ORIGINAL ARTICLE

Phenotypic Detection and Characterization of the Carbapenem resistance in Gram negative Bacilli by using rapid Immunochromatographic Test (ICT)

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ABSTRACT

Treatment significantly differs with the type of carbapenemases as the variation exists with inhibitor drugs. Culture-based phenotypic tests are labor-intensive and time-consuming whilst molecular methods are expensive and need expertise. Therefore, there is a need of rapid, cost effective and simple method for detection of carbapenemase. The aim of this study was to detect and characterize the carbapenemase-producing Gram negative Bacilli among carbapenem-resistant isolates using a rapid Immunochromatographic Test (ICT). A total of 167 CRGNB isolates were subjected to rapid ICT which detects five different types of carbapenems (NDM, OXA-48, KPC, IMP, VIM). Majority of isolates were from pus 64(38.3%) followed by blood 43(25.7%) and urine 27(16.1%). CRGNB included genera Enterobacterales (73.6%) and non-fermenting gram-negative bacilli / NFGNB (26.3%). On characterization with rapid ICT, 125 (74.8%) were positive for one or more of carbapenemases. NDM (83.2%) carbapenemase was the predominate. NDM+OXA48 was detected in 12.80% of isolates whereas IMP was not detected. The carbapenemase production was high in *K. pneumoniae* (78.8%) and *E. coli* (76.4%). Characterization of carbapenemases revealed that, NDM were predominate both in Enterobacterales and NFGNB. Majority of organisms producing carbapenemase NDM, OXA, KPC were multidrug resistant but susceptible to polymyxins and colistin. Rapid ICT being simple, easy to interpret can be incorporated in the clinical microbiology laboratory for the early and preliminary detection of CRGNB to guide the clinicians to select most appropriate antimicrobial drugs for management of the patient.

KEY WORDS: Carbapenemases, Gram-negative bacilli, Multi-drug resistant, Rapid immunochromatographic test

Introduction

Carbapenemase - producing Gram negative bacilli (CRGNB) have become a major therapeutic challenge in hospital and community-acquired infections world wide[1]. These bacteria cause infections such as pneumonia, septicemia, peritonitis, cystitis, meningitis, pyelonephritis, nosocomial and device-related/ associated infections[2]. The production of β-lactamase is the most common mechanism of resistance to β-lactams which includes penicillin, cephalosporins, monobactams and carbapenems especially in gram negative bacteria[3, 4]. Resistance to carbapenems in GNB is commonly associated with the production of carbapenemases which are plasmids encoded[5].

Carbapenemases are defined as group of enzymes that hydrolyze almost all β - lactams, including carbapenems, broad-spectrum penicillin, cephalosporins, and cephamycin. Carbapenemases are classified into Ambler Class A, B and D. *Klebsiella pneumonia* carbapenemase

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(KPC) belongs to the class A carbapenemases and is clinically most important. It was identified in 1996 in the Eastern United States[6, 7]. Class B Metallo Beta lactamases are New Delhi Metallo Beta lactamases (NDM), Verona integron encoded Metallo beta lactamase (VIM) and Imipenemase (IMP). NDM, VIM and IMP have been reported in Greece, Taiwan and Japan which hydrolyze all beta lactams except aztreonam and are inhibited by EDTA but not by clavulanic acid. Most MBL producers are hospital acquired and multidrug-resistant *K. pneumoniae*[8]. New Delhi Metallo-Beta-lactamase (NDM) carbapenemases were first identified in Sweden in 2008 from a patient of Indian origin who had received medical treatment in New Delhi, India and have been rapidly spread worldwide[9]. Next pathogen, OXA48 belongs to the class D carbapenemase. It was first identified from a *K. pneumoniae* isolated in Turkey in 2001[10].

Treatment options may vary with different type of carbapenemases which the organism may produce. Antibiotics recommended for KPC-producing infections include meropenem-vaborbactam, ceftazidime avibactam, and imipenem-cilastatin-relebactam[11]. Cefiderocol is an alternative drug for infection caused by KPC-producing *Enterobacterales*.

