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Phenotypic Characterization and Prevalence of Carbapenemase-Producing *Acinetobacter baumanii* Isolates in Four Health Facilities in Cameroon

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Abstract

Background and Objective: Nowadays, the clinical utility of carbapenems is threatened by the emergence of resistant bacteria, favored by its increasing use. According to the WHO, *Acinetobacter baumannii*: nosocomial infection agent, tops the list of priority antibiotic-resistant pathogens, considered to be the riskiest for humans. This study sought to determine the prevalence of carbapenemase-producing *Acinetobacter baumannii* strains in four health facilities in the Center and Littoral regions of Cameroon and the associated risk factors. **Materials and Method:** An analytical cross-sectional study was conducted over a six-month period from January to June 2022. All suspicious *A. baumanii* isolates obtained from pathological samples at the bacteriology laboratory of the different health facilities were systematically collected and re-identified. Re-identification and antimicrobial susceptibility Testing (AST)

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were performed using the VITEK 2 System and the Kirby-Bauer method according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI). Detection and phenotypic characterization of carbapenemases was performed according to adequate standard procedures. **Results:** A total of 168/226 clinical isolates of *Acinetobacter baumannii* were confirmed after re-identification, among which 52.69% derived from male patients, 55.09% from participants aged between 10 - 39 years old, and 46.71% from pus samples. A very high resistance rates to all families of antibiotics was noted, except to colistin (10.2%). 40.12% of these isolates produced carbapenemase, represented by 62.69% of class B and 37.31% of class A. Carbapenemase production was observed only at HMR1, Centre region and at Laquintinie hospital, Littoral region with 53.33% and 50% respectively, even if there is no significant difference (P = 0.81). In addition, frequent hospitalisation was significantly associated to the production of carbapenemase among *A. baumanii* (Adjusted-OR = 16.53, P-value < 0.0001). **Conclusion:** This study highlighted the emergence of carbapenemase-producing *Acinetobacter baumannii* which is increasingly growing. Continuous drug-resistant monitoring and preventive measures could help to prevent and curb the dissemination of *A. baumanii* resistance genes, especially in health settings.

Keywords

Acinetobacter baumannii, Resistance, Carbapenemases, Health Facilities

1. Introduction

Acinetobacter is a Gram-negative aerobic bacillus or coccobacillus that belong to the *Moraxellaceae* family [1]. Bacteria belonging to this genus are ubiquitous and can survive on dry surfaces for up to a month. They are frequently carried on the skin of healthcare workers, and increase the likelihood of both colonizing patients and contaminating medical equipment. There are several species of Acinetobacter which can cause disease in humans, and *A. baumannii* (AB) accounts for almost 80% of infections [2]. It is responsible for a variety of human infections such as ventilator-associated pneumonia, bacterial meningitis, wound and soft tissue infections, peritonitis, urinary tract infections and healthcare-associated infections [3]. One of the factors contributing to chronic and persistent infection with resistant *Acinetobacter baumanii* is its ability to colonize and then form a biofilm on biotic surfaces. This confers to *Acinetobacter baumanii* the aptitude to easily survive and spread in the hospital environment, by adhering on various biotic and abiotic surfaces such as: foleys catheter vascular catheter, cerebrospinal fluid shunts [4] [5].

Antibiotic resistance is the ability of a microorganism to resist the effects of antibiotics [3]. In the past, clinical isolates of *Acinetobacter baumanii* were susceptible to most groups of available antibiotics until few years ago when they

acquired a high capacity to develop resistance against many antibiotics [5]. This can be explained by the fact that *Acinetobacter baumanii* has a very high capacity to adapt to stress and has experienced prolonged exposure to antibiotics in health care facilities [5].

