

Original Research Article

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Detection of the Production of KPC, NDM, OXA-48, VIM and IMP-Type Carbapenemases by Gram-Negative Bacilli in Resource-Limited Setting

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ABSTRACT

Increased bacterial antibiotic resistance is a global public health problem; this problem is all the more worrying with the appearance and spread of carbapenemases. This study aimed to identify the production and distribution of carbapenemases in Gram-negative bacilli isolated in Douala. A cross-sectional study was conducted from January 2023 to March 2024 (1 year two months). Included in the study were all strains of Gram-negative bacilli isolated in one of the two selected hospitals and resistant to at least 3 classes of antibiotics (multi-resistant). These strains were identified using biochemical tests with colorimetric revelation (Vitek 2). After which, they were subjected to an antibiogram by the agar diffusion method with a range of 20 standard antibiotics. Once confirmed to be multi-resistant, the strains were tested for the production of one of the five carbapenemases detected by immunochromatographic technique (OXA-48, NDM, IMP, VIM, KPC) using the rapid detection kit "NG-TEST/CARBA 5". Statistical analysis of the data was carried out using Epi info version 7.2.2.6 and Excel 2013 software. A total of 475 strains of gram-negative bacilli were collected during the study period, 40 multi-resistant strains were identified, mainly in the ECBU samples (47.0%); 37.5% of the multi-resistant strains produced the carbapenemases detected with a higher frequency at the General Hospital (53.3%). NDM-type carbapenemase was the most frequently identified (47.1%); The prevalence of carbapenemase production was higher in *E. coli* (66.7%), which was also the most isolated species (22.5%) Amikacin was the most active antibiotic on multi-strains resistant and carbapenemase-producing strains OXA-48 and NDM. The production of carbapenemases is increasing given the figures obtained in this study compared to those obtained in 2018.

Keywords

Carbapenemases,
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Introduction

Since the turn of the century, there has been an increasingly rapid spread of extended-spectrum β -lactamases among enterobacteria, mainly in *E. coli* (Doortet *et al.*, 2014). This phenomenon has become uncontrollable in just 10 years, and the epidemic has now been identified internationally as a source of community-acquired infections in particular (Nordmann *et al.*, 2009). In 2004, Greece was hit by a major epidemic caused by a clone of *Klebsiella pneumoniae* producing a Verona Integron-encoded Metallo- β -lactamase (VIM-1), rapidly followed by a second epidemic in 2006 caused by *Klebsiella pneumoniae* producing a xxx-x-type carbapenemase (KPC) (Nordmann *et al.*, 2012; Ebongue *et al.*, 2021).

New Delhi Metallo-lactamase (NDM) carbapenemases were first identified in Sweden in 2008 and have rapidly spread worldwide (Tamma *et al.*, 2018; Sbiti, 2017). Since 2010, numerous outbreaks caused by carbapenemase-producing OXA-48 bacteria have been reported in most European countries (Nordmann, 2014). Taking into consideration the type of carbapenemase and the bacterial host species, KPC, IMP and VIM seem to have been identified so far in the main nosocomial pathogen, *Klebsiella pneumoniae* (Doortet *et al.*, 2014).

However, in the case of NDM and OXA 48 carbapenemases, *K. pneumoniae* and *E. coli* can be considered as sources of both nosocomial and community-acquired infections (Nordmann *et al.*, 2012; Nordmann *et al.*, 2011). In Nigeria in 2015, the prevalence of carbapenemase producing bacteria was 13% (Yusuf *et al.*, 2011); In 2018, a study carried out in the city of Douala in Cameroon on carbapenemase production in Gram-negative bacilli showed a high presence of these enzymes (16%), mainly of the OXA 48 and NDM type (Ebongue *et al.*, 2021).

This study targets a wider range of enzymes and investigates the five main carbapenemases (NDM, OXA 48, KPC, IMP, VIM) in two referral hospitals in Douala, with knowledge of the epidemiological data on these enzymes being a prerequisite for containing their spread.

Materials and Methods

This was a descriptive cross-sectional study conducted from January 2023 to March 2024 (1 year two months).

Strains were collected from two hospitals in the city of Douala: The General Hospital and the Laquintinie Hospital.

The strains were analysed in the clinical biology laboratory of Douala General Hospital. All Gram-negative bacillus strains isolated from pathological products in one of the two selected hospitals during the study period were included in the study.

