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Prevalence of bacterial pathogens and molecular detection of metallo-β-lactamases in Gram-negative bacteria from mobile phones of healthcare workers in a Nigerian tertiary hospital

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Abstract:

Background: The increasing usage of mobile phones in healthcare settings is cause for concern because these gadgets could be used to disseminate harmful bacteria. This study aimed to detect the presence of bacterial pathogens and carriage of metallo-β-lactamase (MBL) genes in Gram-negative bacteria from mobile phones of healthcare workers (HCWs) and medical students at the Olabisi Onabanjo University Teaching Hospital, Ogun State, Nigeria.
Methodology: This cross-sectional study was conducted from February to April 2022. Mobile phones of one hundred and twenty-one HCWs and medical students were swabbed with sterile cotton swabs and inoculated in peptone water overnight, and then sub-cultured on selective media (eosin methylene blue agar, cetrimide agar, *Salmonella-Shigella* agar, and mannitol salt agar). Bacterial isolates were identified using the standard bacteriological method. Antibiotic susceptibility testing was done using the Kirby-Bauer disc diffusion method. The phenotypic presence of MBL and MBL genes was verified using the combined disc method and polymerase chain reaction, respectively.
Results: Ninety-seven bacteria isolates were identified from mobile phones of 72 participants, giving a prevalence of 59.5%, with 65 (67.0%) Gram-positive and 32 (33.0%) Gram-negative isolates. *Staphylococcus aureus* was the most frequent isolate (n=49, 50.5%) and were resistant to azithromycin (63.3%) and ceftazidime (69.4%), but sensitive (100%) to imipenem. Carbapenem resistance (resistance to imipenem and meropenem) was reported in 28.6% (2/7) of *Pseudomonas aeruginosa*, 25.0% (2/8) of *Klebsiella pneumoniae* and 33.3% (1/3) of *Klebsiella oxytoca* isolates. Coagulase-negative staphylococci exhibited the highest resistance to ceftazidime (75%), while *P. aeruginosa* exhibited the highest resistance to aztreonam and amoxicillin/clavulanic acid. The *bla*$_{VIM}$ was detected in 2 of the 32 (6.3%) Gram-negative isolates.
Conclusion: Carbapenem-resistant Gram-negative bacteria isolates carrying *bla*$_{VIM.}$ MBL were isolated from mobile phones of HCWs, which could be a source for the spread of multidrug-resistant nosocomial infections.

Keywords: antibiotic resistance, *bla*$_{VIM}$, bacterial contaminants, mobile phones, health workers

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Prévalence des agents pathogènes bactériens et détection moléculaire des métallo-β-lactamases chez les bactéries à Gram négatif à partir des téléphones portables du personnel soignant d'un hôpital tertiaire Nigérian

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Résumé:

Contexte: L'utilisation croissante des téléphones portables dans les établissements de santé est préoccupante, car ces appareils pourraient être utilisés pour disséminer des bactéries nocives. Cette étude visait à détecter la présence de bactéries pathogènes et le portage des gènes de métallo-β-lactamase (MBL) chez des bactéries à Gram négatif à partir des téléphones portables de professionnels de santé et d'étudiants en médecine du centre hospitalier universitaire Olabisi Onabanjo, dans l'État d'Ogun, au Nigéria.
Méthodologie: Cette étude transversale a été menée de février à avril 2022. Les téléphones portables de cent vingt et un professionnels de santé et étudiants en médecine ont été prélevés avec des cotons-tiges stériles et inoculés dans de l'eau peptonée pendant une nuit, puis repiqués sur des milieux sélectifs (gélose au bleu de méthylène éosine, gélose au cétrimide, gélose *Salmonella-Shigella* et gélose au mannitol). Les isolats bactériens ont été identifiés par la méthode bactériologique standard. Français Les tests de sensibilité aux antibiotiques ont été effectués en utilisant la méthode de diffusion sur disque de Kirby-Bauer. La présence phénotypique des gènes MBL et MBL a été vérifiée en utilisant respectivement la méthode du disque combiné et la réaction en chaîne par polymérase.
Résultats: Quatre-vingt-dix-sept isolats de bactéries ont été identifiés à partir des téléphones portables de 72 participants, ce qui donne une prévalence de 59,5%, avec 65 (67,0%) isolats Gram positifs et 32 (33,0%) isolats Gram négatifs. *Staphylococcus aureus* était l'isolat le plus fréquent (n=49, 50,5%) et était résistant à l'azithromycine (63,3%) et à la céftazidime (69,4%), mais sensible (100%) à l'imipénème. Une résistance aux carbapénèmes (résistance à l'imipénème et au méropénème) a été signalée chez 28,6% (2/7) des isolats de *Pseudomonas aeruginosa*, 25,0 % (2/8) de *Klebsiella pneumoniae* et 33,3 % (1/3) de *Klebsiella oxytoca*. Les staphylocoques à coagulase négative présentaient la plus forte résistance à la ceftazidime (75 %), tandis que *P. aeruginosa* présentait la plus forte résistance à l'aztréonam et à l'amoxicilline/acide clavulanique. Le bla_{VIM} a été détecté chez 2 des 32 isolats Gram négatif (6,3%).
Conclusion: Des isolats de bactéries Gram négatif résistantes aux carbapénèmes et porteuses du bla_{VIM} ont été isolés à partir de téléphones portables de professionnels de santé, ce qui pourrait favoriser la propagation d'infections nosocomiales multirésistantes.

