FULafia Journal of Science & Technology
ISSN (print) 2449-0954 \ ISSN (online) 2636-4972
https://lafiascijournals.org.ng/index.php/fjst
Sponsored By TETFUND TERTIARY EDUCATION TRUST FUND
Manuscript => Received: Oct., 2025; Accepted: Dec., 2025; Published: Dec., 2025 https://doi.org/10.62050/fjst2025.v10n1.669

PREVALENCE OF CARBAPENEM-RESISTANT AND METALLO-BETA-LACTAMASES PRODUCING GRAM-NEGATIVE BACTERIAL FROM CLINICAL SAMPLES IN NIGERIA: A SYSTEMATIC REVIEW

Profit Igba[1]*, Ngwai, Yakubu Boyi[2], Ishaleku David[2], Nkene Istifanus Haruna[2], Owuna Jibril Egwu[2], Akatu Simon Adogwu[2] and Igwe James Chibueze[3]
[1]*Department of Microbiology, Ave Maria University Piyanko, Nasarawa State, Nigeria*
[2]*Department of Microbiology, Nasarawa State University, Keffi, Nigeria*
[3]*Department of Pharmaceutical Microbiology and Biotechnology, Kaduna State University, Nigeria*
*Corresponding email: igbaprofit@gmail.com

ABSTRACT
Carbapenem is a class of antimicrobial agent reserved for infections cause by multidrug-resistant microorganisms. This review, using a public health focused approach, aimed to understand and describe the current status of CR in Nigeria in relation to common causes of infections and drugs recommended in WHO treatment guidelines. Assessment of the prevalence of Carbapenemase-resistance Gram-negative bacteria is necessary in Nigeria. This article reviewed the previously published literature on the Prevalence of Carbapenemase-resistance Gram-negative bacteria. There were 100 % isolation of Gram-negative bacteria such as *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeroginosa*, *Shigella* spp., *Salmonella spp. Citrobacter* spp., *Proteus* spp., *Serratia* spp., *Enterobacter* spp., *Morganella morganii, Providenciae* spp. and *Acinetobacter baumanii* in all the studies reviewed. Veronna integrin-encoded, New Delhi methallo, New Delhi methallo-1, New Delhi methallo-5, *Klebsiella pneumoniae* Carbapenemase, Guiana extended-spectrum beta-lactamase, Oxacillinases-48, Oxacillinases-181, Dhahran Hospital in Saudi Arabia b-lactamase were some of resistance mediated genes observed in some of studies in Nigeria. Exhaustive search for recent articles (2011–2024) was conducted using PubMed, Google search engine, AJOL and other relevant databases in accordance with the PRISMA guidelines. Article retrieval and screening were done using a structured search string and strict inclusion/exclusion criteria. Carbapenem-resistant in Gram-negative bacteria is a clear and present danger in Nigeria, which needs strong surveillance to curb this menace. Public health departments must monitor carbapenem resistant isolates.

Keywords: Carbapenem-resistant, Gram-negative bacteria, Resistant genes, Systematic review

INTRODUCTION
Antimicrobial therapy is threatened by the global rise of resistance, especially in Gram negative bacteria. Of all the agents in the antimicrobial arsenal available to humans, Carbapenems are considered to be the most potent beta-lactam and have the widest spectrum of activity (Uzoamaka *et al.*, 2024). They are used for the treatment of suspected or proven multi drug resistant severe bacterial infections (Aliyu *et al.*, 2020). They include imipenem, meropenem, ertapenem and doripenem. Several studies have shown Carbapenems to demonstrate broad spectrum activity against Gram positive and negative, aerobic and anaerobic clinically important bacteria; time dependent killing and rapid bactericidal effect (Emmanuel *et al.*, 2021; Iduh *et al.*, 2020, Nuhu *et al.*, 2021; Olowo-okere *et al.*, 2020; Uzoamaka *et al.*, 2024). The mechanism of action of this class of antibiotic (Carbapenems) acts on the bacteria by binding to the penicillin binding proteins (PBP) and disrupt cell wall synthesis while resistance to it erupt by production/acquisition of carbapenemase enzymes (Egbule *et al.*, 2020).

Carbapenemases are diverse group of Beta lactamases produced by Gram negative rods. Gram negative bacteria have developed a variety of resistance mechanisms to the beta-lactams including hydrolysis of beta-lactam ring by beta-lactamases, alteration in the penicillin-binding proteins, decrease in outer membrane permeability and expression of efflux pumps. These diverse mechanisms of resistance developed by Gram negative bacteria prompts them into resistant to various categories of *β*-lactam antibiotics such as cephalosporins, monobactams, and carbapenems. Therefore, disregard for early screening for Carbapenem-Resistance-producing organisms will have tremendous consequences including therapy failure, laboratories detection, and infection control issues (Yahaya *et al.*, 2015; Mukail *et al.*, 2019).

Carbapenems evade most lactamases but are hydrolyzed by metallo-betalactamases (MBLs), *Klebsiella pneumonia* carbapenemases (KPC) and OXA-48-like groups, respectively. MBLs are classified as class B and are divided into three main groups of enzymes [active on imipenem (IMP), Verona integron-encoded metallo-betalactamases (VIM), and New Delhi metallo-betalactamases (NDM) (Aliyu *et al.*, 2021).

The carbapenem resistance infections, especially those causes by Gram-negative bacteria are emerging, raising valid concerns that we may reached the end of the antibiotics pipelines. Carbapenem-resistant gram

negative organism are extremely virulent organism exhibiting resistance to carbapenems and most, if not all, of the other classes of antibiotics available today. As a result, they have been associated with high mortality rate (Nuhu *et al.*, 2021; Adesola *et al.*, 2023). In 2017 study by Tamma *et al.* (2017), 32% of patient with carbapenems resistant Gram negative bloodstream infections dies within 14 days of hospitalization. Therefore, the aim of this study is to review published articles on the prevalence of Carbapenems-resistance in Nigeria.

