantial risks for healthcare-associated infections (HAIs) in clinical settings (Adomako *et al.*, 2022; Jimenez & Lewis, 2023). Globally, inadequate infection prevention and control (IPC) practices in medical imaging departments facilitate the transmission of nosocomial pathogens, with high-touch surfaces like ultrasound probes, computed tomography (CT) tables, and X-ray detectors serving as common fomites (Adomako *et al.*, 2022; Jimenez & Lewis, 2023). This challenge is particularly severe in resource-limited environments in developing countries, where limited access to training, inconsistent disinfection protocols, and overburdened facilities hinder effective microbial mitigation (Tabash *et al.*, 2024). In sub-Saharan Africa, including Nigeria, radiology departments report elevated contamination rates, with prevalent isolates that include Staphylococcus aureus, coagulase-negative staphylococci, Klebsiella spp., and Bacillus spp., which often persist despite routine cleaning due to suboptimal adherence to IPC guidelines (Odeh *et al.*, 2023; Osmond *et al.*, 2025; Shaukat *et al.*, 2024).

The problem is compounded in Nigeria's dual healthcare system, where public facilities often face greater resource constraints, higher patient volumes, and delayed maintenance compared to private counterparts, potentially leading to differential microbial profiles and heightened HAI risks (Adomako *et al.*, 2022; Ahmed, 2023). Recent audits in South-East Nigeria reveal that radiology equipment remains contaminated post-decontamination, with methicillin-resistant S. aureus (MRSA) and enteric pathogens detected across accessories, underscoring gaps in protocol enforcement and the need for facility-specific assessments (Odeh *et al.*, 2023). Comparable findings from Palestinian and South African tertiary centres highlight multidrug-resistant organisms on imaging surfaces linked to workload surges, emphasizing the urgency for localized surveillance in understudied regions like Abia State, where no comparative data on public-private disparities are reported (Osmond *et al.*, 2025; Sadhukhan *et al.*, 2025; Tabash *et al.*, 2024).

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This study addressed these gaps by providing the first comparative analysis of microbial contamination on radiology imaging equipment across public and private facilities in Abia State, Nigeria, and by contributing baseline epidemiological data to guide tailored IPC interventions and policy reforms in low-resource settings.

MATERIALS AND METHODS

Study Design and Setting

This cross-sectional comparative study was conducted between January and June 2025 in Abia State, Nigeria, a southeastern region with a population of approximately 3.7 million and a mixed healthcare system comprising public and private facilities. Six facilities were purposively selected: three public hospitals and three private diagnostic centres (chosen based on accreditation by the Nigerian Nuclear Regulatory Authority and comparable radiology workloads). Inclusion criteria for facilities included operational radiology departments with X-ray, ultrasound, and computed tomography (CT) units and a minimum daily patient volume of 20 imaging procedures. Exclusion criteria encompassed facilities undergoing renovation or with recent outbreaks of notifiable infections.

Sampling Procedure

A total of 360 surface samples were collected (180 from public and 180 from private facilities), stratified equally across equipment types to ensure comparability. Within each facility, 60 samples were obtained: 20 from X-ray machines (control panel, cassette holder, and patient table), 20 from ultrasound units (probe handle, gel dispenser, and transducer head), and 20 from CT scanners (gantry surface, control console, and patient couch). Sampling was performed during peak operational hours (8:00 AM-4:00 PM) on weekdays, following routine cleaning protocols to capture real-world contamination levels. Convenience sampling of high-touch sites was employed, guided by a standardized checklist adapted from the Centers for Disease Control and Prevention (CDC) environmental sampling guidelines (CDC, 2019).

Sample Collection

Samples were collected using sterile rayon-tipped swabs (Copan Diagnostics, Inc., Murrieta, CA, USA) pre-moistened with 0.85% sterile saline, following the method described by Rutala *et al.* (2024). Each site (approximately 10 cm²) was swabbed in a zigzag pattern for 30 seconds under aseptic conditions by trained personnel wearing personal protective equipment (nitrile gloves and masks). Swabs were immediately placed in Amies transport medium (BD Biosciences, Franklin Lakes, NJ, USA), labelled with facility type, equipment, site, date, and time, and transported at 4°C to the Microbiology Laboratory at Abia State University, Uturu, within 2 hours. Environmental controls (five blank swabs) were included per session to detect contamination during transport.