Infections caused by NDM, IMP and VIM producing organisms, the preferred antibiotics are ceftazidime-avibactam and Aztreonam combination therapy or cefiderocol monotherapy[12], because ceftazidime-avibactam monotherapy, meropenem-vaborbactam, and imipenem-cilastatin-relebactam are ineffective in Metallo-β lactamase-producing organisms. Ceftazidime-avibactam and cefiderocol are preferred drugs for infection caused by OXA-48-like enzyme producing organisms (CRE)[13]. Carbapenem resistant *Acinetobacter baumannii* (CRAB), the recommended drugs are high dose of ampicillin-sulbactam (if susceptible) or cefoperazone-sulbactam. while Carbapenem Resistant *Pseudomonas aeruginosa*, the preferred antibiotic includes β-Lactam (ceftazidime or cefepime) or β-lactam-β-lactamase inhibitor combination (piperacillin-tazobactam or cefoperazone sulbactam) if it is *in-vitro* is susceptibility.

The Clinical and Laboratory Standards Institute (CLSI) recommends Modified Hodge test, the Carba NP and the modified Carbapenem inactivation Method for phenotypic detection of carbapenemases production[21]. Several diagnostic tools including culture-based methods that identify resistant phenotypes and molecular techniques based on gene amplification are widely used in clinical microbiology laboratories for identification and characterization of different types of carbapenemases[14-17].

However, culture-based phenotypic methods are labor intensive and time consuming and the molecular method needs expensive equipment and high expertise. Recently, multiplex immunochromatographic lateral flow assays for detecting and characterizing carbapenemases are developed[18, 19]. The present study was undertaken to evaluate the utility of the Rapid immunochromatographic test (ICT) for CRGNB isolated from clinical samples.

Material And Methods

A descriptive cross-sectional study was conducted over a period of one year (June 2024 to June 2025) in the Department of Microbiology of tertiary care teaching hospital. Carbapenemases isolates from blood, pus, tissue, body fluids like cerebrospinal fluid, ascitic fluid, pleural fluid, urine and sputum were included[20]. Protocol of the study was approved by the Institutional Ethics Committee (IEC/PGI-OA-15/24). The Antimicrobial susceptibility was done on automated systems Phoenix M50, (B.D. Diagnostics) and interpreted as per CLSI M100[21].

Inclusion criteria:

Gram negative bacilli isolates showing resistance to Imipenem and/or meropenem or both on antimicrobial susceptibility testing were included in the study.

Exclusion criteria:

Multiple isolates from the same patient were excluded from the study.

Methodology:

Bacterial identification and antimicrobial susceptibility testing were performed as per standard microbiological techniques.

Immunochromatography test (ICT):

The carbapenem resistant isolates were evaluated by rapid ICT (TRURAPID O.K.N.V.I.- Resist -5), following the kit procedure which detects five carbapenemases (KPC, NDM, VIM, IMP and OXA-48).

1. Principle: The rapid immunochromatography test is based on a principle of membrane technology with colloidal gold nanoparticles. The test was carried out on a suspension of bacterial colonies using the rapid ICT (TRURAPID O.K.N.V.I.- Resist -5) [Fig. 1].

2. Interpretation: The presence of a reddish / pink line after 15 minutes, indicates a positive result of carbapenemase. If the control line does not appear, the result is invalid, regardless of the appearance of band.

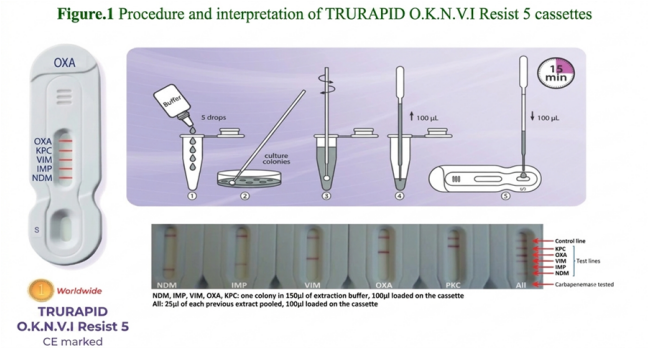

Fig. 1: Diagrammatic representation of Processing for rapid Immunochromatographic test

The results of the rapid test were compared to that of resistance profile of isolates to carbapenems. Clinical details and demographic parameters of patients were recorded and entered in Microsoft excel.