In Geneva in 2017, the WHO published a list of bacteria that have become resistant to several classes of antibiotics, including carbapenems and third-generation cephalosporins [6]. Multi-drug resistant *Acinetobacter baumanii* (MDRAB) has been identified as one of the major relevant multi-drug resistant organisms threatening human health [6]. In the modern health system, *Acinetobacter baumanii* is undoubtedly one of the most dominant pathogen responsible of nosocomial infections, taking into account: its emergent character, its opportunistic pathogenicity, its resistance to antibiotics and its power of epidemic diffusion. Nowadays, few antibiotics are able to treat infections caused by this pathogen [6] [7]. Their resistance to carbapenems is linked to the expression of resistance mechanisms such as: overexpression of extended-spectrum betalactamases, efflux pumps, impermeability; and/or the expression of carbapenem-hydrolysing betalactamase, known as carbapenemase [8]. Carbapenemases are betalactamases belonging to the class B according to the Ambler's classification, capable of hydrolyzing carbapenems [9].

Worldwide, several data on *Acinetobacter baumanii*'s resistance to antibiotics have already been reported. From a systematic review and meta-analysis [10] on the incidence and prevalence of hospital-acquired infections (HAIs) caused by *Acinetobacter baumannii* (HA-AB), particularly HA-carbapenem resistant *A. baumanii* (HA-CRAB) infections in the WHO-defined regions of Europe (EUR), Eastern Mediterranean (EMR) and Africa (AFR),conducted by Soha *et al.* in 2019; it was reported that the pooled incidence and incidence density of carbapenem-resistant *A. baumannii* infections in intense care units (ICUs) were 41.7 (95% CI 21.6 - 78.7) cases per 1,000 patients and 2.1 (95% CI 1.2 - 3.7) cases per 1000 patient days, respectively. In ICUs, *A. baumannii* and carbapenem-resistant *A. baumannii* strains accounted for 20.9% (95% CI 16.5% - 26.2%) and 13.6% (95% CI 9.7% - 18.7%) of all HAIs, respectively [10]. In Africa, high rates of MDR *A. baumannii* infections have been reported in several countries. Laouar *et al* in Algeria in 2019 found that the resistance of *Acinetobacter baumanii* strains to Imipenem evolved impressively over time. It increased from 26% in 2007 to 88.1% in 2016, while 57.1% of carbapenemase-producing strains came from intensive care units [11]. A study undergone by Ogbulu *et al.* in Nigeria in 2020 showed very high resistance rate of *Acinetobacter baumanii* to carbapenems (55.2%) and only low susceptibility rates were observed toward colistin and amikacin [12]. According to Pillay *et al.* in South Africa in 2021, hospital effluents constitute a potential risk to the formation of multi-drug-resistant biofilm of *Acinetobacter baumanii* strains [13].

A systematic review and cumulative meta-analysis of carbapenemase-producing *Acinetobacter baumanii* (CPAB) conducted by Mizan *et al.* in Africa from 2014

to 2019 showed a higher prevalence of CPAB isolates across this time period. The period prevalence CPAB among the clinical specimens in Africa was 56.97%, and the class B carbapenemase, VIM (Verona integron-encoded metallo-beta-lactamase) was the most prevalent [3]. In this review, literature was retrieved from all over Africa except from Central Africa were Cameroon is located [3]. This might show that the scarcity of data on resistant AB in Africa is still a problem for developing countries such as Cameroon. Moreover, applying evidence-based infection control and prevention is still challenging the health system. This might impede patients' care and public health, leaving the vulnerable population. This is the reason why we aimed at determining the prevalence of CPAB isolates and the risk factors associated, in some health facilities in Cameroon.

2. Material and Method

2.1. Study Design, Location and Period

A cross-sectional and analytical study was carried out during a six-month period, from 7 January to 28 June 2021. Isolates were collected from four health facilities located in the two most crowded regions of Cameroon: Centre and Littoral. Three health facilities were located in the Centre region (the Military Hospital of Yaounde, the Dominicain Saint Martin de Porres Hospital, and the Referral Teaching Hospital of Yaounde), and one was located in the littoral region (Laquintinie Hospital). The strains re-identification and further biological analyses were carried out at the laboratory setting of the Military Hospital of Yaounde.