Mots-clés: Résistance aux antibiotiques, bla_{VIM}, contaminants bactériens, téléphones portables, agents de santé

Introduction:

Hospital-acquired infection (HAI) is recognized as a global public health issue (1), and the leading cause of poor patient care outcomes worldwide (2). In many countries, HAIs are responsible for increased length of hospital stay, mortality, morbidity, and healthcare costs (3). In hospitals, healthcare providers may acquire and disseminate infection to patients (4,5). Previous studies have shown that mobile phones used by healthcare workers are contaminated with microorganisms (6,7), that could spread from these healthcare workers' cellphones to their hands or the other way around (8).

Mobile devices have become common in healthcare facilities, resulting in a surge in the creation of software for medical applications (9). Many applications are now available to help healthcare providers with a variety of vital tasks, including access to electronic health record maintenance and data collection (10). Apart from using mobile phones in hospitals for registration and medical treatments, the device is also employed for improved information and time management, communications, care of patients as well as management, therapeutic decision-making, and medical training and education (11,12). As more cellular phones are utilized in healthcare settings, there is an increasing risk of bacterial transmission from smartphones to the hospital environment (13).

Objects with frequent hand contact such as mobile devices could act as reservoirs for pathogens, allowing them to transfer to the hands of healthcare providers before being transmitted to patients (8). These objects are being discovered to act as carriers for infectious agents including *Escherichia coli, Staphylococcus aureus, Acinetobacter,* and *Pseudomonas* species (4,14). Healthcare professionals have been reported to place little focus on frequent hand disinfection and have poor hand washing practices, which expose them and other people and their mobile phones to bacterial colonization (8). Previous studies from Africa have documented the prevalence of bacterial contaminants of mobile phones of healthcare workers (15-17). Researchers from Nigeria have also reported the presence of bacterial contaminants on the mobile phones of healthcare workers (5,12,18).

Metallo-β-lactamases (MBL) are now recognized to be among the most significant resistance mechanisms because of their ability to hydrolyze an array of β-lactam antibiotics, including carbapenems (19). MBL genes are carried on highly mobile genetic elements, allowing for quick spread (20), and are not usually inhibited by therapeutic serine-lactamase inhibitors such as clavulanic acid and

sulfones. They confer multidrug resistance (MDR) profile against a wide range of therapeutically significant β-lactams and other antimicrobial drugs (19,21).

The presence of an MBL-positive isolate in a hospital setting is not only a therapeutic issue but also a major worry for infection control and prevention. They offer considerable hazards, particularly because of their role in unsuspected spread inside healthcare facilities and their capacity to be involved in horizontal MBL gene exchange with other infectious agents in hospitals (22). MBLs have been found in a variety of Gram-negative bacilli from the family Enterobacteriaceae (23), as well as in some non-glucose-fermenters such as *Pseudomonas aeruginosa* and *Acinetobacter* species (21,24,25).

Many researchers from different countries (26,27), including Nigeria (21) have reported the presence of MBL genes in isolates recovered from patients and environments (hospital and community). Although MBL has been discovered in a range of systemic infections and environmental settings in Nigeria, there is no report of MBL genes in Gram-negative isolates from mobile phones. Therefore, this study determines the presence of metallo-beta-lactamase genes in Gram-negative isolates from mobile phones of healthcare workers and students at the Olabisi Onabanjo University Teaching Hospital, Sagamu, Ogun State, Nigeria.

Materials and method:

Study setting, design, participants, and sample collection:

This was a cross-sectional study of 121 volunteer healthcare workers in 18 departments of the Olabisi Onabanjo University Teaching Hospital, Sagamu, Ogun State, Nigeria in February 2022. Sterile swab sticks moistened with normal saline were used to swab the surface and back of each participant's mobile phone, and the swabs were immediately transported to the Pharmaceutical Microbiology Laboratory of the Hospital for microbiological analysis.

Isolation and identification of bacterial isolates from mobile phones:

The swab sticks were used to inoculate sterile peptone broth in test tubes and incubated at 37°C for 24 hours. A loopful of inoculum from the peptone broth was streaked on eosin methylene blue agar, cetrimide agar, *Salmonella-Shigella* agar, and mannitol salt agar, and incubated at 37°C for 24 hours. Distinct colonies were picked and stored in nutrient agar slant at 4°C until further use.

Bacteria were identified to species level by Gram staining and conventional biochemical test schemes that included oxidase, indole, Voges-Proskauer, methyl red, citrate, urease, triple sugar iron (TSI), hydrogen sulfide and gas production for Gram-negative enteric bacteria, and catalase, coagulase and deoxyribonuclease tests, as well as haemolysis patterns on blood agar for Gram-positive bacteria isolates (28).