Statistical analysis:

All the collected data was recorded in Microsoft Excel 2010 and frequencies were calculated.

Results

A total of 167 non-duplicate clinically significant GNB were obtained from the clinical specimens. Out of 167 CRGNB isolates 125 were positive for one or more carbapenemase by rapid ICT. Carbapenem resistant isolates were found more in male patients 101(60.4%) followed by female patients 66 (39.5%).

Age wise distribution of 167 patients showed that, majority of the isolates 45 (26.94%) were found in 41 to 50 yrs followed by 51 to 60 years 33 (19.76%), 20 to 30 years 31 (18.56%), 31 to 40 years 21 (12.57%), 61 to 70 years 16 (9.58%), less than 10 years 9 (5.38%), 11 to 20 years 7 (4.19%) and 71 to 80 years 5 (2.99%) [Fig. 2]. The distribution of Carbapenem resistant isolates was seen more among the ICU patients with the highest number of 105 (63%), followed by indoor patients from Ortho ward 26 (16%), Medicine ward 15 (9%), Surgery ward 10 (6%), ENT ward 7 (4%) and Outpatient unit 4 (2%) [Fig. 3]. Sample wise distribution of the 167 isolates showed that 64 (38.3%) were from pus, 43 (25.7%) blood, 27 (16.1%) urine, 14 (8.3%) sputum, 10 (5.9%) fluids, 9 (5.3%) tissue [Fig. 4].

Out of 167 isolates, 123 were identified as member of Enterobacterales and 44 isolates as non-fermenting gram negative bacilli. Among the family of Enterobacterales isolates, *Klebsiella pneumoniae* 71(42%) was the predominant organisms followed by *Escherichia coli* 34 (20.30%). *Acinetobacter* spp and *Pseudomonas aeruginosa* was the most frequent species among the non-fermenting gram negative bacilli, accounting of 22 (11.37%) and 10 (5.74%).