Microbiological Examination

Upon receipt, swabs were vortexed for 30 seconds in 1 mL of sterile phosphate-buffered saline (PBS, pH 7.4), and serial dilutions (10^{-1} to 10^{-3}) were prepared. Aliquots (0.1 mL) were plated onto selective media: blood agar (5% sheep blood), MacConkey agar, and mannitol salt agar (all from Oxoid Ltd., Basingstoke, UK), and incubated aerobically at 37°C for 24-48 hours. For fungal detection, Sabouraud dextrose agar (Oxoid Ltd) was inoculated and incubated at 25-30°C for up to 7 days. Colonies were enumerated as colony-forming units per square centimetre (CFU/cm²) by dividing counts by the swabbed area and dilution factor. Presumptive identification was performed using standard biochemical tests (e.g., catalase, coagulase, oxidase, and triple sugar iron) and Gram staining, with confirmatory identification using the VITEK 2 automated system (bioMérieux, Inc., Durham, NC, USA) for antibiotic susceptibility profiling against a panel including ampicillin, ciprofloxacin, and vancomycin per Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2023). Multidrug resistance was defined as non-susceptibility to ≥1 agent in ≥3 antimicrobial categories.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 31.0 (IBM Corp., Armonk, NY, USA). Microbial counts were log-transformed ($\log_{10}$ [CFU/cm² + 1]) for normality. Descriptive statistics (means, standard deviations, frequencies) summarized contamination profiles by facility type and equipment. Comparative analyses used independent t-tests for continuous variables (e.g., mean CFU/cm²) and chi-square tests for categorical outcomes (e.g., pathogen prevalence). The correlations between the contamination levels and variables (e.g., patient volume, cleaning frequency) were assessed using Pearson's r, and statistical significance was set at $p<0.05$.

Ethical Considerations

This study adhered to the principles outlined in the Declaration of Helsinki for ethical research conduct. Prior to initiation, ethical approval was obtained from the Ethical and Research Committee of the Abia State Ministry of Health and Abia State University Teaching Hospital. Permissions were secured from the administrations of all participating facilities, with written consents outlining the study's objectives, sampling procedures, and assurances of non-disruption to clinical operations. There were no direct human participants. All samples were anonymized by facility type and equipment site to protect confidentiality, and data were stored securely on password-protected servers, accessible only to the research team.

RESULTS AND DISCUSSIONS

Microbial contamination was detected on 92% of sampled surfaces across all facilities, with mean log-transformed colony-forming units per square centimetre ($\log_{10}$ CFU/cm²) significantly higher in public facilities (1.69±0.28) compared to private ones (1.46±0.22; $t = 8.66$, $p<0.001$), as shown in Table 1. This disparity underscores the amplified HAI risks in resource-constrained public settings, where overburdened infrastructure likely fosters persistent fomite transmission. Notably, CT scanners exhibited the highest contamination (public: 1.80±0.29; private: 1.54±0.23), attributable to their extensive patient contact and complex gantry designs that impede thorough disinfection, aligning with recent observations in African tertiary centres where CT surfaces harboured up to 70% of isolates post-cleaning (Osmond *et al.*, 2025). Ultrasound probes, conversely, showed the lowest levels (public: 1.60±0.27; private: 1.37±0.21), possibly due to gel application masking contaminants, though this may underestimate viable pathogens in gel residues as reported in South African audits (Adomako *et al.*, 2022).

Table 1: Comparative Microbial Contamination Levels on Radiology Imaging Equipment by Facility Type and Equipment Category in Abia State, Nigeria

Equipment Type	Public Mean $\log_{10}$ CFU/ cm² ±SD	Private Mean $\log_{10}$ CFU/ cm² ±SD	p-value
X-ray	1.65±0.26	1.47±0.20	<0.001*
Ultrasound	1.60±0.27	1.37±0.21	<0.001*
CT Scanner	1.80±0.29	1.54±0.23	<0.001*
Overall	1.69±0.28	1.46±0.22	<0.001*

**p<0.05: Statistically significant*

These findings reveal a distinct public-private difference, with public facilities averaging 69% higher CFU counts, correlating positively with daily patient volumes (r = 0.62, p<0.01) and inversely with cleaning frequency (r = -0.58, p<0.01). Such patterns highlight systemic inequities in Nigeria's healthcare dualism, where public sites manage 2-3 times the caseload with fewer IPC resources, exacerbating nosocomial burdens in high-density environments like Abia State. This contrasts with more equitable contamination rates in well-resourced Palestinian hospitals (Odeh *et al.*, 2023), emphasizing the novelty of our work in quantifying these disparities in an understudied Nigerian context amid rising HCAI incidences of 45-60% in sub-Saharan facilities (Shaukat *et al.*, 2024).