2.2. Sampling Method and Selection Criteria

During the study period, all AB or suspicious AB strains isolated from pathological specimens (pus, wounds, urines, bloods, effusion fluids, and cervico-vaginal swabs) at each bacteriology laboratory of the concerned health facilities were systematically collected, stored, and later included in the study for the upcoming re-identification and analyses. Strains non-*A. baumanii* after re-identification and those with a lack of useful clinical information were excluded from the study.

2.3. Re-Identification and Samples Processing

2.3.1. Subculture of Collected Isolates

The isolates contained in cryotubes containing 1.5 mL of brain-heart broth supplemented with 10% glycerol were inoculated around the flame on nutrient agar by the streaking method.

2.3.2. Identification and Antimicrobial Susceptibility Testing (AST)

The colonies obtained were firstly subjected to macroscopic examination (description of the size, color, and appearance of the colonies), followed by an oxidase test on one pure colony. Identification and AST were performed on a bac-

terial suspension (the 0.5 McFarland bacterial suspension was diluted to 1.5 × 107 CFU/ml in 0.45% saline) using the VITEK 2 System (VITEK® 2, BioMerieux, France). The minimum inhibitory concentration (MIC) was determined for the available 12 antibiotics in the Vitek 2 GN ID card (Biomeriux, France), including: ceftazidime, cefotaxime, cefepime, piperacillin/tazobactam, imipenem, meropenem, gentamicin, amikacin, tobramycin, levofloxacin, tetracycline and sulfamethoxazole/trimethoprim. Card was automatically filled, sealed, and loaded into the VITEK 2 instrument for incubation and reading. Kirby-Bauer method was used to test the susceptibility to four other antibiotics, namely: ticarcillin, ticarcillin/clavulanic acid, piperacillin and colistin, not available in the Vitek® system. Results were interpreted according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI) [14].

2.3.3. Detection of Carbapenemases

All isolates of imipinem-resistant AB (IRAB) isolates were subjected to the carbapenemase phenotypic caracterisation tests using Boronic acid and Chelating agent (EDTA), for identification of class A and class B (Metallo-B-Lactamases) carbapenemases respectively. IRAB isolates were tested for KPC carbapenemases production on disks containing boronic acid. A disk containing imipenem (Mast, UK) and another containing imipenem with 400 µg of boronic acid (Sigma-Aldrich, Germany) were placed on the Muller hinton agar on which the test organism was seeded. The diameter of the growth-inhibitory zones around the imipenem disk with boronic acid was compared with that around the corresponding imipenem disk without boronic acid. The test was considered positive for the detection of class A carbapenemase production when the diameter of the growth-inhibitory zone around the imipenem disk with boronic acid was ≥5 mm larger than that around the disk containing only imipenem [15]. The detection of MBL production was performed using the same principle, based on inhibition by EDTA. This technique consisted of two imipenem disks; one with and another without 10 µl of 0.5 M EDTA. An increase of 10 mm in the inhibition zone diameter in the presence of EDTA was considered positive [16].

2.4. Statistical Analysis

The different data collected were recorded in Excel 2013 software and then analyzed with the statistical software, Statview 5.0 (SAS Institute Inc., Cary, NC, USA). The analysis included the calculation of the frequency and their intervals at 95% CI (for qualitative variables) and the mean or the median (for quantitative variables). Odds ratios were used to determine the risk factors associated with *Acinetobacter baumanii*-producing carbapenemases contamination. Chi-square test was used to compare the proportions of categorical variables, and a P-value < 0.05 was considered statistically significant.

2.5. Ethical Consideration

An ethical clearance was issued by the institutional research ethics committee of

the University of Douala (Authorization N˚2737 CEI-Udo/07/2021/M; 13 July 2021 and Autorisation N˚3041 CEI-Udo/04/2022/M; 11April 2022) and research authorizations from the directors of each hospital were obtained.