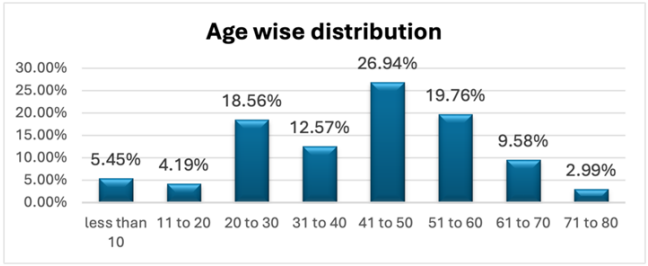

Fig. 2: Age wise distribution of patients with CRGNB isolates

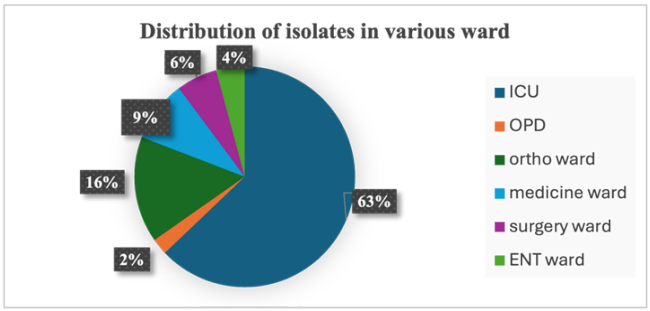

Fig. 3: Distribution of GNB according to hospital location

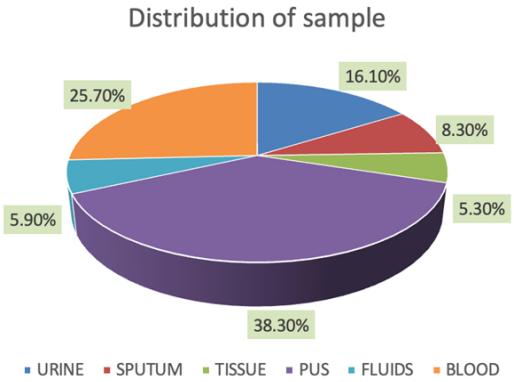

Fig. 4: Distribution of isolates from clinical specimens

Characterization/Differentiation Of Carbapenemases

Results of Rapid test revealed that Carbapenemase were found in 125 (74.8%) of the 167 test isolates [Table. 3] and negative in 42 (25.1%) isolates indicating other mechanisms of resistance to Carbapenems [Fig. 5]. Carbapenemase type NDM was the most identified 104(83.2%), followed by the both NDM plus OXA48-16(9.19%), alone of OXA48 -3(1.72%) with no production of IMP was observed [Table. 1].

Table 1. Characterization of Carbapenemases

Type of carbapenemases	Total (n=125)	Percentage
NDM	104	83.2%
NDM+OXA-48	16	12.8%
OXA-48	3	2.4%
KPC	1	0.8%
VIM	1	0.8%
IMP	-	-

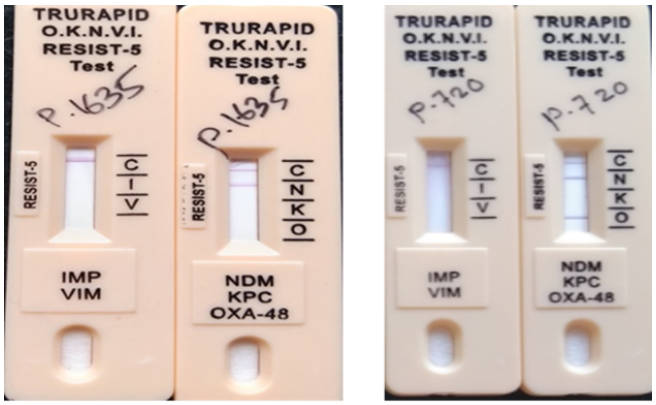

Fig. 5: Characterization of Carbapenemases. a) Isolate showing positive result for NDM carbapenamase. b) Isolate showing positive result for NDM plus Oxa-48 carbapenamase

Table 2. Distribution of carbapenemases in various clinical samples (n=125)

Sample	NDM (%)	KPC (%)	OXA-48 (%)	VIM (%)	NDM+OXA-48 (%)	Total (%)
Urine	17 (73.9)	1 (4.3)	1 (4.3)	-	4 (17.3)	23(18.4)
Sputum	13 (92.8)	-	-	-	1 (7.14)	14(11.2)
Tissue	8 (88.8)	-	-	-	1 (11.1)	9(7.2)
Pus	40 (86.9)	-	2 (4.34)	1 (2.17)	3 (6.5)	46(36.8)
Fluids	6 (85.7)	-	-	-	1 (14.2)	7(5.6)
Blood	20 (76.9)	-	-	-	6 (23.0)	26(20.8)
Total	104(83.2)	1(0.8)	3(2.44)	1(0.8)	16(12.8)	125(100)

As shown in [Table. 2], VIM was detected only in single isolate from pus, whereas KPC was noted in single isolate from urine sample.

Out of 125 GNB isolates positive for one of the carbapenemase by rapid ICT, 95 (75.2%) were Enterobacterales and 30 (24.8%) NFGNB. The production of carbapenemase rate was 78.8% in *K. pneumoniae* and 76.4% in *E.coli*. Among NFGNB, the Carbapenemase production was more in *Acinetobacter spp* (94.73%) followed by *P. aeruginosa* (70%), *A. iwofii* (50%) [Table. 3]. In the family of *Enterobacterales*, the NDM production was highly seen in *K. pneumoniae* (42.3%) and *E.coli* (21.1%), In the present study there was only one isolate of *K. Pneumoniae* which showed KPC Production. OXA-48 carbapenemase was seen in 1 isolate of each *K. pneumoniae (*33.3%), *E. coli* (33.3%) and *Citrobacter freundii* (33.3%). A combination of 2 carbapenemases NDM+OXA48was found in 62.5% of *K. pneumoniae and 31.2% of E. coli* isolates.Among the group of non-fermenters, the NDM production was highly seen in *Acinetobacter* spp. of 16.3% and *P.aeruginosa* of 5.76%. VIM production were only seen in 1 isolate of *P.aeruginosa* whereas NDM+OXA48 was seen in 6.25% of *Acinetobacter spp*.