Collection of Samples

The strains were collected using a sterile swab from their primary culture medium (EMB, CLED, Mac Conkey, SS), and then transported in screw tubes containing ordinary broth. These tubes were placed in a cooler and quickly transported to the analysis site, where the strains were re-isolated on an EMB culture medium and incubated at 37°C for 18 to 24 hours.

Identification and Antibiotic Susceptibility

The strains were identified by the automated colourimetric method using Vitek2TM (Biomérieux), after an antibiogram was carried out using the Mueller Hinton agar diffusion method with a range of 20 standard antibiotics, namely: Amoxicillin + clavulanic acid (30 μ g); Ticarcillin + clavulanic acid (85 μ g); Piperacillin + Tazobactam (85 μ g); Tobramycin (10 μ g); Levofloxacin (5 μ g); Norfloxacin (5 μ g); Ceftriaxone (30 μ g); Cefixime (5 μ g); Cefepime (30 μ g); Ceftazidime (30 μ g); Meropenem (10 μ g); Ertapenem (10 μ g); Imipenem (10 μ g); Amikacin (30 μ g); Gentamicin (15 μ g); Ofloxacin (5 μ g); Ciprofloxacin (5 μ g); Cefotaxime (30 μ g); Fosfomycin (50 μ g); Nalidixic acid (30 μ g).

Sensitivity testing was interpreted according to the standards of the European Committee for Antimicrobial Susceptibility Testing (EUCAST v 6.0) (Bonnet *et al.*, 2013).

Detection of Carbapenemases

Carbapenemases were detected in multi-resistant strains, i.e. strains resistant to at least 3 classes of antibiotics. Testing for the production of one of the five carbapenemases (OXA-48, NDM, KPC, VIM and IMP) was carried out on a bacterial suspension using the rapid immuno-chromatography technique with the 'NG-TEST/CARBA 5' kit. The principle of this test is based

on the detection of a coloured indicator after 15 minutes indicating the presence of carbapenemase, and the result obtained was interpreted according to the manufacturer's recommendations (Figure 1).

Statistical Analysis

Microsoft Office Excel 2010 was used to record the data and calculate the frequencies. Categorical variables were presented as frequencies and the Chi square test was used to compare variables. The difference was considered statistically significant for the p-value of less than 0.05.

Results and Discussion

Isolated Strains

During the study period, 475 strains of Gram-negative bacilli were isolated in the selected laboratories; *Enterobacteriaceae* constituted the most represented group with *E. coli* as the most frequent species (30%) followed by *K. pneumoniae* (23%). *Pseudomonas aeruginosa* was the most frequent species among non-fermenting Gram-negative bacilli, accounting for 11% of strains.

Multi-resistant strains

A total of 40 multi-resistant strains were identified, representing a relative frequency of 11.9%. The frequency of these strains was higher at the Douala General Hospital and the Laquintinie Hospital, with 53.3% and 46.7% respectively (Table I). Among the multidrug-resistant strains, *E. coli* was the most represented species among the enterobacteria (22.5%), followed by *K. pneumoniae* (20.0%), and the non-fermenting Gram-negative bacilli were mainly *P. aeruginosa* (15.0%) and *A. baumannii* (15.0%). These strains came mainly from urine and pus, 41% and 32% respectively.

Carbapenemase-producing strains

Carbapenemases were found in 15 of the 40 multidrug-resistant strains, with the greatest number found at the General Hospital. Carbapenemase type NDM was the most frequently identified (20.0%) and no production of KPC was observed (Table II); carbapenemase-producing strains were mainly found in ECBU followed by pus (Table III).

Enterobacteriaceae were the group that produced the most carbapenemases tested (82.3%). The prevalence of carbapenemase production was highest in *E. coli* (35.3%). *Acinetobacter baumannii* produced the most carbapenemases tested (11.7%) in non-fermenting Gram-negative bacilli (Table IV).

Susceptibility to Antibiotics

Strains producing carbapenemases OXA-48 and NDM were almost completely resistant to all antibiotics except for Amikacin and Imipenem. However, strains producing IMP and VIM were not sensitive to any of the antibiotics tested (Table V).

A good frequency of strains (46.4%) resistant to the three Carbapenem antibiotics (Imipenem, Meropenem and Ertapenem) did not produce any of the five types of Carbapenemases tested. (Table VI).