MATERIALS AND METHODS

Search Strategies

PubMed, Science Daily, the Cochrane Database for Systematic Reviews, African Journals Online Library and Free-text Web Searches using Google Scholar were searched for articles published in English from 2011 to 2024 June. Reference lists of relevant articles were checked for additional titles for inclusion in the review. Key words used for the search were "Carbapenem-Resistance Prevalence", "Gram-Negative bacteria", "Nigeria", Clinical samples, phenotypic and molecular detection of Carbapenem resistance and Enterobacteriaceae. The review was performed using the preferred reporting items for systematic review and Meta-analysis (PRISMA) statement.

Inclusion and Exclusion Criteria

The original published articles on the prevalence of Carbapenem-resistant strains of Gram-Negative bacteria from hospital acquired infections in Nigeria were considered. Before an article will be considered useful to this study include, phenotypic screening and molecular analysis screening, its antibiotic susceptibility testing should use reference standard methods and recommendations by the Clinical and Laboratory Standards Institute (CLSI) for drug susceptibility testing of Gram-negative bacteria against most commonly used antimicrobial agents, Carbapenem resistance detection. Due to the following reasons, some studies were excluded from this studies; articles not following CLSI recommended drug susceptibility testing methods, case reports, meta analyses or systematic reviews, letters to editor, review articles, non-English, duplicate publication and without these relevant database that listed the variables; author, year of study, location of study, methods of identification, commonest microorganism isolated.

Data Synthesis

Data extraction was done using a predesigned and pretested database, developed for the purposes of this review, using the PRISMA statement. Information extracted included article information (first author, year of publication, and country), study design (hospital acquired number of specimens collected), Gram-negative bacteria identification and antimicrobial susceptibility testing methodology, and Carbapepenem resistance data.