Organisms producing carbapenemases, colistin and polymyxin B being most reliable agents, with susceptibility ranging from 94.2–100%. Carbapenem susceptibility was uniformly 0% across all carbapenemases. Among NDM producers (n=104), susceptibility to other agents was low (≤6%), though nitrofurantoin (86.5%) and norfloxacin (84.6%). The single VIM isolate was full susceptibility to amikacin, gentamicin, piperacillin-tazobactam, and aztreonam, while remaining resistant to fluoroquinolones, co-trimoxazole, and cephalosporins; KPC (n=1) and OXA-48 (n=3) isolates showed near-complete resistance, with OXA-48 being partial susceptibility to amikacin (33.4%) and norfloxacin (66.7%). Given the extremely small sample sizes for VIM, KPC, and OXA-48, these percentages should be interpreted with caution and are not generalizable. NDM+OXA-48 co-producers (n=16) showed preserved susceptibility to tetracycline (31%), nitrofurantoin (87%) and norfloxacin (94%), exceeding NDM alone [Table. 4].

Table 3. Distribution of Carbapenemases among CRGNB (n=125)

Gram negative bacilli (n)	Carbapenemase produced (%)	NDM (%)	KPC (%)	OXA-48 (%)	VIM (%)	NDM + OXA48 (%)
Enterobacterales (95)						
K.pneumoniae(71)	56 (78.8)	44(42.3)	1(100)	1(33.3)	-	10(62.5)
E.coli (34)	28 (76.4)	22(21)	-	1(33.3)	-	5(31.25)
K. aerogenes (1)	-	-	-	-	-	-
K. oxytoca (1)	1(100)	1(0.96)	-	-	-	-
C. freundii (7)	4 (57.1)	3(2.88)	-	1(33.3)	-	-

Gram negative bacilli (n)	Carbapenemase produced (%)	NDM (%)	KPC (%)	OXA-48 (%)	VIM (%)	NDM + OXA48 (%)
C. koseri (4)	2 (50)	2(1.9)	-	-	-	-
P. mirabilis(1)	1 (100)	1(0.96)	-	-	-	-
M. morganii (1)	-	-	-	-	-	-
P.agglomerance (2)	2 (100)	2(1.9)	-	-	-	-
S. marcescens (1)	1 (100)	1(0.96)	-	-	-	-
Non-fermenters bacilli (30)						
A.baumanii (5)	1 (20)	1(0.96)	-	-	-	-
A. baumannii complex (7)	3 (42.85)	3(2.88)	-	-	-	-
Acinetobacter spp (19)	18 (94.7)	17(16.3)	-	-	-	1(6.25)
A. iwofii (2)	1 (50)	1(0.96)	-	-	-	-
P.aeruginosa (10)	7 (70)	6(5.76)	-	-	1(100)	-
S. maltophilia (1)	-	-	-	-	-	-
Total (167)	125 (74.85)	104 (83.2)	1 (0.8)	3 (2.4)	1(0.8)	16 (12.8)

Table 4. Antimicrobial susceptibility pattern of CRGNB (N=125)