Multidrug-resistant strains were isolated in two referral hospitals due to the type of use and level of activity of these facilities since complex cases are transferred to them for better management. The multidrug-resistant strains came mainly from pus and urine samples, a result similar to those obtained in other national studies in 2021 (Ebongue *et al.*, 2021). Pathologies caused by carbapenem-resistant bacteria are mainly urinary tract infections, as well as sepsis and soft tissue infections (Betbeu *et al.*, 2015; Diene *et al.*, 2014). The prevalence of carbapenemase production was high in our study (37.5%) compared with the work of Ebongue *et al.*, (2021) in Cameroon in 2021 (16%) and Yusuf *et al.*, (2011) in Nigeria in 2011 (13.3%) (Ebongue *et al.*, 2021; Liazid and Asma, 2012). This observed increase could be justified by the search for a wider range of enzymes in this study, five in total (Dortet *et al.*, 2013). NDM-type carbapenemase from the metallo-beta-lactamase group was the most common.

This observation is similar to that of the study by Ebongue *et al.*, (2021), confirming the predominance of this enzyme among the carbapenemases identified in Cameroon (Ebongue *et al.*, 2021; Hajar, 2017). The NDM and OXA-48 type carbapenemases identified were respectively more frequent in *Enterobacteriaceae* and mainly in *E. coli* and *K. pneumoniae*. In France, Vaux *et al.*, (2022) showed a higher frequency of *K. pneumoniae*, as did Yusuf *et al.*, (2011) in Nigeria (Yusuf *et al.*, 2011; Lagha *et al.*, 2015).

Table.1 Distribution of multi-resistant strains according to species identified

Groups	Genus	Species	HGD N=18	HLD N=22	Total N=40(%)
Enterobacteria	<i>Escherichia</i>	<i>E.coli</i>	3	6	9(22.5%)
	<i>Klebsiella</i>	<i>K.pneumoniae</i>	4	4	8(20.0%)
	<i>Citrobacter</i>	<i>C. freundii</i>	1	0	1(2.5%)
		<i>C.diversus</i>	0	1	1(2.5%)
	<i>Enterobacter</i>	<i>E. cloacae</i>	2	1	2(5.0%)
	<i>Proteus</i>	<i>P. mirabilis</i>	0	2	2(5.0%)
	<i>Shigella</i>	<i>S. shigella</i>	0	1	1(2.5%)
	<i>Serratia</i>	<i>S. liquefaciens</i>	0	1	1(2.5%)
	<i>Raoutella</i>	<i>R. ornithinolytica</i>	0	1	1(2.5%)
	Non-fermenting	<i>Pseudomonas</i>	<i>P.aeruginosa</i>	3	3
<i>Acinetobacter</i>		<i>A. baumannii</i>	4	2	6(15.0%)
		<i>A.lwoffii</i>	1	0	1(2.5%)

Legend: HGD=General Hospital Douala; HLD=Laquintinie Hospital Douala

Table.2 Types of carbapenemases identified

Types of carbapenemases	Count	Frequency (%)
OXA 48	4	10
NDM	8	20
IMP	4	10
VIM	1	2.5
KPC	0	0.0
None	23	57.5
Total	40	100

Legend: OXA-48=Oxacillinase48; NDM=New Delhi Metallo-β-lactamase; KPC: *Klebsiella Pneumoniae* Carbapenemase; IMP= Imipenemase; VIM= Verona Integron-encoded Metallo-β-lactamase

Table.3 Distribution of carbapenemase-positive strains according to strain origin

Origin	NDM	OXA 48	IMP	VIM	Total(%)
ECBU	3	3	2	0	8(47.0)
Pus	4	1	1	1	7(41.1)
HEMOC	1	0	0	0	1(5.9)
SU	0	0	1	0	1(5.9)

Legend: OXA-48=Oxacillinase48; NDM=New Delhi Metallo-β-lactamase; KPC: *Klebsiella Pneumoniae* Carbapenemase; IMP= Imipenemase; VIM= Verona Integron-encoded Metallo-β-lactamase; ECBU=Urine cytobacteriological examination; SU=Urinary Catheter; Hemoc= Hemoculture