3. Results

3.1. Description of the Source Characteristics of the Isolates Collected

From the 226 strains collected initially, 167 (73.89%) were finally confirmed as *Acinetobacter baumanii* after re-identification (Table 1).

The majority of isolates were obtained from Laquintinie Hospital of Douala in Littoral region, Cameroon, 70.66% (118/167), from male patients, 52.69% (88/167) and from participants aged between 10 - 39 years old, 55.09% (92/167). Moreover, 46.71% (78/167) of isolates derived from pus samples and 4.79% (8/167) from vaginal samples.

3.2. Susceptibility of *Acinetobacter baumanii* Isolates to Beta-Lactams

The drug susceptibility profile of AB to beta-lactams is presented in Figure 1.

Table 1. Frequency distribution of AB isolates in hospitalized patients in Cameroon according to source characteristics.

Characteristcs	Categories	Number (N = 167)	Percentage (%)
Partcipant's age (years)	<10	29	17.37
	[10 - 39]	92	55.09
	≥40	46	27.54
Participant's gender	Female	79	47.31
	Male	88	52.69
Health care facility	DSMPH	14	8.38
	CHUY	20	11.98
	HMR1	15	8.98
	Laquintinie	118	70.66
Sample type	Urine	44	26.35
	Blood	37	22.16
	Vaginal swab	8	4.79
	Pus	78	46.71
Antibiotherapy	No	66	39.52
	Yes	101	60.48
Frequent hospitalisation	No	85	50.90
	Yes	82	49.10

The sensitivity profile of AB showed a very high resistance rate to all beta-lactams such as: penicillins (piperacillin: 94.7% and ticarcillin: 99.1%), cephalosporins (cefotaxime: 70.6%, ceftazidime: 82.9% and cefepime: 74.1%) and carbapenems (imipenem: 61.7% and meropenem: 65.2%). It was also noted a high resistance to beta-lactams supplemented with beta-lactamase inhibitors (piperacillin/tazobactam: 79.6% and ticarcillin/clavulanic acid: 81.9%).

3.3. Resistance Profile of *Acinetobacter baumanii* to Other Families of Antibiotics

Resistance Profile of AB to aminoglycosides, fluoroquinolones, tetracyclines, polymyxin and cotrimoxazol were tested in order to determine their resistance profile (Figure 2).

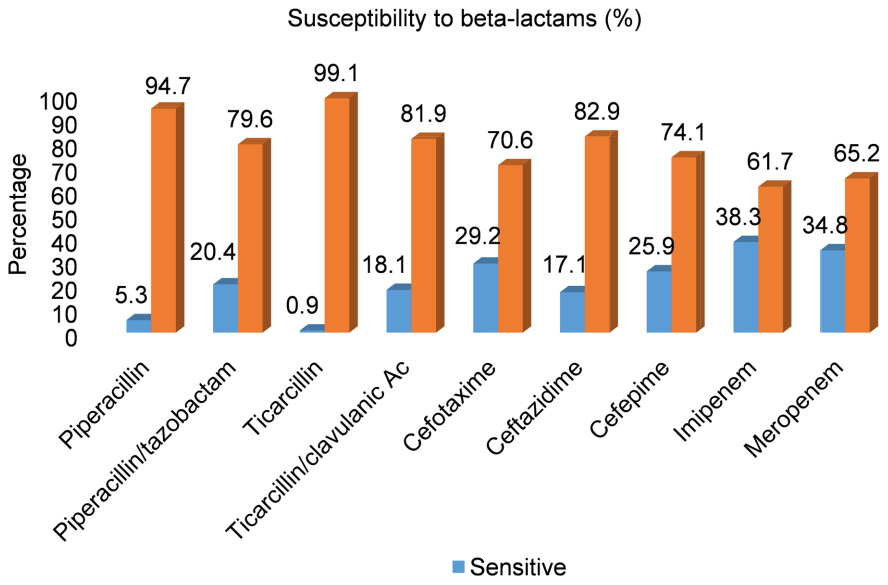

Figure 1. Susceptibility profile of *Acinetobacter baumanii* isolates to beta-lactams in hospitalized patients in Cameroon.