Antibiotic susceptibility testing:

The antibiotic susceptibility test (AST) of each isolate was determined by the Kirby-Bauer disc diffusion technique to selected antibiotics including amoxicillin-clavulanic acid (20/10µg), cefoxitin (30µg), cephalexin (30µg), ceftazidime (30µg), cefotaxime (30µg), cefepime (30µg), aztreonam (30µg), amikacin (30 µg), azithromycin (15µg), ciprofloxacin (5µg), imipenem (10µg), and meropenem (30µg).

The surface of Mueller Hinton (MH) agar plate was inoculated with bacterial suspension from overnight culture growth standardized to 0.5 McFarland turbidity standard, using a sterile cotton swab. The antibiotic discs (Mast, UK) were aseptically placed on the inoculated agar surface with sterile forceps and allowed to diffuse in the agar medium for one hour. The culture plates were incubated at 37°C for 24 hours (29).

Zones of growth inhibition observed were measured in millimeters and isolate was classified as sensitive, intermediate, or resistant in accordance with the Clinical and Laboratory Standards Institutes (CLSI) guideline (30).

Combined disc test (CDT) for detection of MBL:

Standardized inoculum (0.5 McFarland standard) of each carbapenem-resistant Gram-negative isolate in the AST was inoculated onto a sterile MH agar plate. Two each of imipenem and meropenem antibiotic discs were placed on the surface of the agar medium. Then, 10µL of 750µg ethylene diamine tetra-acetic acid (EDTA) was added to one disc of imipenem and one disc of meropenem followed by incubation at 37°C for 18 hours. If the zone of growth inhibition of the imipenem-EDTA disc or meropenem-EDTA was greater than 7mm than that of the imipenem disc or meropenem alone, the isolate was regarded as metallo-β-lactamase positive (31).

Molecular detection of MBL genes:

DNA extraction:

The bacterial chromosomal DNA was extracted using the boiling technique as described by Diagbouga et al., (32). Briefly, a culture of tryptic soy agar (TSA) was inoculated in 2 ml Luria Bertani (LB) broth and incubated for 18-24 hours. The LB broth was centrifuged at 10,000 rpm/min for 10 minutes. Bacterial cells were suspended in 500µL phosphate buffer (100 mM, pH 7) to weaken the

cell membranes. The cells were then submerged in a boiling water bath at 100°C for 15 minutes to remove genetic materials. The DNA was precipitated using 250 µL of 100% alcohol, washed twice with 1000 µL of 70% alcohol, and resuspended in 100 µL sterile water.

***PCR assay*:**

The PCR total volume of 25µL consists of 12.5µL of 2x master mix (Inqaba, South Africa), 1µL of DNA, 1µL of forward and reverse primers (10µmol/L) (Table 1), and 9.5µL of molecular grade water. The tubes were placed into a thermal cycler instrument (Applied Biosystems). The following thermal cycling conditions were employed to detect *bla*$_{IMP,}$ *bla*$_{NDM,}$ and *bla*$_{VIM}$; initial denaturation for 5 minutes at 94°C, was followed by 30 cycles of denaturation at 94°C for 30 seconds and annealing at 52°C for *bla*$_{IMP}$, 60°C for *bla*$_{NDM}$ and 55°C for *bla*$_{VIM}$ for 30 seconds and extension at 72°C for 30 seconds, followed by a 5-minute extension at 72°C (33).

The PCR products were stained with ethidium bromide (0.5µg/ml) and electrophoresed on 1.5% agarose gel alongside a DNA ladder (100 bp or 1 kb plus ladder) and viewed under UV light in the gel documentation system.

Statistical analysis:

For data analysis, the Statistical Package for Social Sciences version 22.0 (Chicago, USA) was used. Categorical variables were presented as percentages and frequencies in the study.

Ethical approval:

The study protocol was approved by the Human Research Ethics Committees of Olabisi Onabanjo University Teaching Hospital, Sagamu, Ogun state (OOUTH/ HREC/486/2022AP).

Results

Distribution of samples among health workers:

Table 2 presents the distribution of the 121 study participants across various departments/units of the hospital and their respective gender demographics. The frequency of the female participants is 62.8% (n=76) while that of the male participants is 37.2% (n=45). The medical records department had the highest number of participants (n=17 with 11 females and 6 males), followed by social works, general wards, and accident and emergency units, with 12 participants each (Table 3).

The highest number of samples was obtained from mobile phones of other health workers (67.0%, n=81), while nurses contributed the second highest at 13.2% (n=16).

Table1: List of primers used for the detection of metallo-β-lactamase genes

Primer	Sequence (5' to 3')	Gene	Amplicon size (bp)	Reference
IMP-F	GGAATAGAGTGGCTTAAYTCTC	*bla*$_{IMP}$	188	Ellington et al., (33)
IMP-R	CCAAACYACTASGTTATCT			
VIM-F	GATGGTGTTTGGTCGCATA	*bla*$_{VIM}$	390	Ellington et al., (33)
VIM-R	CGAATGCGCAGCACCAG			
NDM-F	GGGCAGTCGCTTCCAAGGT	*bla*$_{NDM}$	475	Deshpande et al., (34)
NDM-R	GTAGTGCTCAGTGTCGGCAT			

Table 2: Distribution of participants with respect to gender demographics across hospital departments/units