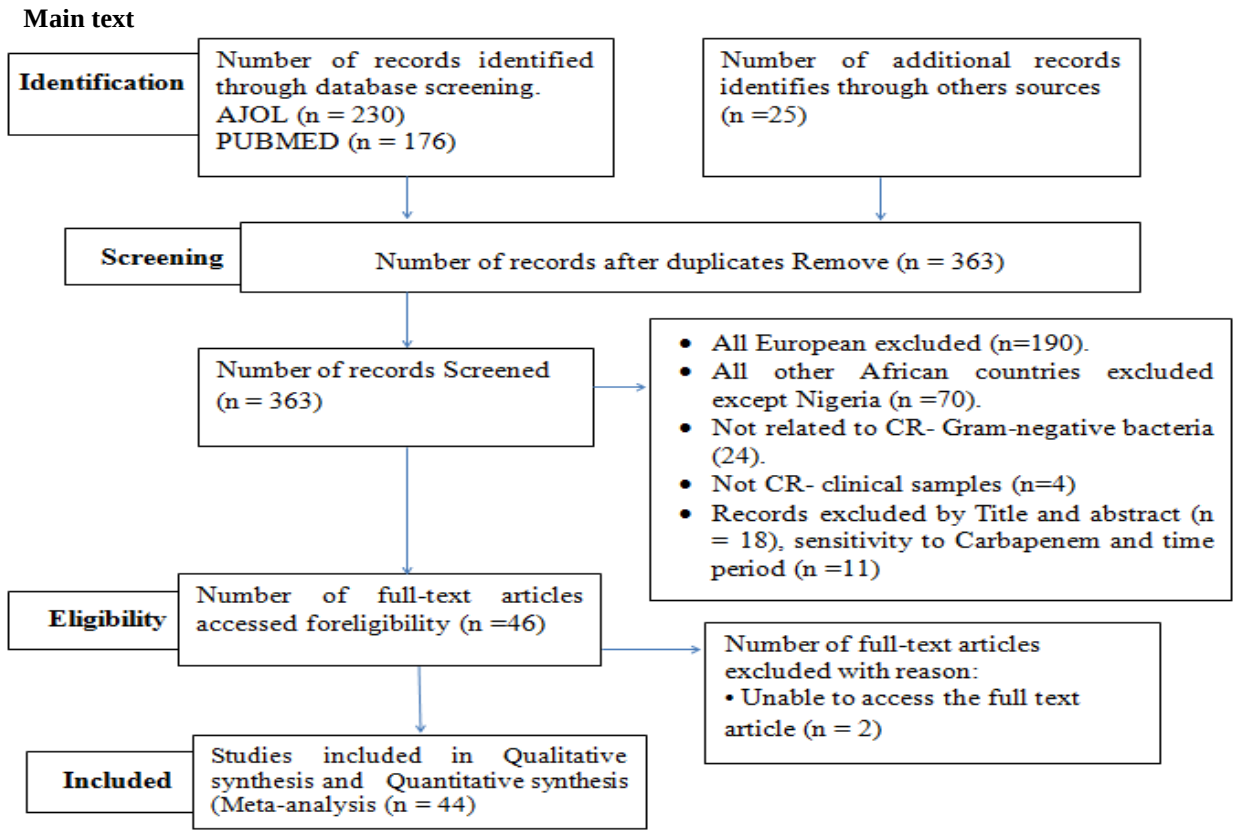

Figure 1: Systematic review and meta-analysis

Table 1: Bacteria most evaluated organism with most carbapenem resistance gene

Author (s)	Location of study	Sample size	Method of identification	Commonest *Gram-negative organism*/identified/%	Type of samples	Carbapenems Resistance (%)	Genes
Abdu *et al.* (2019)	Bayelsa	153	PCR	*E. coli* (25.3%), *Klebsiella* spp, (14.1%), *Proteus*spp, (3%), *Ps. aeruginosa* (37.4%).	Urine, Wound swabs, Endocervical swabs, High vaginal swabs, Throat swabs, Eye swab and Ear swabs	50.0%	VIM, NDM
Abdullahi *et al.* (2017)	Kano	500	MHT/PCR	*E. coli* (37.4%), *Klebsiella* spp, (26%), K. oxytoca (0.6%) *P. mirabilis (17.4%), P. vulgaris (5.8%), Ps. aeruginosa (11.2%), S. paratyphi (0.4%), S. typhi (1.2%)*	Blood, urine, catheter tip	32.4%	NDM-1
Abiola *et al.* (2013)	Ibadan,	NR	MHT/PCR	*Acinetobacter baumannii* (60.0%).	Clinical isolates	60.0%	blaOXA-23,
Adebola *et al. (*2019)	Port-Harcourt	300	Phenotypic screening	K. *pneumonia (40.7%), E. coli (57.8%)*	Urine	41.4%	NR
Adesola *et al.* (2020)	Lagos	175	PCR	*K. pneumonia (35.4%), E. coli (64.6%)*	Clinical isolates	27.4%	NDM, OXA-181,
Adesola *et al.* (2022)	Lagos	123	PCR	*Pseudomonas aeruginosa*	Wound, urine, surgical swab, ear swab, sputum,vaginal swab	89%	VIM-2, VIM-5, bla-NDM-1
Akinduti *et al.* (2012)	Abeokuta,	426	MHT	*Klebsiella spp, Pseudomonas spp* and *Proteus spp, Salmonella spp, Citrobacter freundii, Enterobacter cloacae,*	Stool	3.3%	NR
Aliyu *et al.* (2021)	Kano	190	MHT/PCR	*K. pneumonia (3.9%), K. ozaenea (2.6%), K. oxytoca (2.6%), Salmonella spp. (2.6%), E. coli (44.7%), Proteus Mirabilis (5.3%), Enterobacter aerogenes (3.9%), Proteus Vulgaris (2.6%), Citrobacter freundii (2.6%), Enterobacter agglomerans (2.6%), Enterobacter cloacae and Serratia odorifera (1.3%),,*	Urine, blood, sputum, tracheal aspirate, and swab	9.2%	VIM , NDM, KPC
Anibijuwon *et al.* (2018)	Ilorin	300	Phenotypic screening	*E. coli (52.5%), Enterobacter (23.8%), Klebsiella (10.2%) Proteus (13.6)*	Blood and urine	7.7%	NR
Ayorinde *et al.* (2021)	Ibadan	141	PCR	*K. pneumonia, K. quasipneumoniae, Acinetobacter baumannii, Ps. aeruginosa*	Blood, urine, stool, throat, rectal, oculat swab	8.5%	OXA-48, NDM-1,NDM-5
Brinkac *et al.* (2019)	Abuja	476	PCR	*Klebsiella spp*	blood	NR	NDM-5
Christiana *et al.* (2017)	Edo	218	Molecular Method	*Escherichia coli, Klebsiella Pneumonia, Enterobacter cloacae*	Endocervical swab, urine, Peritoneal Fluid, Unidentified source	22.2%	*bla*VIM, *bla*GES, *bla*NDM, *bla*OXA-181, and *bla*KPC*bla*OXA-48
Egbule *et al.* (2020)	Delta	84	MHT	*K.* pneumonia (75%)., *E. coli (36.7%), Ps. aeroginosa (37.5%)*	blood, urine, wound and stool	47.62%	NR
Ejikeugwu, *et al.* (2012)	Awka	79	Phenotypic screening	*E. coli* 3.8% and *K. pneumonia*, 7.6%	Urine	12.8%	NR
Emmanuel *et al.* (2021)	Makurdi	583	CM/MIC/ PCR/WGS	*K. pneumonia (51.8%), E. coli (48.2%),*	Stool, urine, environment, swab, liver	9.1%	OXA-1, DHA
Enwurum *et al.* (2011)	Lagos	60	CDDT & DDST	*E.coli* and *Klebspp,*	Clinical isolates	98.33%	NR
Glolabo *et al.* (2023)	Kogi	420	PCR	*Klebsiella pneumoniae*	Urine, blood,sputum, wound swabs, high vaginal swab, pus, stool, trachea aspirate, semen	7.0%	VIM (43%), OXA (28.9), IMP (22.7), NDM (17.2), KPC(13.3%), CMY (11.7%), FOX (9.4%).
Hussaini *et al.*(2020)	Zaria	150	MHT	*K.* pneumonia (12.67%), *E. coli (17.33%),*	Urine, wound swab, sputum	15.6%	NR
Iduh *et al.* (2020)	Sokoto	191	Phenotypic screening	K.spp, *E. coli, Pseudomona.* spp. *Salmonella* spp.	Stool	15.7%	NR
Ijeoma *et al.* (2020)	Anambara	187	MHT	*E. coli (*21.9%)	blood, urine, wound swab	11.23%	OXA-48 (6.4%), NDM (1.6%)
Isabella *et al.* (2021)	Yola	66	WGS	*Gram negative bacteria*	Clinical isolates	13.6%	OXA-10, OXA-1