	NDM (n=104)	KPC (n=1)	OXA-48 (n=3)	IMP (n=0)	VIM (n=1)	NDM + OXA-48 (n=16)
Antibiotic	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible
Amikacin	3%	0%	33.4%	-	100%	6%
Gentamicin	6%	0%	0%	-	100%	6%
Co-trimoxazole	3%	0%	0%	-	0%	6.25%
Ciprofloxacin	2%	0%	0%	-	0%	6%
Cefotaxime	5%	0%	0%	-	0%	0%
Ceftazidime	4%	0%	0%	-	0%	0%
Tetracycline	6%	0%	0%	-	0%	31%
Imipenem	0%	0%	0%	-	0%	0%
Meropenem	0%	0%	0%	-	0%	0%
Piperacillin/ Tazobactam	2%	0%	0%	-	100%	12%
Aztreonam	4.8%	0%	0%	-	100%	6%
Cefepime	2%	0%	0%	-	0%	0%
Colistin	98.08%	100%	100%	-	100%	100%
Polymyxin B	94.21%	100%	100%	-	100%	100%
Norfloxacin	84.62%	0%	66.7%	-	-	94%
Nitrofurantoin	86.54%	0%	-	-	-	87%

Discussion

The prevalence of Carbapenem resistance in GNB varies from hospital to hospital. In the present study carbapenem resistance was observed in 33% of Gram-negative bacilli isolates. Ebongue *et al*.[22] found a rate of 37.5%. in Cameroon during the year of 2021, while study conducted by Amber T *et al*.[23] found prevalence rate of 34.15% in India. In the present study, male predominance (60.4%) was observed, similar male predominance has also been observed in other studies. In the present study, majority of carbapenem resistant isolates were predominantly obtained from pus (38.3%), followed by blood (25.7%). Whereas Ebongue *et al.*[22] and Amber T *et al*.[23] reported that majority of isolates were obtained from urine samples (47.0 %) and urine samples (42%) respectively.

In the present study, *Klebsiella pneumoniae* (78.8%) and *Escherichia coli* (76.4%) were the predominant carbapenemase producing Enterobacterales and *Acinetobacter spp* (94.7%) and *P.aeruginosa* (70%) were among non- fermenting Gram negative bacilli. Similarly, Ebongue *et al*.[22] for observed that *Escherichia coli* was the most commonly isolated organism 68.13%

followed *Acinetobacter baumannii* produced the most carbapenemases tested (11.7%) in non-fermenting Gram negative bacilli. Similar findings were reported in a study conducted by Amber T *et al*[23], where *Escherichia coli* (54%) was the predominant organism, followed by *Klebsiella pneumoniae* (20%).

NDM was the predominant carbapenemase detected (83.2%). Similar observations were reported in studies conducted by Ebongue *et al*.[22] and Amber T *et al*.[23]with rates of 47.50% and 60 % respectively. At present, NDM production in gram negative bacilli has been reported all over the world, specifically in Asia with Indian subcontinent being the main reservoir. The limitation of this study was that molecular confirmation of carbapenemase gene expression could not performed due to resource limits.

Table 5. Prevalence of carbapenemases in various studies

Author	NDM	KPC	OXA-48	VIM	IMP	NDM+OXA-48
Ebongue *et al.*[22]	47.50%	23.55%	23.55%	5.80%	-	-
Amber T *et al.*[23]	60%	-	37.43%	-	-	2.57%
Present study	83.2%	0.80%	2.40%	0.80%	-	12.80%

Conclusion

Rapid Immunochromatographic test is simple and easy to implement in the workflow of clinical microbiology laboratory for the early and preliminary detection of carbapenemases producing GNB. Its use can aid clinicians in selecting appropriate antimicrobial therapy.