Department/unit	Gender		Total (%)
	Male (%)	Female (%)	
Social Works	6	6	12
Medical Laboratory Science	4	7	11
Surgery	4	6	10
Microbiology	3	5	8
Paediatric Infectious Disease	3	1	4
Laundry	5	3	8
Parasitology	2	3	5
Male Medical Ward	3	2	5
Female Medical Ward	-	1	1
Tailoring	-	4	4
Medical Records	6	11	17
Assessment Department	1	1	2
General Outpatient Department	-	5	5
Orthopaedics and Trauma	-	1	1
Pharmacy	-	2	2
Cash unit	-	2	2
General Ward	5	7	12
Accident and Emergency	3	9	12
Total	**45 (37.2)**	**76(62.8)**	**121 (100.0)**

Table 3: Distribution of participants with respect to categories of healthcare works across hospital departments/units

Department/unit	Categories of healthcare workers					Total (%)
	Doctor	Nurse	Pharmacists/ technicians	Other health workers	Students	
Social Works	-	-	-	11	1	12
Medical Laboratory Science	5	-	-	6	-	11
Surgery	-	8	-	2	-	10
Microbiology	-	-	-	8	-	8
Paediatric Infectious Disease	-	-	-	4	-	4
Laundry	-	-	-	8	-	8
Parasitology	-	-	-	5	-	5
Male Medical ward	-	2	-	1	2	5
Female Medical ward	-	1	-	-	-	1
Tailoring	-	-	-	4	-	4
Medical Records	-	-	-	12	5	17
Assessment Department	-	-	-	2	-	2
General Outpatient Department	-	2	2	1	-	5
Orthopaedics and Trauma	-	-	-	1	-	1
Pharmacy	-	-	2		-	2
Cash unit	-	-	-	2	-	2
General Ward	-	-	-	8	4	12
Accident and Emergency	3	3	-	6	-	12
Total	**8 (6.6)**	**16 (13.2)**	**4 (3.3)**	**81 (66.9)**	**12 (9.9)**	**121 (100.0)**

Table 4: Frequency of bacterial isolates from mobile phones of healthcare workers

Bacterial species	No of bacterial isolates	Percentage
Staphylococcus aureus	49	50.5
Coagulase negative staphylococci	16	16.5
Escherichia coli	14	14.4
Pseudomonas aeruginosa	7	7.2
Klebsiella pneumoniae	8	8.3
Klebsiella oxytoca	3	3.1
Total	**97**	**100.0**

Isolation/identification of bacterial isolates:

Swab samples were positive for bacterial growth from mobile phones of 72 (59.5%) participants. Ninety-seven bacteria were isolated from these, including 65 (67.0%) Gram-positive isolates and 32 (33.0%) Gram-negative isolates.

Staphylococcus aureus was the most frequent isolate (n=49, 50.5%) followed by coagulase-negative staphylococci (n=16, 16.5%). Others include *E. coli* (n=14, 14.4%), *K. pneumoniae* (n=8, 8.3%), *P. aeruginosa* (n=7, 7.2%) and *K. oxytoca* (n=3, 3.1%) (Table 4).

Antibiotic resistance profiles of bacterial isolates:

Table 5 shows the antibiotic resistance profiles of bacterial isolates obtained from the mobile phones of the healthcare workers and medical students. *S. aureus* was resistant to both azithromycin (63.3%) and ceftazidime (69.4%) but sensitive to imipenem.

Carbapenem resistance (resistance to imipenem and meropenem) was observed in 28.6% (2/7) of *P. aeruginosa*, 25.0% (2/8) of *K. pneumoniae* and 33.3% (1/3) of *K. oxytoca*. *E. coli* species were sensitive to meropenem, ceftazidime, and cefepime. Coagulase-negative staphylococci isolates exhibited the highest resistance to ceftazidime (75%), while *P. aeruginosa* exhibited the highest resistance to aztreonam and amoxicillin/clavulanic acid.

The antibiotic resistance profiles of the multidrug-resistant bacterial isolates from the mobile phones of the healthcare workers and students are displayed in Table 6. Each isolate displays a unique resistance profile, indicating varying levels of multidrug resistance. The frequency of MDR was significantly higher among Gram-negative bacterial isolates (19/32, 59.4%) than among Gram-positive bacterial isolates (24/65, 36.9%) (OR=2.5, 95%CI= 1.1-5.9, p=0.05).

Table 5: Antibiotic resistance of bacterial isolates from mobile phones of healthcare workers and students