Iregbu *et al.* (2022)	Abuja	218	MIC/PCR	*E. coli, Klebsiella*	Clinical isolates	12.5%	Bla (OXA-48,244,833 andd KPC),
Kabiru *et al.* (2021)	Lagos	127	MHT/PCR	K. pneumonia (34%)	Urine, blood, wound , stool, nasal swab abscesses	7.0%	NR
Lloduba *et al.* (2021)	Bayalsa	142	MHT/PCR	*K. pneumonia (10.6%),*	Swab samples	53%	NR
Magashi *et al.* (2012)	Kano	135	MHT	*K. pneumonia (16.7%), E. coli (12.5%) Proteus, spp (16.0%). And Serratia spp. (1.0%)*	Clinical isolates	14.0%	NR
Motayo *et al.* (2013)	Abeokuta	97	MHT	*K. pneumonia , E. coli*	Blood, urine, cerebrospinal fluid, genitals,	9.3%	NR
Muhabat *et al.* (2013)	Lagos	38	MIC/PCR	K. *pneumonia (31.4%), E. coli (42.2%) Proteus,* mirabilis (9.8%), *Enterobacter cloacae (3.9), Morganella morganii (1.9%), Citrobacter spp (1.0%).*	Urine, blood, skin, soft tissues, surgical site, tracheal, ear, body fluid.	3.7%	NR
Mukail *et al.* (2019)	Zaria	164	MHT	*K. oxytoca (14.0%), K. pneumoniae (12.8), K.ozaenae (1.2%), Enterobacteriaceae (72%).*	Urine (35.4%), sputum (26.2%), ear swab (17.1%), wound swab (13.4%), Vaginal swab (7.9%)	24%	NR
Nuhu *et al.* (2020)	Sokoto	576	PCR	*E. coli* (3.9%)	Vaginal swab, pus, urine, stool, aspirate, wound swab,	45.7%	NR
Odih *et al.* (2020)	Ibadan	86	PCR	A. baumannii	Clinical isolates	32.2%	blaNDM-1, blaOXA-23 (34.9%)
Oduyebo *et al.* (2015)	Lagos	177	Phenotypic screening	*K. pneumonia, K. oxytoca, K. ozaenae, E. coli, Enterobacter (agglomerans, aerogenes, cloacae), Proteus (mirabilis and vulgaris), Serratia rubidaea, Morganella morganii, Citrobacter freundi, Providencia rettgeri*	Urine (30.4%), blood (28.1%), sputum (8.3%), wound (21.2%), pus (11.9%)	12.4%	OXA-48, KPC
Ogbolu *et al.* (2014)	Osun	182	MIC/PCR	*Gram-negative bacteria*	Clinical isolates	5.5%	NDM, VIM, GES
Oladipo *et al.* (2021)	Osun	100	Phenotypic screening	*K. pneumoniae*	Clinical isolates	8.6%	NR
Olaniran *et al.* (2021)	southwest	430	PCR	*Ps. aureginosa*	Clinical isolates	56.2%	*bla*GES, *bla*NMC-A, *bla*BIC-1, *bla*SME, *bla*IMP, *bla*VIM, *bla*SPM, *bla*NDM, *bla*AIM, *bla*DIM, *bla*SIM, *bla*GIM, *bla*OXA-48, *bla*OXA-58
Olowo-Okere *et al.* (2019)	Sokoto	110	MIC	*Gram-negative bacteria*	High vaginal swab, sputum, stool, urine,wound	38.0%	NR
Olowo-Okere *et al.* (2020)	Sokoto	292	Modified Carba NP Test /MIC/ PCR	*K. pneumonia (n=28), E. coli (n=51), Proteus Mirabilis (14), Enterobacter cloacae (n=18)), Citrobacter freundii (n=10)), Morganella morganii (n=4), Providenciaerettgerii (n=1), Providenciaestuartii (n=3)*	Urine, sputum, stool, wound swab and ear swab	6.9%	NDM-5, OXA-181
Oluwafolajimi *et al.* (2020)	Ibadan	800	MHT	*K. pneumonia (33.3%),K.oxytoca (13.6%), E. coli (20.3%), Ps. aureginosa (17.5%) Proteus Mirabilis (6.8%), Enterobacter cloacae (1.7%),Acinetobacter baumanii (1.7%), Proteus Vulgaris (1.7%), Ps. luteola (1.1%),Morganella morganii (1.1%) Providencia spp. (0.6%)*	Urine (40.7%), wound(28.3%), sputum(7.3%), tracheal aspirate (9.0%), cartheter tip (4.40%), pleural fluid (3.4%), eye swab (2.3%), pus (1.7%), ear swab(1.1%), tissue biopsy (1.1%), rectal swab (0.6%)	22%	NR
Onipede *et al.* (2021)	Ile-Ife	144	Phenotypic screening	*Pseudomonas aeruginosa*	Clinical isolates	28.6%	VIM, NDM1, IMP.
Shuwaram *et al.* (2019)	Yola	1741	PCR	Gram-negative organism	Wound (21.8%), Sputum (10.9%),, stool (12.6%),, urine (46.2%), genital tract (6.0%), pleural aspirate (0.8%).	25.2%	*bla*NDM and *bla*VIM

Sulaiman *et al.* (2020)	Kano	540	Phenotypic screening	*Shigella* spp	Stool	40%	NR
Suwaiba *et al.* (2020)	Kaduna	350	PCR	*K. pneumonia (13%),E. coli (41.1%),*	Urine	1.4%	NR
Umar *et al.* (2018)	Sokoto	150	MIC	*Ps. aeruginosa* (36.7%).	Wound swab, ear swab	54.5%	NR
Umar *et al.* (2022)	Kano	348	Phenotypic screening	*K. pneumonia, E. coli , Proteus mirabilis, Proteus vulgaris, Ps. aeruginosa*	Urine, blood, wound, sputum, semen, vaginal swab	14.9%	NR
Uzoamaka *et al.* (2024)	Enugu	150	Phenotypic screening	*K. pneumonia (27.7%), E. coli (25.9%),*	urine	12.0%	NR
Yahaya *et al.* (2015)	Sokoto	225	MIC/ MHT/PCR	*K. pneumonia (32.4%), E. coli (27.1%), Citrobacter sedlakii (0.9%), Proteus mirabilis (8.0%), Serratia, marcescens (3.1%), Morganella morganii (5.3%), Enterobacter aerogenes (1.4%), Klebsiella mozaenae (1.4%), K. oxytoca (5.8%)*	Urine, blood, sputum, cerebrospinal fluid	10.2%	KPC (47.8%), VIM (8.7%), NDM-1(21.7%)
Yusuf *et al.* (2014)	Kano	633	MHT	*Proteus mirabilis (16.0%), Ps. aeruginosa* and *K. pneumonia (13.3%), and E. coli (11.5%).*	Urine, catheter tips, stool, semen, urogenitals, and abscesses	11.5%	NR
Yusuf *et al.* (2017)	Kano	248	MHT	*E. coli* and *K. pneumoniae.*	urine, catheter tips and wounds, and abscesses	38.7%	NR
Zubair *et al.* (2018)	Abuja	200	Phenotypic detection and PCR	*Pseudomonas aeruginosa*	Wound swab, ear swab, blood, urine, eye swab, sputum, nasal swab, bone tissue	2.5%	BlaVIM-1