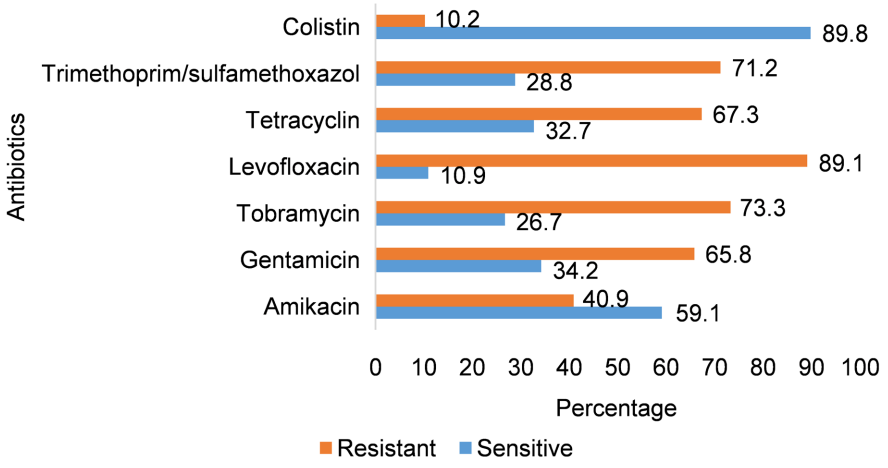

Figure 2. Susceptibility profile of *Acinetobacter baumanii* isolates to others families of antibiotics in hospitalized patients in Cameroon.

There was high resistance to fluoroquilonones (89.1% to levofloxacin), to tetracyclin (67.3%), to aminoglycosides (73.3% to tobramycin, 64.8% to gentamicin and 40.9% to amikacin) and to cotrimoxazol (71.2%). However, there was a low resistance rate to colistin (10.2%).

3.4. Prevalence of Carbapenemase Producing *Acinetobacter baumanii*

The frequency production frequency of carbapenemase and the classification of carbapenemases are shown in Figure 3.

In this study, the overall prevalence of *Acinetobacter baumanii*-producing carbapenemase was 40.12% (67/167), including 62.69% (42/67) of class B (metallo-beta-lactamase) and 37.31% (25/67) of class A.

Furthermore, the distribution of carbapenemase producing isolates is presented in Table 2.

It can be observed from Table 2 that null carbapenemase producing isolate have been recovered from DSMPH and CHUY. Conversely, frequent carbapenemase producing *Acinetobacter baumanii* was observed in other Health care facilities, even though no significant difference (P = 0.81). Similarly, there was no significant difference between carbapenemase producing *Acinetobacter baumanii* prevalence within different socio-demographic (age and gender) categories (P ≤ 0.05) (Table 2).

3.5. Analysis of Risk Factors Related to *Acinetobacter baumanii*'s Carbapenemase Production

Univariate analysis of risk factors to the carriage of carbapenemase producing *Acinetobacter baumanii* among infected participants is presented in Table 3. Significant risk factors in this previous analysis were introduced in a multivariate model (Table 4).

This current research revealed that frequent hospitalisation was significantly associated to the carriage of carbapenemase producing *Acinetobacter baumanii* among infected patients (Adjusted-OR = 16.53, P-value < 0.0001).