Antibiotics	***S. aureus* (n=49)**	**CoNS (n=16)**	***E. coli* (n=14)**	***P. aeruginosa* (n=7)**	***K. pneumoniae* (n=8)**	***K. oxytoca* (n=3)**
Imipenem	-	1 (6.3)	-	2 (28.6)	2 (25.0)	1 (33.3)
Cefepime	14 (28.6)	4 (25.0)	-	2 (28.6)	3 (37.5)	1 (33.3)
Augmentin	5 (10.2)	3 (18.8)	9 (64.3)	6 (85.7)	4 (50.0)	2 (66.7)
Amikacin	1 (2.1)	3 (18.8)	2 (14.3)	3 (42.9)	2 (25.0)	1 (33.3)
Azithromycin	31 (63.3)	10 (62.5)	ND	ND	ND	ND
Meropenem	3 (6.1)	1 (6.3)	-	2 (28.6)	2 (25.0)	1 (33.3)
Ceftazidime	34 (69.4)	12 (75.0)	-	3 (42.9)	1 (12.5)	-
Cefotaxime	8 (16.3)	4 (25.0)	3 (21.4)	2 (28.6)	4 (50.0)	2 (66.7)
Ciprofloxacin	7 (14.3)	6 (37.5)	4 (28.6)	4 (57.1)	5 (62.5)	1 (33.3)
Cefoxitin	10 (20.4)	4 (25.0)	10 (71.4)	6 (85.7)	7 (87.5)	3 (100.0)
Cephalexin	26 (53.1)	12 (75.0)	13 (92.9)	7 (100.0)	7 (87.5)	3 (100.0)
Aztreonam	ND	ND	4 (28.6)	4 (57.1)	4 (50.0)	1 (33.3)

ND- Not determined; CoNS-Coagulase-negative staphylococci

Phenotypic and molecular detection of MBL genes:

The result of phenotypic and molecular detection of MBL genes in 5 carbapenem-resistant Gram-negative bacterial isolates is shown in Table 7. Among the Gram-negative bacterial isolates, MBL enzyme was detected in 15.6% (5/32). The *bla*$_{VIM}$ MBL gene was detected in 6.3% (2/32) (Fig 1), while *bla*$_{IMP}$ and *bla*$_{NDM}$ were not detected in any isolate.

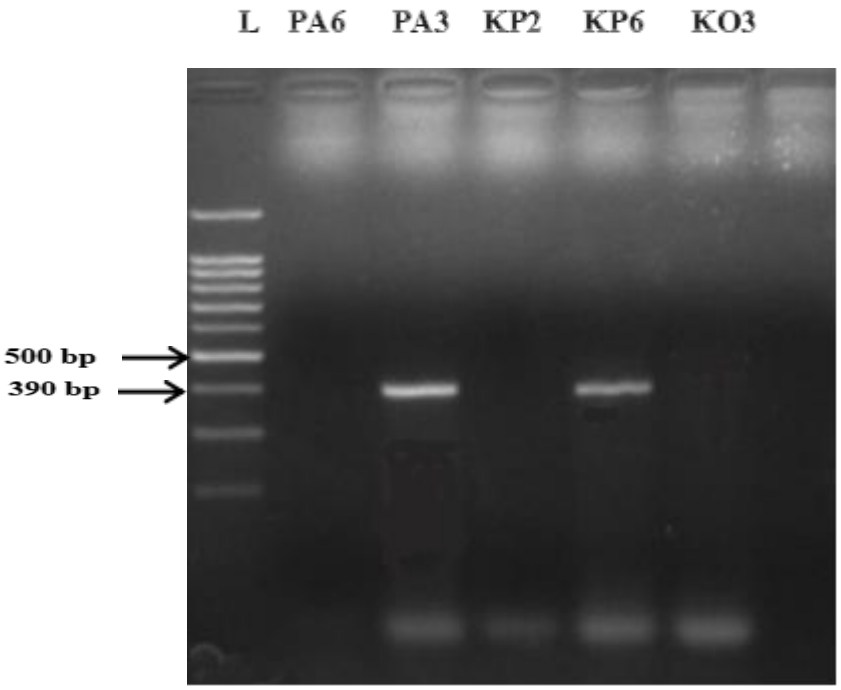
Table 6: Multidrug resistance profiles of bacterial isolates from mobile phones of healthcare workers

Category	**Isolate types**	**No of isolates**	**No of MDR isolates**	**% MDR isolates**
Gram-positive	*Staphylococcus aureus*	49	18	36.7
	Coagulase-negative staphylococci	16	6	37.5
Subtotal		**65**	**24**	**36.9**
Gram-negative	*Pseudomonas aeruginosa*	7	6	85.7
	Escherichia coli	14	6	42.9
	Klebsiella oxytoca	3	2	66.7
	Klebsiella pneumoniae	8	5	62.5
Subtotal		**32**	**19**	**59.4**
Overall Total		**97**	**43**	**44.3**

Table 7: Phenotypic and molecular detection of MBLs in carbapenem-resistant Gram-negative isolates

Isolates	**Phenotypic MBL (zone of inhibition in mm)**				**MBL genes**		
	IMP	**IMP+EDTA**	**MEM**	**MEM+EDTA**	***bla*$_{IMP}$**	***bla*$_{VIM}$**	***bla*$_{NDM}$**
P. aeruginosa (PA3)	10	32	8	28	-	+	-
P. aeruginosa (PA6)	0	29	0	26	-	-	-
K. pneumoniae (KP2)	8	32	0	28	-	-	-
K. pneumoniae (KP6)	8	30	0	28	-	+	-
K. oxytoca (KO3)	0	28	0	27	-	-	-

IMP-imipenem; MEM-meropenem; EDTA: Ethylene diamine tetra-acetic acid; MBL-metallo-β-lactamase



L = 100 bp ladder; PA3 = *P. aeruginosa*; PA6 = P. *aeruginosa*; KP2 = *K. pneumoniae*; KP6 = *K. pneumoniae*; KO3 = *K. oxytoca*

Fig 1: Amplification of *bla*$_{VIM}$ genes in Gram-negative bacteria

Discussion:

Mobile phones of healthcare workers are potential sources of nosocomial infections as they are extremely susceptible to pathogenic bacteria in healthcare settings (5, 36). Contaminated hands of HCWs play a significant role in the spread of HAIs (15). The prevalence of bacterial contaminants on mobile phones was 59.5% in this study, which is lower than 80.0% and 94.6% reported in other Nigerian studies (12,37), but comparable to the study of Akinyemi et al., (18) who reported a prevalence of 62.0%. In a study conducted in Ghana, Olu-Taiwo et al., (17) reported an overall prevalence of 83.3% of bacterial contaminants on mobile phones.