MHT – Modified Hodge Test method, MIC – Minimum inhibitory Concentration, CM – Carbapenem inactivation method, PCR – Polymerase Chain Reaction, WGS – whole genome sequencing, Combined Disc Diffusion Test (CDDT), Double Disc Synergy Test (DDST), NR – Not Recorded, *Ps – Pseudomonas*

Data and Study Characteristics

In total, 463 articles were identified. Of those, 44 studies met the inclusion criteria and were included in the final analysis. Samples sizes were analyzed in all the selected studies. Percentage distribution of Carbapenem resistance in Nigeria were mostly from Northern Nigeria 19(43.3%), follow by Western 17(38.6%), Southern (6(14.3%) while the least percentage was in Eastern Nigeria region 2(4.6%). Articles published within a decade between January 2011 and June, 2024 was analyzed for this study. High percentages 56.8% (25/44) were published after 2020. Most of this studies review are primary samples with the prevalence of 75% (33/44) while 25% (11/44) were secondary samples (clinical isolates) . All the studies were published with susceptibility data and few of the studies reviewed, gave the prevalence of the clinical samples analyzed (Mukail *et al.,* 2019; Oluwafolajimi *et al.,* 2020; Shuwaram *et al.,* 2019).

Effect of method adopted and detection of Carbapenem resistance indicate high percentage 56.8% (25/44) of the studies used the phenotypic screening method for detection carbapenem resistance. Among the different studies, eight different methods used includes phenotypic screening of imipenem-meropenem disc test, minimum inhibitory concentration, modified Carba NP Test, modified Hodge Test method, Carbapenem inactivation method, PCR, WEG, susceptibility testing and two different interpretation guidelines were used (EUCAST, CSLI) in all the studies. Percentage isolation of Carbapenem resistance from different samples source were mostly with urine 17.2% (29/163), wound 12.3%(20/163) and blood 9.2%(15/163) and the percentage is from Skin 0.6%(1/163).

Among the Gram negative Bacteria, *E. coli, Klebsiella pneumoniae* and *Proteus mirabilis* were the most commonly investigated bacteria. Generally, other studies report the level of carbapenems- resistance base on individual bacteria. *Ps. aeruginosa* (89%) had the highest resistance profile to carbapenem, followed by *Acinetobacter baumannii* (60.0%), *E. coli* (45.7%), *Shigella* spp (40%) while the least was recorded among *Klebsiella pneumonia* (2.5%) in table 1 (Abiola *et al.,* 2013; Lloduba *et al.,* 2021; Sulaiman *et al.,* 2020; Umar *et al.,* 2018 and Nuhu *et al.,* 2020). the most prevalent Carbapenem resistance genes in Nigeria were NDM and VIM gene 13%(9/69). There were significant correlation between the phenotypic detection methods and molecular techniques used. However, the molecular techniques gave more reliable results than phenotypic tests.

RESULTS AND DISCUSSION

Antimicrobial resistance (AMR) especially caused by Metallo-*βeta*-lactamases (MBL) producing *K. pneumoniae* (MBL-Kp) has become a global public health concern. Globally, these isolates especially gram negative bacteria, have remained the most important causes of several infections, associated mortality and morbidity rates (Teklehaimanot *et al.,* 2021). The current review describes recently (2011–2024, JUNE) published data on carbapenem-resistance in Gram-negative bacteria from Nigeria. The lack of consistency in the measurement and reporting of susceptibility data for carbapenem-resistance makes it difficult to compare findings among different countries and laboratories, sometimes even within one country (Lee *et al.,* 2015; ECDC, 2014).

Given the findings of our review, similar harmonization efforts are urgently needed in Nigeria. Standardizing AMR methods and interpretation guidelines could allow for better comparability of results and improved resistance tracking. Furthermore, improved access to reference laboratories and EQA schemes are needed augmenting the current WHO initiative to scale up the global antimicrobial surveillance system (GLASS) based on country specific priority pathogens (WHO, 2018). Currently, in the absence of a uniform laboratory methodology the GLASS goals will be very difficult to meet. The observed differences between data published, the current work could indicate carbapenem-resistance in certain pathogens. However it could also be because of the differences in CR testing methodologies underlining the need for harmonization of laboratory method in the region.

Finally, resistance data obtained with different laboratory methodologies were combined for the purposes of this review. However, as the majority of studies used the phenotypic screening of imipenem-meropenem disc test, Minimum Inhibitory Concentration, Modified Carba NP Test, Modified Hodge Test method, Carbapenem inactivation method, PCR, WEG, susceptibility disk diffusion method and CLSI guidelines, the impact of the variation in CR methodology on the validity of the final results is thought to be minimal.

CONCLUSION

This review highlights three important findings: first, some region of Nigeria did not have much recent Carbapenem-Resistance data published in the public domain and only a few of those were surveillance data. Second, a high level of Carbapenem-resistance exists in Nigeria region. Third, the standardization and quality of the microbiological identification and susceptibility testing methods needs to be improved to allow national and international organizations to monitor the extent of the Antimicrobial resistant especially carbapenem-resistance problem. All of the identified areas of concern need urgent attention by the global health community in order to halt the public health threat associated with spreading carbapenem-resistant.

Ethics approval and consent to participate: Ethical clearance was obtained from Federal Medical Centre Keffi. Name of ethical committee in Federal Medical Centre Keffi and Nasarawa State University, Nigeria: Dr. Yahaya Baba Adamu**,** and Prof. Ngwai Y. B. Chairman of supervisor team and committee member.

Competing interests: The authors have no competing interest.