Disclosure

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

1. Glasner C, Albiger B, Buist G, Tambic´ Andrasevic´ A, Canton R, Carmeli Y, *et al*. Carbapenemase-producing Enterobacteriaceae in Europe: a survey among national experts from 39 countries, February 2013. Eurosurveillance. 2013; 18(28). Available from: https://doi.org/10.2807/1560-7917.es2013.18.28.20525
2. Nordmann P, Naas T, Poirel L. Global Spread of Carbapenemase-producing*Enterobacteriaceae*. Emerging Infectious Diseases. 2011; 17(10):1791-1798. Available from: https://doi.org/10.3201/eid1710.110655
3. Viswanathan R, Singh AK, Basu S, Chatterjee S, Sardar S, Isaacs D. Multi-drug resistant gram negative bacilli causing early neonatal sepsis in India. Archives of Disease in Childhood - Fetal and Neonatal Edition. 2012; 97(3):F182-F187. Available from: https://doi.org/10.1136/archdischild-2011-300097
4. Kang CI, Kim SH, Park WB, Lee KD, Kim HB, Kim EC, *et al*. Bloodstream Infections Caused by Antibiotic-Resistant Gram-Negative Bacilli: Risk Factors for Mortality and Impact of Inappropriate Initial Antimicrobial Therapy on Outcome. Antimicrobial Agents and Chemotherapy. 2005; 49(2):760-766. Available from: https://doi.org/10.1128/aac.49.2.760-766.2005
5. Queenan AM, Bush K. Carbapenemases: the Versatile β-Lactamases. Clinical Microbiology Reviews. 2007; 20(3):440-458. Available from: https://doi.org/10.1128/cmr.00001-07
6. Yigit H, Queenan AM, Anderson GJ, Domenech-Sanchez A, Biddle JW, Steward CD, *et al*. Novel Carbapenem-Hydrolyzing β-Lactamase, KPC-1, from a Carbapenem-Resistant Strain of*Klebsiella pneumoniae*. Antimicrobial Agents and Chemotherapy. 2001; 45(4):1151-1161. Available from: https://doi.org/10.1128/aac.45.4.1151-1161.2001
7. Nordmann P, Cuzon G, Naas T. The real threat of *Klebsiella pneumoniae* carbapenemase-producing bacteria. The Lancet Infectious Diseases. 2009; 9(4):228-236. Available from: https://doi.org/10.1016/s1473-3099(09)70054-4
8. Walsh TR, Toleman MA, Poirel L, Nordmann P. Metallo-β-Lactamases: the Quiet before the Storm?. Clinical Microbiology Reviews. 2005; 18(2):306-325. Available from: https://doi.org/10.1128/cmr.18.2.306-325.2005
9. Sbiti M. Profil épidémiologique des entérobactéries uropathogènes productrices de bêta-lactamases à spectre élargi. Pan African Medical Journal. 2017; 28:245-248. Available from: https://doi.org/10.11604/pamj.2017.28.29.11402
10. Nordmann P. Carbapenemase-producing Enterobacteriaceae: Overview of a major public health challenge. Médecine et Maladies Infectieuses. 2014; 44(2):51-56. Available from: https://doi.org/10.1016/j.medmal.2013.11.007
11. Shields RK, Nguyen MH, Chen L, Press EG, Potoski BA, Marini RV, *et al*. Ceftazidime-Avibactam Is Superior to Other Treatment Regimens against Carbapenem-Resistant Klebsiella pneumoniae Bacteremia. Antimicrobial Agents and Chemotherapy. 2017; 61(8). Available from: https://doi.org/10.1128/aac.00883-17
12. Shaw E, Rombauts A, Tubau F, Padullés A, Càmara J, Lozano T, *et al*. Clinical outcomes after combination treatment with ceftazidime/avibactam and aztreonam for NDM-1/OXA-48/CTX-M-15-producing Klebsiella pneumoniae infection. Journal of Antimicrobial Chemotherapy. 2018; 73(4):1104-1106. Available from: https://doi.org/10.1093/jac/dkx496
13. Pfaller MA, Huband MD, Mendes RE, Flamm RK, Castanheira M. In vitro activity of meropenem/vaborbactam and characterisation of

carbapenem resistance mechanisms among carbapenem-resistant Enterobacteriaceae from the 2015 meropenem/vaborbactam surveillance programme. International Journal of Antimicrobial Agents. 2018; 52(2):144-150. Available from: https://doi.org/10.1016/j.ijantimicag.2018.02.021