This study identified *S. aureus,* coagulase-negative staphylococci*, E. coli, P. aeruginosa, K. pneumoniae,* and *K. oxytoca* in swab samples from mobile phones. Other studies have reported the presence of these bacterial pathogens including *Enterobacter* species, *Acinetobacter baumannii, Bacillus* species, *Streptococcus* species and *Proteus* species (12,16,17). *S. aureus* was the most frequent isolate (50.5%), followed by coagulase-negative staphylococci (16.5%) in our study, similar to other studies in Nigeria that have reported *S. aureus* to be the most frequent isolate (5,37), but differ from Nwankwo et al., (12) who reported *S. epidermidis* to be the most frequent bacterial isolate.

The most important health challenge in treating patients is pathogen resistance to multiple antibiotics (38). In this study, 36.9% and 59.4% of Gram-positive and Gram-negative bacteria respectively, were resistant to three or more classes of antibiotics. This demonstrates that unless essential norms and controls for phone usage and disinfection in healthcare settings are enforced, mobile devices will worsen the burden of nosocomial infections caused by antimicrobial resistant pathogens (5). The overall prevalence of multi drug resistance among the isolates in this study was 43.3%. This contrasts the study by Bodena et al., (15), who reported higher levels of multidrug resistance. In our study, *S. aureus* and CoNS were susceptible to imipenem and amikacin but resistant to ceftazidime, cephalexin, and azithromycin. *P. aeruginosa* and *K. pneumoniae* were resistant to amoxicillin-clavulanate, ciprofloxacin, cefoxitin, cephalexin, and aztreonam. Nwankwo et al., (12) also reported a high level of antibiotic resistance of *P. aeruginosa* isolates from the mobile phones of health workers.

Among the several mechanisms of carbapenem resistance, the production of MBL is of great significance due to its strong carbapenem hydrolyzing capacity, ability to hydrolyze all beta-lactam antibiotics except aztreonam, and resistance to beta-lactamase inhibitors (39). Although the carriage of carbapenem-resistance gene among Gram-negative isolates was low (6.3%) in our study, it is of great concern considering that it is a 'last-

resort' antibiotic and the likelihood of transmission from healthcare personnel to susceptible patients in the hospital and vulnerable people in the community. This is because MBL-encoding genes are typically found on mobile genetic elements that also carry genes that encode resistance to other antibiotics, leading to multidrug resistance (40).

There have been reports of *bla*$_{VIM}$ and *bla*$_{NDM}$ in Gram-negative bacteria isolated from patients' samples in Nigeria (21), and from environmental contexts (41), but no reports of *bla*$_{VIM}$ and *bla*$_{NDM}$ in mobile phone isolates. To the best of our knowledge, this is the first report of *bla*$_{VIM}$ in Gram-negative bacterial isolates recovered from mobile phones of Nigerian healthcare personnel.

Conclusion:

Our findings revealed the presence of the carbapenem-resistant gene (*bla*$_{VIM}$) in Gram-negative isolates on healthcare workers' mobile phones and the extensive contamination of these phones with various bacterial pathogens linked to nosocomial infections in healthcare facilities. This study emphasizes the significance of mobile phones as a reservoir for bacteria containing clinically significant antibiotic-resistant genes.

To mitigate the risk of cross-contamination and the spread of resistant pathogens, implementing routine cleaning protocols can help ensure that these devices do not contribute to healthcare-associated infections.

Contributions of authors:

FOB and FTI were involved in collection and processing of data; FOB, AOM and OOB were involved in analysis of data and interpretation of results; FOB, FTI, AOM, and OOB were involved in manuscript writing. All authors approved the final manuscript submitted for publication.