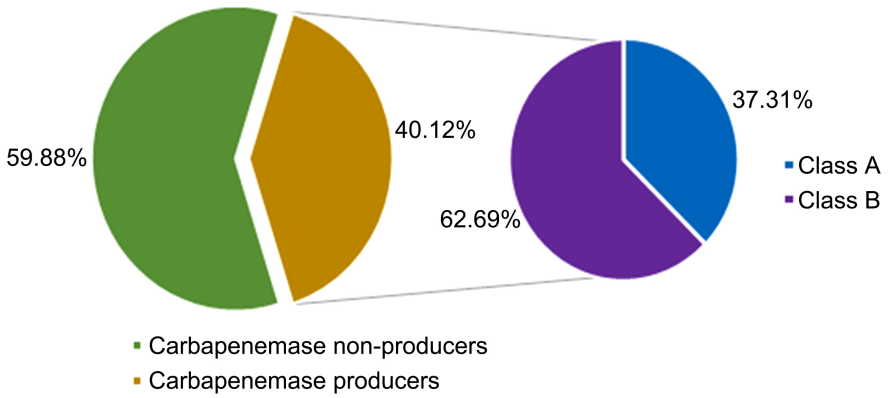

Figure 3. Prevalence and classification of carbapenemase-producing *Acinetobacter baumanii* in hospitalized patients in Cameroon.

Table 2. Distribution of carbapenemase producing *Acinetobacter baumanii* in hospitalized patients in Cameroon according to source characteristics.

Characteristics		N	CPAB		P-value
			n	n/N (%)	
	Total	167	67	100	-
Age	<10	29	15	51.72	0.23
	[10 - 39]	92	32	34.78	
	≥40	46	20	43.48	
Gender	Female	79	26	32.91	0.07
	Male	88	41	46.59	
Health care facility	DSMPH	14	0	0.00	0.81
	CHUY	20	0	0.00	
	HMR1	15	8	53.33	
	Laquintinie	118	59	50.00	
Sample type	Urine	44	23	52.27	0.11
	Blood	37	17	45.95	
	Vaginal swab	8	2	25.00	
	Pus	78	25	32.05	

Table 3. Univariate analysis of risk factors related to carbapenemase producing *Acinetobacter baumanii* in hospitalized patients in Cameroon.

Variables	Categories	Carbapenemase producing *Acinetobacter baumanii* n (%)	OR (95% CI)	P-value
Antibiotherapy	No	2 (3.03)	1	Ref
	Yes	65 (64.36)	57.78 (13.35 - 250.07)	<0.0001
Hospial food consumption	No	55 (40.15)	1	Ref
	Yes	12 (40.00)	0.99 (0.44 - 2.23)	0.99
Frequent hospitalisation	No	5 (5.88)	1	Ref
	Yes	62 (75.61)	49.60 (17.63 - 139.57)	<0.0001
Using common toilet	No	2 (20.00)	1	Ref
	Yes	65 (41.40)	2.83 (0.58-13.74)	0.32

Table 4. Multivariate analysis of risk factors related to carbapenemase producing *Acinetobacter baumanii* in hospitalized patients in Cameroon.

Variables	Categories	Ajusted-OR (95% CI)	P-value
Antibiotherapy	No	1	Ref
	Yes	6.00 (0.92 - 38.98)	0.06
Frequent hospitalisation	No	1	Ref
	Yes	16.53 (4.36 - 62.66)	**<0.0001**

4. Discussion

In order to fight against the emergence and spread of multiresistant bacteria, this study aimed to determine the prevalence and risk factors of carbapenemase-producing *Acinetobacter baumannii* isolated from four health facilities in Cameroon. The study took place in two regions of Cameroon (Central and Littoral regions). Out of 226 collected strains, 168 (74.34%) were confirmed *Acinetobacter baumannii* isolates. The majority of isolates came from Laquintinie Hospital of Douala in Littoral region, Cameroon (70.66%).