Table.4 Distribution of carbapenemase types identified according to species

Species	Count	Carbapenemase produced %	NDM	OXA48	IMP	VIM	KPC	Prevalence%
<i>E.coli</i>	9	6(35.3%)	2	3	1	0	0	66.7%
<i>K.pneumoniae</i>	8	4(23.5%)	3	1	0	0	0	50%
<i>C. freundii</i>	1	1(5 ;88%)	0	0	1	0	0	100%
<i>E. cloacae</i>	3	1(5.88%)	1	0	0	0	0	33.3%
<i>S. shigella</i>	1	2(11.7%)	1	0	1	0	0	200%
Total 1	27	14(82.3%)	7	4	3	0	0	51.8%
<i>P.aeruginosa</i>	6	2(11.7%)	1	0	0	1	0	33.3%
<i>A. baumannii</i>	6	1(5.88%)	0	0	1	0	0	16.7%
Total 2	13	3(17.7%)	1	0	1	1	0	23.1%
Total 1+2	40	17(100.0%)	8	4	4	1	0	42.5%

Legend: OXA-48=Oxacillinase48; NDM=New Delhi Metallo-β-lactamase; KPC: *Klebsiella Pneumoniae* Carbapénèmase; IMP= Imipenemase; VIM= Verona Integron-encoded Metallo-β-lactamase

Table.5 Frequency of resistance to the antibiotics tested in Gram-negative bacilli linked to expression of the carbapenemases NDM, OXA-48, IMP and VIM

Antibiotics	NDM (N=6)	OXA 48(N=4)	IMP (N=2)	NDM+IMP (N=2)	VIM (N=1)
	Resistance %	Resistance %	Resistance %	Resistance %	Resistance %
AUG	100%	100%	100%	100%	100%
TTC	100%	100%	100%	100%	100%
PIT	100%	100%	100%	100%	100%
CFM	100%	100%	100%	100%	100%
CRO	100%	100%	100%	100%	100%
CAZ	100%	100%	100%	100%	100%
CTX	100%	100%	100%	100%	100%
FEP	100%	100%	100%	100%	100%
IMI	83.3%	75%	100%	100%	100%
MRP	100%	100%	100%	100%	100%
ERT*	100%	100%	100%	100%	/
AK	66.7%	75%	100%	100%	100%
CN	83.3%	100%	100%	100%	100%
TOB	100%	100%	100%	100%	100%
NA	100%	100%	100%	100%	100%
CIP	83.3%	100%	100%	100%	100%
LEV	100%	100%	100%	100%	100%
NOR	100%	100%	100%	100%	100%
OFL	100%	100%	100%	100%	100%
FOS	100%	100%	100%	100%	100%

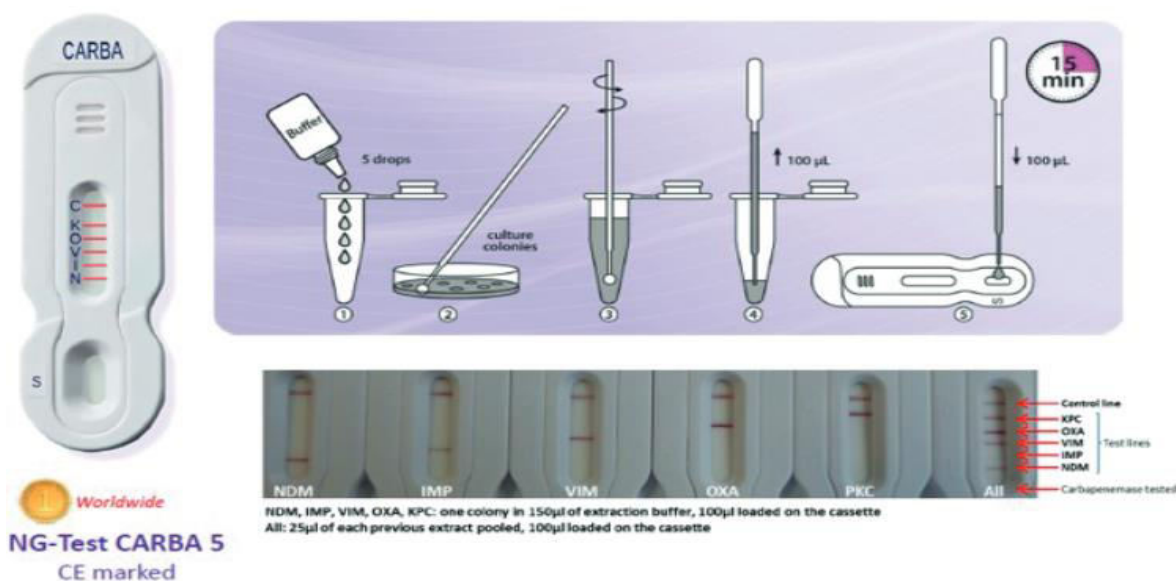
Legend: OXA-48=Oxacillinase48; NDM=NEW Delhi Metallo-β-lactamase; IMP= Imipenemase ; VIM= Verona Integron-encoded Metallo-β-lactamase ; AUG =Amoxicilline+clavulanic acid; TTC=Ticarcilline+acideclavulanique; PIT=piperacilline+tazobactam;CFM=cefixime; CRO=ceftriaxone; CAZ: ceftazidime; CTX=cefotaxime; FEP =cefepime; IMI =imipénème; MRP= meropénème; ERT =ertapénème; AK=amikacine; CN=gentamicine; TOB=tobramycine; NA=nalidixic acid; CIP =ciprofloxacin; LEV=levofloxacin; NOR=norfloxacin; OFL=ofloxacin; FOS= fosfomycine