Acknowledgements: We wish to express our profound gratitude to the management of Nasarawa State University Keffi for their unreserved support toward this research work, as well as the Staff of Microbiology Department in Ave Maria University and Nasarawa State University Keffi for their support rendered.

REFERENCES

Abdullahi, S. A., Arzai, A. H., Yusuf, I., Adamu, S. M., Adamu, S., Koki, Y. A., Rabi, M. A. and Abbas, A. M. (2017). Molecular detection of New Delhi Metallo beta-lactamase 1 (NDH-1) producing bacterial isolates in Kano-Northwest Nigeria. *Annual Research and Review in Biology*, 14(4), 1-6.

Abdulrasheed, B. A., Tolulope, O. A., Oluwayemisi, A. O. and Powei, A. J. (2019). Prevalence of Metallo-β-lactamase (blaIMP, blaVIM,and blaNDM) genes among clinical isolates from two tertiary hospitals in Yenagoa, Bayelsa State, Nigeria. *International Journal of Research and Innovation in Applied Science*, 4(12).

Abiola, O. O., Meryem, B., Obasola, E. F., Olawale, O. A., John, A. A. and Jean, M. R. (2013). Emergence of multidrug-resistant *Acinetobacter baumannii* producing OXA-23 carbapenemase, Nigeria. *International Journal of Infectious Diseases*, 17, 468-470.

Adebola, O., Chibugo, H. V. and Darlington, D. E. (2019). Carbapenem-resistant among extended spectrum-beta-lactamase producing *E. coli* and *Klebsiella pneumonia* isolates from patients with urinary tract infections in Port-Harcourt, Nigeria. *Nigeria Journal of Pharmaceutical and Applied Science Research*, 8(1), 16-23.

Adesola, O., Baris, K. B., Bamidele, I., Sophia, W., Albert, L., Adobi, D., Morounke, M.U., Libera, L. P., Jan, L., Julia, G., Paul, D. and Silke, P. (2023). High incidence of carbapenemase-producing *Pseudomonas aeruginosa* clinical isolates from Lagos, Nigeria. *JAC Antimicrob. Resit.*, 5(2), 038.

Adesola, O., Francis, O., Bamidele, I., Alexander, M., Karsten, B. and Frieder, S. (2020). High proportion of carbapenemase producing *E. coli* and *Klebsiella pneumonia* among extended-spectrum-beta-lactamase-producera in Nigeria Hospital. *Journal of Global Antimicrobial Resistance*, 21, 8-12.

Akinduti, P. A., Oluwaseun, E., Motayo, B. O. and Adeyakinu, A. F. (2012). Emerging multidrug resistant ampc beta-lactamase and carbapenemase enteric isolates in Abeokuta. *Nature and Science*, 10(17), 70–74.

Aliyu A, Isa M. I., Mustafa, A. Y., Rabiu, I. J., Fatimah, I. T. A., Mohammed, Y., Abdu, A. A., Yahaya, Y., Farouq, M. D., Chinagozi, P. E., Sadiq, G. and Galadima, B. G. (2021). Carbapenem-resistant Enterobacteriaceae infections among patient admitted to intensive care units in Kano, Nigeria. *Sahel Medical Journal*, 24(1), 1-9.

Anibijuwon, I. I., Gbala, I. D. and Adebisi, O. O. (2018). Carbapenem-resistant Enterobactericeae among in patients of tertiary hospital in southwest, Nigeria. *Notulae Scientia Biological*, 10(3), 310-317.

Ayorinde, O. A., Anderson, O. O., Aaron, O. A., Olatunde, F. O., Adewale, A. A., Oyekola, V. A., Veronica, O. O., Anthony, U., Erkison, E. O., Abolaji, T. A., Adeyemi, T. A., Temitope, O. O., Sophia, D., Silvia, A., Monica, A., Abiodu, E., Chikwe, I., David, M. A. and Iruka, N. O. (2021). Clones and clusters antimicrobial-resistance *Klebsiella* from Southwest, Nigeria. *Preprint Server for Biology*,

Brinkac, L. M., White, R., D'Souza, R., Nguyen, K., Obaro, S. K. and Fouts, D. E. (2019). Emergence of New Delhi Metallo-β-Lactamase (NDM-5) in *Klebsiella quasipneumoniae* from neonates in a Nigerian Hospital. *mSphere*, 4, e00685-18.

Christiana, J., Burkhard, S., Sarah, L., Franz, A. and Werner, R. (2017). Carbapenemase Producing *Enterobacteriaceae* Isolates from Edo State, Nigeria. *Journal Antimicrobial Agents and Chemotherapy*, 61(8).

ECDC (2014). Surveillance Report: Annual Report of the European Antimicrobial Resistance Surveillance Network (EARS-net). Sweden: Stockholm. http://ecdc.europa.eu/en/publications/Publications/antimicrobial-resistanceeurope-

Egbule, O. S and Odih, E. E. (2020). Prevalence of extended-spectrum beta-lactamases (ESBLs) and metallo-beta lactamases (MBLs) among healthy and hospitalized children in Abraka and Eku Communities, Delta State, Nigeria. *Nigerian Journal of Basic and Applied Science*, 28(1), 07-14. http://dx.doi.org/10.4314/njbas.v28i1.2

Ejikeugwu P. C., Ugwu C. M., Araka C. O., Gugu T. H., Iroha I. R., Adikwu M. U. and Esimone, C. O. (2012). Imipenem and meropenem resistance amongst ESBL producing *Escherichia coli* and *Klebsiella pneumonia* clinical isolates. *International Research Journal of Microbiology*, 3(10), 339-344,

Emmanuel, O. N., Folasade, A., Anil, P., Anwar, K, Patrick, K., Yi, Y., Andrew, M. A., Salem, T. D., Alex, A. A, Chinedu, A. A., Paul, O. A., Levi, M. M., Nanven, A. M., Mohammed, I. A., Olivia, L., Patrick, B. and Chengming, W. (2021). Concurrent resistance to carbapenem and colistin among enterobacteriaceae recovered from human and animal sources in Nigeria is associated with multiple genetic mechanism. *Front. Microbiol.*, 12, 740348. DOI: 10.3389/fmicrb.2021.740348

Gera, T., Shah, D., Garner, P., Richardson, M. and Sachdev, H. S. (2016). Integrated management of childhood illness (IMCI) strategy for children under five. *Cochrane Database Syst. Rev.*, 6, CD010123.