In the present study, 88 (52.69%) clinical isolates included were from male patients with highest number of isolates from patients aged between 10 - 39 years old. This is in line with a recent study realized by Rao *et al.* which reported a high proportion of males (81.8%) [17]. These findings suggest that male and elderly were more vulnerable for infections in both studies. 46.71% of these strains came from suppurations, 26.35% from urine and 22.16% from blood samples. These results are in agreement with those of Okalla *et al.* in 2015, in Cameroon which found that the majority of their strains came from suppurations, urine and urinary catheters [18]. In addition, Castilho *et al.* in 2017 revealed that in terms of the topography of infection, the lungs were the most common site (53.1%), followed by the site of surgical intervention (postoperative wounds) (10.9%), the urinary tract (7.8%) and the blood stream (*i.e.*, sepsis) (6.2%) [19]. This can be explained by the fact that, in the hospital environment, wounds and other lesions are prone to contamination with a multitude of organisms including *Acinetobacter baumannii*, which is one of the bacteria mostly incriminated in nosocomial infections. CAUTIs (catheter-associated urinary tract infections) continue to be one of the most common health-care-related illnesses worldwide. CAUTIs are incriminated in 40% of all hospital-acquired infections and 80% of all nosocomial urinary tract infections (UTIs). Urine catheters are frequently implanted to inpatients at some health facilities, and they are indwelling urinary catheter most of the time. Urinary catheters, made up of plastic materials, inhibit the urinary tract's natural defense mechanisms and enhance the bacterial colonization or biofilm formation on the catheter surface, which may cause CAUTIs [20].

From antimicrobial susceptibility testing, the percentage rates of resistance to

tested antibiotics range from 40.9% to 99.1% with the exception of colistin, toward which a resistance was of 10.2% was observed. Carbapenem resistant *A. baumannii* is a major concern since it is the drug of choice in the treatment of *A. baumannii* infections [21]. The results showed that *Acinetobacter baumanii* had a very high resistance rate to beta-lactams (82.9% ceftazidime and 74.1% cefepime) including carbapanems (resistant to both imipenem 61.7% and meropenem 65.2%). In accordance to the current study, a recent study in South Africa high resistance rates toward cefepime (73%) and ceftazidime (80%) [22]. Similarly, Anane *et al.* in 2020 reported very high resistance rates toward beta-lactams, including imipenem (81%) and meropenem (83%) [23]. Comparing the results of this current study with these earlier ones previously mentioned indicates that the resistant rate of *A. baumannii* to various antibiotics has not really decreased. High levels of resistance toward third and fourth generation cephalosporins, and carbapenems in this study indicates that they are no longer really effective in the treatment of infections caused by *A. baumannii* in Cameroon. Thus, this phenomenon constitutes a great challenge given that these antibiotic families are used as the last therapeutic alternatives in cases of antibiotic therapy failure.

The antibiotic susceptibility testing results also showed high resistance to fluoroquinolones (89.1% to levofloxacin), to tetracyclin (67.3%), to aminoglycosides (73.3% to tobramycin, 64.8% to gentamicin and 40.9% to amikacin) and to trimethoprim/sulfamethoxazol (71.2%). Resistance was a hence mostly enhanced toward fluoroquinolones (FQs) and conversely, a lower resistance rate was observed toward amikacin as compared to other aminoglycosides. Our results are higher than those of Okalla *et al.* in 2013 in Cameroon which revealed a resistance rate of 24.43% to Amikacin and 50% to fluoroquinolones [18], which fortifies the fact that resistant *Acinetobacter baumanii* is evolving. This could be explained by the fact that FQs have the widest use and are currently recommended by different physicians as they have multiple applications and different advanced generations [24]. Nevertheless, the emergence and spread of bacterial resistance to FQs among Gram-negative bacteria generally, and *A. baumannii* specifically, is becoming increasingly serious with their extensive use. The developing resistance of *A. baumannii* to antimicrobial agents has been described and this was attributed to the abundance of these antibiotics in multiple pharmaceutical markets [25], and their misuse [26]. *A. baumannii* burden is difficult to remedy, due to the its ease to acquire antimicrobial resistance genes favored by the suppleness of its genome [27]. Compared to the study realised by Anane *et al.* in 2020, which observed 5% resistance to colistin [23], there is an increase in the resistance rate to colistin. The susceptibility of *A. baumannii* to colistin in this study indicates that colistin is still a better option for the treatment of infections caused by *A. baumannii* in Cameroonian health facilities. However, the issue of nephrotoxicity, neurotoxicity, colistin-resistance, and hetero-resistance shown by colistin monotherapy is a challenge in the management of this infection [28].