Table.6 Frequency of carbapenemase-producing strains tested among carbapenem-resistant strains

Gram-negative bacilli Groups	Number of Multi-Resistant Strains	Number of strains Resistant to 3 Carbapenems	Number of Strains OXA48/NDM/IMP/VIM Positive (%)	Number of Strains OXA48/NDM/VIM/VIM Negative (%)
Enterobacteria	27	19	12(42.9)	7(25.0)
Non-fermenting	13	9	3(10.7)	6(21.4)
Total	40	28	15(53.6)	13(46.4)

Legend: GNB=Gram Negative Bacille; OXA-48=Oxacillinase48; NDM=New Delhi Metallo-β- lactamase; IMP= Imipenemase; VIM= Verona Integron-encoded Metallo-β-lactamase; KPC: *Klebsiella Pneumoniae* Carbapenemase

Figure.1 Procedure and interpretation of NG-Test CARBA 5 cassettes



Currently, NDM production in Enterobacteriaceae has been reported almost everywhere in the world, particularly in Asia, Australia, America and Europe, with the Indian subcontinent being the main reservoir (Zhanel *et al.*, 2007).

NDM-4 β-lactamase with increased carbapenemase activity compared with NDM-1 was described in a patient hospitalised in India; Dortet *et al.*, (2013) showed that this variant was also present in Africa, isolated in particular from a patient in Douala, who carried *E. coli* strains expressing two NDM variants (Nordmann *et al.*, 2009).

We did not identify any KPC-producing strains in the geographical area covered by this study, although they are currently the most clinically important in the world

(Livermore, 2000). Originally described in the USA and now distributed worldwide, this enzyme is most commonly found in *K. pneumoniae* and *Enterobacter spp* and is rare in *P. aeruginosa* and other Enterobacteriaceae (Nordmann *et al.*, 2009; Livermore, 2000).

The most common carbapenemases found in *P. aeruginosa* are mainly metallo-beta-lactamases of the VIM and IMP types; in *A. baumannii* the NDM, IMP, VIM and OXA-23, 40 and 58 types are specific to it, but not OXA 48 (Nordmann *et al.*, 2013).

OXA-48-producing bacteria, which often cause outbreaks of nosocomial infections, have been widely reported in Turkey, followed by countries in North Africa, the Middle East and India (Ktas *et al.*, 2008). The

carbapenem-resistant strains isolated in this study that did not produce NDM, OXA-48, VIM, IMP or KPC could produce carbapenemases not investigated here or have developed other resistance mechanisms (NCCLS, 2000).

These isolates are often associated with reduced external permeability, which is common in Enterobacteriaceae species that naturally produce a cephalosporinase, such as *Enterobacter spp* (Nordmann *et al.*, 2009).

The sensitivity profile showed good activity of Amikacin on multi-resistant strains and significant activity on OXA-48-producing strains; also reported by Harchay *et al.*, (2016) on MDR strains and by Okalla *et al.*, (2021) on *Enterobacteriaceae* producing Extended-Spectrum Beta-lactamases (ESBL) in Douala (Ebongue *et al.*, 2021; Bonnet *et al.*, 2013). The good activity of this antibiotic on these strains could be attributed to the low use of this molecule in our environment.