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Conflict of interest

No conflict of interest is declared

References:

1. Benenson, S., Cohen, M. J., Schwartz, C., Revva, M., and Levin, P. D. Is it financially beneficial for hospitals to prevent nosocomial infections? BMC Health Serv Res. 2020; 20: 653 doi: 10.1186/s12913-020-05428-7.
2. Sikora, A., and Zahra, F. Nosocomial Infections. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. 2023. https://www.ncbi.nlm.nih.gov/books/NBK559312/
3. World Health Organization. WHO launches first-ever global report on infection prevention and control. https://www.who.int/news/item/06-05-2022-who-launches-first-ever-global-report-on-infection-prevention-and-control (Accessed July 9, 2023)
4. Tagoe, D., Gyande, V., and Ansah, E. Bacterial contamination of mobile phones: when your mobile phone could transmit more than just a call. Webmed Central. 2011; 2 (10): 2011 doi:10.9754/journal.wmc.2011.002294
5. Eze, J. C., Agbo, J. A., Ugwuanyi, D. C., et al. Mobile Phones as a Source of Nosocomial Infection in the Radiology Department of a Teaching Hospital. J Health Med Sci. 2022; 5 (2): 118-123. https://doi.org/10.31014/AIOR.1994.05.02.221
6. Brady, R. R., Verran, J., Damani, N. N., and Gibb, A. P. Review of mobile communication devices as potential reservoirs of nosocomial pathogens. J Hosp Infect. 2009; 71(4): 295–300. doi: 10.1016/j.jhin.2008.12.009
7. Olsen, M., Campos, M., Lohning, A., et al. Mobile phones represent a pathway for microbial transmission: a scoping review. Travel Med Infect Dis. 2020; 35: 101704. doi: 10.1016/j.tmaid.2020.101704.
8. Chang, C. H., Chen, S. Y., Lu, J. J., Chang, C. J., Chang, Y., and Hsieh, P. H. Nasal colonization and bacterial contamination of mobile phones carried by medical staff in the operating room. PLoS One. 2017; 12(5): e0175811. doi: 10.1371/journal.pone.0175811.
9. Aungst, T. D. Medical applications for pharmacists using mobile devices. Ann Pharmacother. 2013; 47(7–8): 1088–1095. doi: 10.1345/aph.1S035.
10. Ventola, C. L. Mobile devices and apps for health care professionals: uses and benefits. Pharm Therap 2014; 39(5): 356-364.
11. O'Neill, K. M., Holmer, H., Greenberg, S. L., and Meara, J. G. Applying surgical apps: Smartphone and tablet apps prove useful in clinical practice. Bull Am Coll Surg. 2013; 98 (11): 10–18.
12. Nwankwo, E. O., Ekwunife, N., and Mofolorunsho, K. C. Nosocomial pathogens associated with the mobile phones of healthcare workers in a hospital in Anyigba, Kogi state, Nig J Epidemiol Glob Health. 2014; 4 (2): 135-140. doi: 10.1016/j.jegh.2013.11.002.
13. Kuriyama, A., Fujii, H., Hotta, A., Asanuma, R., and Irie, H. Prevalence of bacterial contamination of touchscreens and posterior surfaces of smartphones owned by healthcare workers: a cross-sectional study. BMC Infect Dis. 2021; 21: 681. https://doi.org/10.1186/s12879-021-06379-y
14. Singh, A. and Purohit, B. Mobile phones in hospital settings: a serious threat to infection. Occup Health Saf. 2014; 81(3): 42–44.
15. Bodena, D., Teklemariam, Z., Balakrishnan, S., and Tesfa, T. Bacterial contamination of mobile phones of health professionals in Eastern Ethiopia: antimicrobial susceptibility and associated factors. Trop Med Health. 2019; 47: 15. doi: 10.1186/s41182-019-0144-y.
16. Lubwama, M., Kateete, D. P., Ayazika, K. T., et al. Microbiological Contamination of Mobile Phones and Mobile Phone Hygiene of Final-Year Medical Students in Uganda: A Need for Educational Intervention. Adv Med Educ Pract. 2021; 12: 1247-1257. doi: 10.2147/AMEP.S333223.
17. Olu-Taiwo, M., Laryea, C. A., Mykels, D. K., and Forson, A. O. Multidrug-Resistant Bacteria on the Mobile Phones and Computer Keyboards of Healthcare University Students in Ghana. Canadian J Infect Dis Med Microbiol. 2021; 1-8. doi: 10.1155/2021/6647959.
18. Akinyemi, K. O., Atapu, A. D., Adetona, O. O., and Coker, A. D. The potential role of mobile phones in the spread of bacterial infections. J Infect Dev Countries. 2009; 3: 628-632. doi: 10.3855/jidc.556.