14. Paterson DL, Bonomo RA. Extended-Spectrum β-Lactamases: a Clinical Update. Clinical Microbiology Reviews. 2005; 18(4):657-686. Available from: https://doi.org/10.1128/cmr.18.4.657-686.2005
15. Maurer FP, Castelberg C, Quiblier C, Bloemberg GV, Hombach M. Evaluation of Carbapenemase Screening and Confirmation Tests with Enterobacteriaceae and Development of a Practical Diagnostic Algorithm. Journal of Clinical Microbiology. 2015; 53(1):95-104. Available from: https://doi.org/10.1128/jcm.01692-14
16. Kim H, Sung JY, Yong D, Jeong SH, Song W, Lee K, *et al*. Disk Carbapenemase Test for the Rapid Detection of KPC-, NDM-, and Other Metallo-β-Lactamase-Producing Gram-Negative Bacilli. Annals of Laboratory Medicine. 2016; 36(5):434-440. Available from: https://doi.org/10.3343/alm.2016.36.5.434
17. Hong JS, Kim D, Yoon EJ, Lee H, Jeong SH. Performance evaluation of the PANA RealTyper™ CRE Kit for detecting carbapenemase genes in Gram-negative bacilli. Journal of Global Antimicrobial Resistance. 2019; 18:100-103. Available from: https://doi.org/10.1016/j.jgar.2019.02.002
18. Bogaerts P, Berger AS, Evrard S, Huang TD. Comparison of two multiplex immunochromatographic assays for the rapid detection of major carbapenemases in Enterobacterales. Journal of Antimicrobial Chemotherapy. 2020; 75(6):1491-1494. Available from: https://doi.org/10.1093/jac/dkaa043
19. Boutal H, Vogel A, Bernabeu S, Devilliers K, Creton E, Cotellon G, *et al*. A multiplex lateral flow immunoassay for the rapid identification of NDM-, KPC-, IMP- and VIM-type and OXA-48-like carbapenemase-producing Enterobacteriaceae. Journal of Antimicrobial Chemotherapy. 2018; 73(4):909-915. Available from: https://doi.org/10.1093/jac/dkx521
20. Procop GW, Church DL, Hall GS, Janda WM. *Koneman's color atlas and textbook of diagnostic microbiology*. Jones & Bartlett Learning; 2020 Jul 1
21. CLSI. *Performance standards for antimicrobial susceptibility testing*. 34th ed. CLSI supplement M100. Clinical and Laboratory Standards Institute; 2024.
22. Ebongue CO, Simo GG, Mefo'o JP, Dalle Ngondi G, Mengue ER, Ngaba GP, *et al*. Detection of the Production of *Klebsiella Pneumoniae* Carbapenemase, New Delhi Metallo-Beta-Lactamase and Oxacillinase-48-Type Carbapenemases by Gram-Negative Bacilli in Resource-Limited Setting. Advances in Microbiology. 2021; 11(10):579-590. Available from: https://doi.org/10.4236/aim.2021.1110042
23. Amber T, Tak H, Kapaganty VC. In-house Carba NP - II test to identify and differentiate carbapenemase-producing Gram-negative bacteria among various clinical isolates in comparison with immunochromatography assay. IP International Journal of Medical Microbiology and Tropical Diseases. 2024; 10(2):155-160. Available from: https://doi.org/10.18231/j.ijmmtd.2024.028
24. Yusuf I, Haruna M, Hamid KM, Muhammad B, Jega SA. Detection of AmpC, Carbapenemase and Extended spectrum beta lactamases among clinical bacterial pathogens in Nigeria. *AJSTSS*. 2011;1(1):8-24
25. Simo GG, Mefo'o JP, Temfemo A, Ngondi G, Ebongue CO, Ngaba GP, *et al*. Detection of the Production of KPC, NDM, OXA-48, VIM and IMP-Type Carbapenemases by Gram-Negative Bacilli in Resource-Limited Setting. International Journal of Current Microbiology and Applied Sciences. 2024; 13(8):76-84. Available from: https://doi.org/10.20546/ijcmas.2024.1308.009
26. Zhanel GG, Wiebe R, Dilay L, Thomson K, Rubinstein E, Hoban DJ, *et al*. Comparative Review of the Carbapenems. Drugs. 2007; 67(7):1027-1052. Available from: https://doi.org/10.2165/00003495-200767070-00006

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