Rapid techniques for detecting carbapenemase activity (hydrolysis in *Enterobacteriaceae*, *P. aeruginosa* and *A. baumannii*), but not resistance genes, are highly sensitive and specific, with results available quickly, unlike costly molecular techniques (Yusuf *et al.*, 2011).

In a study carried out in Turkey on *K. pneumoniae* isolates, the results obtained by the RESIST-3 OKN K-SeT immuno-chromatographic method were identical to those obtained by PCR targeting the carbapenemase genes bla KPC, bla NDM and/or bla OXA-48, with 100% concordance (Harchay *et al.*, 2016).

Ebongue *et al.*, (2021) demonstrated the good performance of rapid immunochromatographic tests on clinical isolates, compared with molecular techniques (sensitivity greater than 99.4% according to the manufacturer and specificity of 100% for all the tests used in their study) (Ebongue *et al.*, 2021; Harchay *et al.*, 2016).

Limitations

At this stage of the study, confirmation of carbapenemase gene expression using PCR and DNA sequencing techniques has not been carried out. This study was aimed at the rapid detection of carbapenemases, demonstrated the presence of gram-negative bacilli-producing carbapenemases, in particular types NDM-1, OXA-48, VIM and IMP in the city of Douala. It is

essential to identify these strains to prevent their spread, the emergence of which could be linked to mutations that need to be explored using molecular techniques.

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Availability of data

All data supporting these results are available for consultation in the Bacteriology Unit of the DGH Clinical Biology Laboratory.

Authors' contributions

JPNM and AT coordinated the study; GGS, JPNM and GN drafted the manuscript; GGS, ERM, GPN, DA and COE collected data and participated in its design; COE, GGS, ERM, AAPN and MEJP performed the statistical analysis. All authors read and approved the final manuscript.

Ethics

The study was conducted following the ethical guidelines for research in Cameroon. We obtained research authorisations from the Directors of the hospitals concerned, ethical authorisation from the Institutional Ethics Committee for Human Health Research of the University of Douala (N° 1405/UD/FMSP), and approval from the Douala General Hospital.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no conflict of interest regarding the publication of this article.

References

Betbeu, Chafa A, Kamga *et al.*, Phenotypic detection of extended spectrum beta-lactamase and