19. Walsh, T. R., Toleman, M. A., Poirel, L., and Nordmann, P. Metallo-ß-lactamases: the quiet before the storm? Clin Microbiol Rev. 2005; 18: 306–325. doi: 10.1128/CMR.18.2.306-325.2005
20. Behera, B., Mathur, P., Das, A., Kapil, A., and Sharma, V. An evaluation of four different phenotypic techniques for detection of metallo-beta-lactamase producing *Pseudomonas aeruginosa*. Indian J Med Microbiol. 2008; 26: 233–237. doi: 10.4103/0255-0857.39587.
21. Olaniran, O. B., Adeleke, O. E., Donia, A., Shahid, R., and Bokhari, H. Incidence and Molecular Characterization of Carbapenemase Genes in Association with Multidrug-Resistant Clinical Isola- tes of *Pseudomonas aeruginosa* from Tertiary Healthcare Facilities in Southwest Nigeria. Curr Microbiol. 2021; 79 (1): 27. doi: 10.1007/s00284-021-02706-3.
22. Deshmukh, D. G., Damle, A. S., Bajaj, J. K., Bhakre, J. B., and Patwardhan, N. S. Metallo-β-lactamase-producing clinical isolates from patient of a tertiary care hospital. J Lab Physicians. 2011; 3(2):93-97. doi: 10.4103/0974-2727.86841.
23. Shrestha, A., Acharya, J., Amatya, J., Paudyal, R., and Rijal, N. Detection of Beta-Lactamases (ESBL and MBL) Producing Gram-Negative Pathogens in National Public Health Laboratory of Nepal. Int J Microbiol. 2022; 1-7. doi: 10.1155/2022/5474388.
24. Kaur, A., Gupta, V., and Chhina, D. Prevalence of metallo- β-lactamase-producing (MBL) *Acinetobacter* species in a tertiary care hospital. Iranian J Microbiol. 2014; 6 (1): 22-25.
25. Olu-Taiwo, M. A., Opintan, J. A., Codjoe, F. S., and Forson A. O. Metallo-Beta-Lactamase-Producing *Acinetobacter* spp. from Clinical Isolates at a Tertiary Care Hospital in Ghana. BioMed Res Int. 2020; 3852419. doi: 10.1155/2020/3852419.
26. Wang, W., and Wang, X. Prevalence of Metallo-β-lactamase genes among *Pseudomonas aeruginosa* isolated from various clinical samples in China. J Lab Med. 2020; 44(4): 197-203. https://doi.org/10.1515/labmed-2019-0162
27. Rameshkumar, G., Dhandapani, R., Lalitha, P., et al. Prevalence and Molecular Characterization of Metallo β-Lactamase Producing Gram-Negative Pathogens Causing Eye Infections. Front Publ Health. 2022; 10: 870354. https://doi.org/10.3389/fpubh.2022.870354
28. Cheesbrough M. District Laboratory Practice in Tropical Countries, Part II, 2nd edition. New York, NY: Cambridge University Press. 2006; 112–113.
29. Bauer, A. W., Kirby, W. M., Sherris, J. C., and Turck, M. Antibiotic susceptibility testing by a standardized single disk method. Am J Clin Pathol. 1966; 45(4): 493-496.
30. Clinical and Laboratory Standards Institute (CLSI). Performance Standards for Antimicrobial Susceptibility Testing, M100, 2021 Edition.
31. Ranjan, S., Banashankari, G. S., Sreenivasa B. and Babu, P. R. Evaluation of phenotypic tests and screening markers for detection of metallo β lactamases in clinical isolates of *Pseudomonas aeruginosa:* A prospective study. Med J DY Patil Univ. 2015; 8: 599-605. doi: 10.4103/0975-2870.164977
32. Diagbouga, S., Salah, F. D., Sadji, A. Y., et al. Detection of High Prevalence of TEM/SHV/CTX-M Genes in ESBL Producing and Multidrug Resistant *Klebsiella pneumoniae* and *Klebsiella oxytoca*. J Clin Diagn Res. 2016; 4:130. doi: 10.4172/2376-0311.1000130.
33. Ellington, M. J., Kistler, J., Livermore, D. M., and Woodford, N. Multiplex PCR for rapid detection of genes encoding acquired metallo-β-lactamases. Antimicrob Chemother. 2007; 59: 321–322. doi:10.1093/jac/dkl48
34. Deshpande, P., Rodrigues, C., Shetty, A., Kapadia, F., Hedge, A., and Soman, R. New Delhi Metallo-beta-lactamase (NDM-1) in Enterobacteriaceae: treatment options with carbapenems compromised. J Assoc Physicians India. 2010; 58: 147-149.
35. Poirel, L., Revathi, G., Bernabeu, S., and Nordmann, P. Detection of NDM-1-producing *Klebsiella pneumoniae* in Kenya. Antimicrob Agents Chemother. 2011; 55: 934–936. doi: 10.1128/AAC.01247-10
36. Ayalew, W., Mulu, W., and Biadglegne, F. Bacterial contamination and antibiogram of isolates from health care workers' fomites at Felege Hiwot Referral Hospital, northwest Ethiopia. Ethiop J Health Dev. 2019; 33: 128–141. doi: 10.1128/AAC.01247-10
37. Kawo, A. H., and Musa, A. M. Enumeration, Isolation and antibiotic susceptibility profile of bacteria associated with mobile cellphones in a university environment. Nig J Basic Applied Sci. 2023; 21 (1): 39-44. doi: 10.4314/njbas.v21i1.6
38. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States. Atlanta: CDC; 2013: 2013.
39. Cornaglia, G., Giamarellou, H., and Rossolini, G. M. Metallo-beta-lactamases: a last frontier for beta-lactams? The Lancet Infect Dis. 2011; 11: 381–393. doi: 10.1016/S1473-3099(11)70056-1
40. Walsh, T. R. Clinically significant carbapenemases: an update. Curr Opin Infect Dis. 2008; 21: 367–371. doi: 10.1097/QCO.0b013e328303670b
41. Adelowo, O. O., Vollmers, J., Mäusezahl, I., Kaster, A. K., and Müller, J. A. Detection of the carbapenemase gene bla_{VIM-5} in members of the *Pseudomonas putida* group isolated from polluted Nigerian wetlands. Sci Rep. 2018; 8(1): 15116. https://doi.org/10.1038/s41598-018-33535-3