Hussaini, I. M., Olonitola, O. S., Suleiman, A. B. and Mohammed, Y. (2020). Occurrence of carbapenemase among *Klebsiella pneumoniae* and *Escherichia coli* isolates from selected Hospitals in Zaria. *Nigerian Journal of Pharmarmaceutical Science*, 18(1), 64-72.

Iduh, M. U., Mohammed, M. K., Nataala, S. U. and Abdulkadir, A. (2020). The prevalence of carbapenem-resistance among Enterobacteriaceae isolates from patient attending UDUTH Sokoto, Northwest Nigeria. *International Journal of Tropical Disease and Health*, 41(6), 55-64.

Ijeoma, M. A., Comfort, N. A., Iioduba, N. A., Simon, N. U., Akachukwu, E. O., Robinson, O. O., Chibuke, J. E., Micheal, C. E. and Mabel, O. O. (2020). Emergence of New-Delhi methallo-betalactamase-1 and oxacillinase-48 positive E.coli in South-Eastern Nigeria. *Nigeria Journal of Medicine*, 29(4), 701-706.

Iregbu, K., Jamal, W., Al Fadhli, A., Khodakhast, F., Nwajiobi-Princewill, P., Medugu, N. and Rotimi, V. O. (2020). A point-prevalence survey of carbapenem-resistant Enterobacteriaceae in two different cities in Kuwait and Nigeria. *Afr. J. Clin. Exper. Microbiol.* 2022; 23(4), 358 – 368.

Isabella A. T. and Binta, A. D. (2021). Characterization of carbapenem resistance gram negative isolates from nigeria by whole genome sequence. *National Centre for Biotechnology Information*, 101(1).

Kabiru, O. A., Rebecca, O. A., Bamidele, A. I., Christopher, O. F., Oliwia, M., Heinrich, N., Mathias, W. P. and Gamal, W. (2021). The emergence of *K. pneumonia* with reduce susceptibility against third generation cephalosporin and carbapenem in Lagos, Nigeria. *MDPI Journal*, 10(2).

Lee, M. and Chung, H-S. (2015). Different antimicrobial susceptibility testing methods to detect ertapenem resistance in enterobacteriaceae: VITEK2, MicroScan, Etest, disk diffusion, and broth microdilution. *J. Microbiol. Methods*, 112, 87–91.

Magashi, F., Ibrahim, Y., Firdausi, F. S., Sharif, A. A., Mohammad, I. G. and Jamilu, B. A. (2012). Phenotypic Detection of Carbapenemasee in member of Enterobacteriaceae in Kano, Nigeria. *Journal of Clinical Microbiology*, 2, 802–806.

Motayo, B. O., Akinduti, P. A., Adeyakinu, F. A., Okerentugba, P. O., Nwanze, J. C., Onoh, C. C., Innocent-Adiele, H. C. and Okonko, I. O. (2013). Antibiogram and plasmid profiling of carbapenemase and extended spectrum â-lactamase (ESBL) producing *Escherichia coli* and *Klebsiella pneumoniae* in Abeokuta, South western, Nigeria. *African Health Sciences*, 13(4), 1091-1097.

Muhabat, A. R. and Vincent, O. R. (2013). Point-surveillance of antibiotics resistance in Enterobacteriaceae isolates from patient in a Lagos teaching Hospital, Nigeria. *Journal of Infection and Public Health*, 6(6), 431-437.

Mukail, A., Tytler, B. A., Adeshina, G. O. and Igwe, J. C. (2019). Incidence of carbapenemase production among antibiotic resistant *Klebsiella* isolates in Zaria, Nigeria. *Nigeria Journal of Biotectnology*, 36(1).

Nuhu, T., Olayinka, A. T., Bolaji, R. O., Eugene, B. B., Mohammed, Y. and Olayinka, B. O. (2021). Genetic relatedness in extended-spectrum beta-lactamase-producing *Escherichia coli* from clinical isolates using enterobacterial repetitive intergenic consensus polymerase chain reaction in Nigeria. *Int. J. of Health Sci.*, 15(5).

Oduyebo, O. O., Falayi, O. M. and Ettu, A. O. (2015). Phenotypic determination of carbapenemase producing enterobacteriaceae isolates from clinical specimens at a tertiary hospital in Lagos, Nigeria. *Nig. Postgra. Med. J.*, 22(4), 223-227.

Ogblu, D. O. and Webber, M. A. (2014). High-level and novel mechanisms of carbapenem resistance in Gram-negative bacteria from tertiary hospitals in Nigeria. *International J. of Antimicrobial Agents*, 43(5), 412-417.

Olaitan, J. O., Mobolaji, A. T., Comfort, O. F. and Yinka, T. (2021). Assessment of multidrug-resistant phenotypes and detection of ampicillin-resistant determinants among *Escherichia coli* isolates of groundwater origin: Case study—Osogbo, Southwest Nigeria. … 9(8), 2-12.

Olaniran, O. B., Adeleke, O. E., Donia, A. (2021). Incidence and molecular characterization of carbapenemase genes in association with multidrug-resistant clinical isolates of *Pseudomonas aeruginosa* from tertiary healthcare facilities in Southwest Nigeria. *Curr. Microbiol.*, 79, 27.

Olowo-okere, A., Abdullahi, M. A., Ladidi, B. K., Suleiman, S., Tanko, N., Ungokore, H. Y. and Aliyu, A. (2019). Emergence of Metallo-B-Lactamase producing gram-negative bacteria in a hospital with no history of carbapenem usage in Northwest Nigeria. *Ife J. of Sci.*, 21(2), 323-330.