- carbapenemases produced by *Klebsiella* spp isolate from three referrals hospitals in Yaounde, Cameroon. *Br Microbiol Res J*, 2015, 9.1: 1-9 <https://doi.org/10.9734/BMRJ/2015/18250>
- Bonnet R, Caron F, Cavallo J D, Chardon H, Chidiac C, Courvalin P, Drugeon H, Dubreuil L, Jarlier V, Jehl F, Lambert T. Comité de l'antibiogramme de la société française de microbiologie. In *Recommandations* 2013: 1-22
- Diene, Seydina M, Rolain, J.-M. Carbapenemase genes and genetic platforms in Gram-negative bacilli: Enterobacteriaceae, Pseudomonas, Acinetobacter species. *Clinical Microbiology and Infection*, 2014, 20.9: 831-838 <https://doi.org/10.1111/1469-0691.12655>
- Doortet L, Brechard L, Cuzon G, *et al.*, Strategie de detection rapide des enterobacteries productrices de carbapenemases. *Agent anti microbiens et chimiotherapie*, 2014, 58, 114-118
- Dortet, Laurent, Poirel, Nordmann. Epidemiologie, détection et identification des enterobacteries productrices de carbapenemases. *Feuillet de biologie*, 2013, 312
- Ebongue C, *et al.*, "Evolution de la résistance aux antibiotiques des entérobactéries isolées à l'Hôpital Général de Douala de 2005 à 2012." *The Pan African Medical Journal* 20 (2015). <https://doi.org/10.11604/pamj.2015.20.227.4770>
- Ebongue C, Simo G, NDA J P, Adiogo D *et al.*, Détection of production of *Klebsiella pneumoniae* Carbapenemase, New Delhi Metallo-Beta-lactamase and Oxacillinase-48-Type Carbapenemases by Gram-négative Bacilli in Resource-Limited setting. *Advances in microbiology*, 2021, 11, 579-590 <https://doi.org/10.4236/aim.2021.1110042>
- Hajar, Mlle Hnich. la résistance bactérienne: mécanisme et méthodes de détection au laboratoire. 2017: 1-32
- Harchay C, Battikh H, Fendri C. Clonal Dissemination of a multidrug-resistant strain of *Klebsiella pneumoniae* producing OXA-48 carbapenemase at a Tunisian Hospital. *Int. J. New Technol. Res.* 2016;2:21-7
- Ktas Z, Kayacan C, Schneider I. Carbapenem-hydrolyzing oxacillinase OXA-48 persists in Istanbul, Turkey. *Chemother.* 2008;54:101 - 106
- Lagha, Nouria, *et al.*, Etude de la résistance aux antibiotiques des enterobacteries productrices de b-lactamases à spectre étendu isolée de l'hôpital de Laghouat. Thèse de doctorat. 2015: 1-56
- Liapid and Asma. Etude de la résistance aux antibiotiques des bacteries à Gram négatif non fermentantes au niveau du CHU de Tlemcen. 2012: 1-73
- Livermore D M. Carbapenemases; a problem in waiting? *Curr Opin Microbiol* 2000: 1-43
- NCCLS (National Committee for Clinical Laboratory Standards). Performance standards for antimicrobial disk susceptibility testing. 7th edition (2000): 1-8
- Nordmann P, Cuzon G, Naas T. The real threat of *Klebsiella pneumoniae* carbapenemase-producing bacteria. *Lancet Infect Dis.* 2009; 9(4):228-236. [https://doi.org/10.1016/S1473-3099\(09\)70054-4](https://doi.org/10.1016/S1473-3099(09)70054-4)
- Nordmann P, Dortet L, et Poirel L. Résistance aux carbapenemes chez les enterobacteries : c'est la tempête ! *Tendances mol. Med.* 2012, 18 :263-272. <https://doi.org/10.1016/j.molmed.2012.03.003>
- Nordmann P, Naas T, Poirel L. Global spread of carbapenemase-producing enterobacteriaceae *Emerg Infect Dis* 2011, 17: 1791-1798 <https://doi.org/10.3201/eid1710.110655>
- Nordmann P. Carbapenemase-producing enterobacteriaceae: overview of a major public health challenge. *Med Mal Infect*, 2014, 44, 51-56 <https://doi.org/10.1016/j.medmal.2013.11.007>
- Nordmann P., Dortet L., Poirel L. Multi résistance aux antibiotiques: l'émergence des enterobacteries productrices de carbapénemases. *Revue francophone des laboratoires.* 2013 1; 449: 35-7 [https://doi.org/10.1016/S1773-035X\(13\)71854-9](https://doi.org/10.1016/S1773-035X(13)71854-9)
- Okalla CE, Donfack D, Penda CI, Essome H, Koum DK, Mengue ER, Chuengoue A, Adiogo D. 2021. Prevalence of anti-measles antibodies in infants from 0 to 9 months : Case of three hospitals in the city of Douala (Cameroon). *Microbes Infect Dis* 2021; 2(4): 682-689.
- Sbiti, M. Profil epidemiologique des enterobacteries uropathogenes productrices de beta-lactamases à spectre élargi. *The Pan African Medical Journal*, 2017, 28, 245-248 <https://doi.org/10.11604/pamj.2017.28.29.11402>
- Tamma, Pranita D, Praticia J *et al.*, Detection phenotypique d'organismes producteurs de carbapenemases à partir d'isolats cliniques. *Journal de microbiologie clinique*, 2018, 56, 322-325
- Yusuf, I., *et al.*, Detection of AMPC Carbapenemase and

extended spectrum betalactamases among clinical bacterial pathogens in Nigeria. *Africa Journal of Science, Technology and Social Sciences*, 2011, 1.1: 8-24

Zhanel G G, Wiebe R, Dilay L, Thomson K, Rubinstein E, Hoban D J, *et al.*, Comparative review of the carbapenems. *Drugs* 2007; 67: 1027-52
[https://doi.org/10.2165/00003495-200767070-](https://doi.org/10.2165/00003495-200767070-00006)

[00006](https://doi.org/10.2165/00003495-200767070-00006)

Vaux S., Viriot D., Forgeot C. 2022. Bronchiolitis Epidemics in France During the SARS-CoV-2 Pandemic: The 2020-2021 and 2021-2022 Seasons, *Infectious Diseases Now* 52, no. 6: 374–378.

<https://doi.org/10.1016/j.idnow.2022.06.003>.

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doi: <https://doi.org/10.20546/ijcmas.2024.1308.009>