Out of the 168 isolates of *A. baumanii*, the carbapenemase producers represented

40.12%, among which 37.31% were belonging to class A carbapenemase and 62.29%to class B. This prevalence is lower than the one obtained by Mizan *et al.* in 2020 (56.97%) [3] and could therefore be explained by the fact that, it was a cumulative meta-analysis including several studies made in Africa. Metallo-beta-lactamase (MBL) was the most represented among CPAB isolates. This is consistent with other reviews that were conducted globally [29] [30]. Indeed, carbapenemases represent three classes of β-lactamases. The three classes are Ambler class A and D carbapenemase (serine carbapenemases), and class B carbapenemases (zinc dependent). The latter are inhibited by metal chelators, such as EDTA and are called metallo-β-lactamases (MBLs). Metallo-β-lactamases (MBLs) enzymes are able to hydrolyze all β-lactam antibiotics and MBL genes are usually located on transferable genetic elements such as plasmids and integrons, along with other antibiotic resistance genes [27]. Therefore, dissemination of strains harboring MBL genes is of crucial importance, and appropriate measures should be taken into consideration by infection control programs [31]. In Cameroon, studies carried out over the past two to three years have sounded the alarm regarding the production of beta-lactmases, including carbapenemases, by bacteria, which calls for greater vigilance and monitoring rigorous epidemiology [32] [33] [34] [35] [36].

By analyzing the risk factors, the current study revealed that frequent hospitalisation was significantly associated to the carriage of carbapenemase producing *Acinetobacter baumanii* among infected patients (Adjusted-OR = 16.53, P-value < 0.0001). According to Pillay *et al.* in South Africa in 2021, hospital effluents pose a potential risk of multidrug-resistant biofilm formation of *Acinetobacter baumanii* strains [13]. The impressive spread and prevalence of *A. baumannii* in healthcare settings has been facilitated by its ability to withstand dry and humid environments, its resistance to disinfectants and antibiotics, and its biofilm-forming property that leads to colonization of inert surfaces and medical devices [37].

The limitation of this study was the inability to carry out a molecular characterization of the *Acinetobacter baumanii* isolates due to the lack of funding. This funding aspect could make it possible later in order to deepen the research with molecular analyses for a complete evaluation of the genes encoding the production of carbapenemases, including class D beta-lactamases which are not inhibited by β-lactamase inhibitors [38].

5. Conclusion

This study highlighted a high prevalence of *Acinetobacter baumanii*-producing carbapenemase. The patients being frequently hospitalised were the most affected. However, only amikacin and colistin were antibiotics toward which beta-lactam resistant *A. baumanii*-resistant expressed higher susceptibility. Continuous drug-resistant monitoring and preventive measures could help to prevent and stem the dissemination of AB resistance genes, especially in health facilities.

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Consent for publication

All authors consented for publication.

Availability of data and material

All data generated or analysed in the course of this study are included in this manuscript.

Authors' Contributions

Conceptualization, C.I.D. and N.A.M.; Methodology, C.I.D., P.D.D.D, A.M. and B.N.; Software, P.D.D.D., C.S.N. and C.G.; Validation, A.M., B.D.T.P. and C.I.D.; Formal Analysis, P.D.D.D., B.N., and H.V.S.N.; Investigation, C.G., C.K.P., H.V.S.N., Y.G.K., B.T.C., G.N.F, O.P. and M.J.T.; Resources, C.I.D and B.D.T.P.; Data Curation, P.D.D.D. and C.S.N.; Original Draft Preparation, P.D.D.D. and C.G.; Writing, Review & Editing C.I.D., P.D.D.D., R.K.W., C.S.N. and B.D.T.P.; Visualization, C.I.D. and B.D.T.P.; Supervision, B.D.T.P. and T.A.; Project Administration, C.I.D., B.D.T.P. and N.A.M.; Funding Acquisition, C.I.D.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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