Olowo-okere, A., Ibrahim,Y. K. E., Olayinka, B. O., Ehinmidu, J. O., Mohammed, Y., Nabti, Z. L., Rolain, J-M. and Diene, S. M. (2020). Phenotypic and genotypic characterization of clinical carbapenem-resistance Enterobacteriaceae isolates from Sokoto Northwes, Nigeria. *PubMed.*, 2, 107.

Oluwafolajimi, A. A. and Hilda, A. I. (2020). Carbapenem-resistant enterobacteriaceae and gram-negative bacterial infections in Southwest Nigeria: a retrospective epidemiology surveillance study. *AIMS*, 7(4), 804-815.

Onipede, A., Odetoyin, B. and Ojo, O. (2021). Detection of NDM-1 in metallo-beta-lactamase-producing strains of *Pseudomonas aeruginosa* isolates from a tertiary hospital in Southwest Nigeria. *West Afri. J. Med.*, 38, 1072–79. https://doi.org/10.55891/wajm.v38i11.16

Perdigao-Neto, L. V., Oliveira, M. S., Rizek, C. F., Carrilho, C. M., Costa, S. F. and Levin, A. S. (2014). Susceptibility of multiresistant gram-negative bacteria to fosfomycin and performance of different susceptibility testing methods. *Antimicrob Agents Chemother*., 58(3), 1763–1767.

Shuwaram A. Shettimaa, Isabella A. Ticklerb, Caitlin M. delaCruzb and Fred C. Tenover (2019). Characterization of carbapenem-resistant gram-negative organisms from clinical specimens in Yola, Nigeria. *J. of Global Antimicr. Resistance*, DOI: https://doi.org/10.1016/j.jgar.2019.08.017

Sulaiman, M. A., Aminu, M., Ella, E. E. and Abdullahi, I. O. (2020). Prevalence, risk factors and antibiotic susceptibility pattern of *Shigella* spp isolated from gastroenteritis patients attending some Hospitals in Kano State, Nigeria. *UJMR*, 5(1), 18 – 23.

Suwaiba, M., Dadah, A. J., and Sanusi, S. B. (2020). Prevalence of Carbapenem resistant *Escherichia coli* and *Klebsiella pneumonia* in urine samples of patient attending selected general hospitals within Kaduna metropolis. *Science World Journal*, 15(4).

Tamma, P. D., Goodman, K. E. and Harris, A. D. (2017). Comparing the outcomes of patients with carbapenemase-producing and non-carbapenem-producing Carbapenem-resistant Enterobacteriaceae Bacteremia. *Clinical Infection Disease*, 64, 257-264

Umar, A. I., Garba, I., Jidda, M. L., Ganau, A. M., Fanas, A. S., Umar, A. I. and Malami, F. M (2019). Multidrug-resistant pseudomonas aeruginosa isolated from ear and wound swabs in some selected hospital laboratories in Sokoto, Nigeria. *Calabar J. of Health Sci.*, 3(1), 31-35.

Umar, M. K., Mohammed, Y. and Dabo, N. T. (2022). Prevalence of carbapenem resistance in clinical bacterial species isolated from Kano, North west Nigeria. *Bayero Journal of Pure and Applied Science*, 13(1), 485-490.

Uwaezuoke, N. S., Kieffer, N., Iregbu, K. C. and Nordmann, P. (2017). First report of OXA-181 and NDM-1 from a clinical *Klebsiella* pneumonia isolate from Nigeria. *Int. J. Infect. Dis*., 61, 1–2. DOI: 10.1016/j.ijid.2017.05.004

Uzoamaka, C. M., Clara, I. E., Chidi, G. M., Chiamaka, C. O., Chioma, L. E. and Cornellius, O. O. (2024). Methallo-Beta-lactamase producing isolates of E. coli and Klebsiella pneumoniae and their resistance profile in Enugu, Nigeria. A threat to public health. *Journal of advance in Microbiology.*, 2(2), 11-19.

World Health Organization (WHO) (2018). Antimicrobial Resistance: Global Report on Surveillance. https://apps.who.int/iris/bitstream/handle/10665/112642/9789241564748_eng.pdf;jsessionid=DF1DFD88C7B094F3DD20B313C8984D5?sequence=1

Yahaya, M., Sambo, B. Z., Anthony, O. O., Bala G. G., Baffa, S. I., Mohammed, M., Mohammad, Z. S., Mahmoud, M. D. and Patrick, N. (2018). Comparison of three phenotypic methods for the screening of Carbapenem resistance among clinical isolates of enterobacteriaceae, *Sub-Saharan Africa Journal of Medicine*, 5(1), 10-14.

Yahya, M., Sambo, B. Z. and Anthony, O. O. (2015). Characterization of KPC, NDM, and VIM type carbapenem resistance Enterobactericeae from north Eastern, Nigeria. *Journal of Biosciences and Medicine*, 3(11).

Yusuf, I., Arzai, A. H., Haruna, M., Sharif, A. A. and Gestso, M. I. (2014). Detection of multi-drug resistant bacteria in major Hospitals in Kano, Northwes, Nigeria. *Brazil Journal of Microbiology*, 45(3).

Yusuf, I., Yusha'u, M., Sherif, A. A., Getso, M. I., Yahaya, H., Bala, J. A., Aliyu, I. A. and Haruna, M. (2012). Detection of metallo beta lactamases among gram negative bacteria isolates from Murtala Muhammed Specialist Hospital, Kano and Almadina Hospital Kaduna, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 5(2), 84.

Zubair, K. O. and Iregbu, K. C. (2018). Resistance pattern and detection of methallo-beta-lactamase genes in clinical isolates of pseudomonas aeruginosa in a central Nigeria Tertiary Hospital. *Nigeria J. of Clinical Practice*, 21(2), 176-182.