Pathogen Profiles and Antimicrobial Resistance Patterns

Predominant isolates in public facilities included Staphylococcus aureus (35%), coagulase-negative staphylococci (CoNS; 25%), and Klebsiella spp. (20%), shifting to CoNS (30%) and S. aureus (25%) in private settings, with Klebsiella reduced to 15% (χ^2=12.4, p=0.03). Gram-negative enteric pathogens like Escherichia coli (10% public vs. 5% private) prevailed in public CT and X-ray surfaces, likely propelled by cross-contamination from overcrowded waiting areas, a vulnerability amplified in tropical climates favouring biofilm formation (Tabash *et al.*, 2024). Fungal growth (Candida spp.) was low (2-4%) and confined to ultrasound gel dispensers.

Multidrug-resistant (MDR) strains were detected in 45% of public isolates versus 25% in private (χ^2=18.7, p<0.001), with MRSA comprising 28% of S. aureus in public sites, exhibiting >80% resistance to ciprofloxacin and ampicillin. This MDR escalation signals a critical public health issue, where weak surveillance in underfunded facilities fosters resistant reservoirs, mirroring 2024 Nigerian reports of 40-50% MDR on imaging fomites (Odeh *et al.*, 2023; Raze *et al.*, 2025). Our profiling is innovative for linking these profiles to the type of facility, revealing private centres' edge through proprietary disinfectants and staff training, which curbed Gram-negative dominance, unlike uniform highs in Gaza's overburdened public imaging units (Tabash *et al.*, 2024). These insights advocate targeted stewardship, as unchecked MDR could inflate Abia's HAI rates by 20-30%, consistent with projections by Shaukat *et al.* (2024).

Implications for Infection Prevention and Future Directions

The elevated public facilities contamination, driven by operational strains, not only validates lapses in IPC, but is also a call for adaptive strategies including: facility-tailored protocols that integrate alcohol-based wipes for probes and UV adjuncts for CT gantries could slash loads by 40-60%, as in the trial in recent African interventions (Jimenez & Lewis, 2023; Kaur, 2025). Our baseline data filled a gap in Abia-specific epidemiology, where prior studies overlooked public-private dichotomies, and offers policymakers an evidence-base for equitable resource allocation in the midst of Nigeria's 2025 HCAI surge (Adomako *et al.*, 2022). The limitation of this study is its cross-sectional design, which precludes causality thus we recommend longitudinal surveillance with molecular genotyping. Ultimately, this work highlights the role of radiology as an HAI link and urges integrated reforms to safeguard vulnerable populations in low-resource dual systems.

CONCLUSION

This study demonstrated that radiology imaging equipment in public facilities of Abia State exhibited significantly higher microbial contamination levels and multidrug-resistant pathogen prevalence compared to private counterparts, with CT scanners emerging as the most contaminated sites, highlighting the prevalent threat of healthcare-associated infections in resource-stratified environments. These findings illuminate the critical importance of targeted surveillance in mitigating nosocomial risks, particularly in overcrowded public settings where elevated patient volumes and inconsistent disinfection amplify transmission, to potentially avert substantial morbidity and economic burdens in low-resource healthcare systems. While our cross-sectional approach provided robust baseline data, it is limited in its inability to infer temporal dynamics and causal pathways; and potential bias from peak-hour sampling may overestimate operational exposures. The relevance of this work extends to informing equitable infection prevention strategies across Nigeria's dual healthcare landscape, offering actionable insights for policymakers to bridge public-private disparities amid rising antimicrobial resistance. Practically, these profiles enable customized decontamination protocols, such as enhanced probe wiping and gantry audits, to reduce contamination and foster safer diagnostic workflows. To advance patient safety, we recommend integrating routine microbial audits into facility accreditation, improving staff training on evidence-based cleaning, and prioritizing resource reallocation toward public radiology units to cultivate resilient, infection-resilient imaging services.

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