

Original Research Article

Prevalence Of Carbapenem Resistant *Klebsiella pneumoniae* in Clinical Samples From Some Selected Hospitals in Zaria, Kaduna State.

ABSTRACT

Aims: To determine the prevalence of carbapenem resistant *Klebsiella pneumoniae* in clinical samples from some selected hospitals in Zaria, Kaduna state.

Study design: Hosital based cross sectional study.

Methodology: A total of 150 clinical samples were collected from which 19 *Klebsiella pneumoniae* were isolated. Antibiotic susceptibility testing was carried out for all the isolates. The isolate that was resistant to Imipenem was screened for *K. pneumoniae* carbapenase production using the Modified Hodge Test. Out of the 19 isolates screened, only one was intermediately resistant to Imipenem. This isolate was screened for *Klebsiella pneumoniae* carbapenemase (KPC) production using the Modified Hodge Test (Cloverleaf test). The isolate was a non KPC producer, suggesting the resistance to Imipenem is likely due to other mechanism such as decreased outer membrane permeability, over expression of β -lactamases, production of cephalosporinase and porin loss but not due to carbapenemase production. The prevalence of carbapenems resistant *Klebsiella pneumoniae* in Zaria as seen in this study is 5.26% and that of KPC producing *Klebsiella pneumoniae* is 0%.

Results: Out of the 19 isolates screened, only one was intermediately resistant to Imipenem. This isolate was screened for *Klebsiella pneumoniae* carbapenemase (KPC) production using the Modified Hodge Test (Cloverleaf test). The isolate was a non KPC producer, suggesting the resistance to Imipenem is likely due to other mechanism such as decreased outer membrane permeability, over expression of β -lactamases, production of cephalosporinase and porin loss but not due to carbapenemase production. The prevalence of carbapenems resistant *Klebsiella pneumoniae* in Zaria as seen in this study is 5.26% and that of KPC producing *Klebsiella pneumoniae* is 0%.

Conclusion: Even though the level of carbapenem resistance was low and none of the isolates was a KPC producer, most of the isolates were multidrug resistant isolates and this is alarming.

Keywords: carbapenems, *Klebsiella pneumoniae*, *Klebsiella pneumoniae* carbapenemase (KPC), Modified Hodge Test, Imipenem, resistance.

1.0 INTRODUCTION

Klebsiella pneumoniae is a Gram-negative, non-motile, encapsulated, lactose fermenting, facultative anaerobic, rod shaped bacterium found in the normal flora of the mouth, skin and intestines. In the recent years, *Klebsiella pneumoniae* has become important pathogen in nosocomial infections. *Klebsiella pneumoniae* is most frequently recovered from clinical specimens and can cause a classic form of primary pneumonia. *Klebsiella pneumoniae* can also cause a variety of extrapulmonary infections, including enteritis and meningitis in infants, urinary tract infections in children and adults and septicaemia. Carbapenems are a class of β -lactam, broad spectrum antibiotic which act by inhibiting the cell wall synthesis and are known to be most effective against Gram negative infections. Carbapenem in

combination with other agents, remain a mainstay of therapy in patients with serious hospital acquired infections. The introduction of carbapenem into clinical practice represents a great advancement for the treatment of β -lactam resistant bacteria. Due to their broad spectrum of activity and stability to hydrolysis by most beta lactamases, the carbapenem have been the drug of choice for treatment of infections caused by penicillin or cephalosporin resistant Gram negative bacilli [1].

Carbapenems exhibit bacteriocidal activity by binding to the penicillin binding proteins (PBP), thus preventing the linking of peptidoglycan strands and further synthesis of the bacterial cell wall [2]. Resistance to carbapenem is produced through 3 mechanisms: reduced permeability, efflux and synthesis of carbapenem β -lactamases [3].

Until recently, carbapenems were the choice for the therapeutic management of multidrug-resistant Gram-negative bacterial infections. Currently, the spread of carbapenem-resistant bacteria has caused grave concern due to the limited choice in antibiotics for treating infections caused by Gram negative bacilli [4]. Resistance in bacteria to carbapenems mainly is due to the production of carbapenem hydrolyzing enzymes called carbapenemases. These bacteria have the potential to spread rapidly within the hospital environment and also across continents [5].

In 2001, the first KPC-producing *K. pneumoniae* isolate was reported in North Carolina, USA [6]. The enzyme (KPC-1), an Ambler class A beta-lactamase, was not the first carbapenemase to be detected in *K. pneumoniae*, as isolates harboring Ambler class B metallo-beta-lactamases capable of hydrolyzing carbapenems had previously been reported in Japan as early as 1994 [7].

Klebsiella pneumoniae carbapenemase production is an important mechanism of resistance for an increasingly wide range of Gram-negative bacteria and is no longer limited to *K. pneumoniae*. KPC-producing bacteria are often misidentified by routine microbiological susceptibility testing and incorrectly reported as sensitive to carbapenems; however, resistance to the carbapenem antibiotic ertapenem is common and a better indicator of the presence of KPCs. Carbapenem antibiotics are generally not effective against KPC-producing organisms. The common drugs of choice based on *in vitro* susceptibility testing are the polymyxins, tigecycline, and less frequently the aminoglycosides [8].

In 2012, [9] conducted a study on carbapenem resistant *Klebsiella pneumoniae* isolated from in-patients at the Lagos University Teaching Hospital over a period of 6 months. Out of the 153 *Klebsiella pneumoniae* isolates from in-patients, 8 were resistant to carbapenem while only 4 of the 8 CRKP were recognized by Modified Hodge Test as carbapenemase producers.

Resistance mechanisms have been found for every class of antibiotics [10]. The metallo β -lactamase in Gram negative bacilli is becoming a therapeutic challenge, as this enzyme usually possesses a broad hydrolysis profile that includes the carbapenems and other β -lactam antibiotics [11]. In Nigeria there have been reports of carbapenemase producing clinical isolates of enteric bacteria particularly among *E. coli* and *Klebsiella* spp [12].

Infections caused by KPC-producing *K. pneumoniae* have been associated with increased cost and length of stay as well as frequent treatment failures and death [13]. Risk factors for infection include advanced age [14], being severely ill [15], previous treatment with antibiotics [16], organ or stem-cell transplantation, mechanical ventilation, and long hospital stays [17]. In addition to the infection control challenges that have arisen, infections caused by these organisms present clinicians with serious treatment challenges, due to limited antibiotic options [8].

KPC-producing bacteria present a significant problem in clinical situations where administration of effective empiric antibiotics is essential to preventing mortality. This applies to serious infections such as bacteremia, but also extends to other infections in patients undergoing organ transplants and cancer treatment, where the immunocompromised status of patients requires effective empiric antibiotics [8]. [18] reported two cases of orthotopic liver transplant recipients that died as a result of infections caused by KPC-producing *K. pneumoniae*. Both patients were initially treated with meropenem based on the results of routine susceptibility testing.

The treatment of patients with serious Gram negative infection must be both prompt and correct. Numerous studies have demonstrated that mortality risk is significantly increased when the antibiotic regimen does not adequately cover the infecting pathogen [3].

Accurate and timely detection of these resistance mechanisms (i.e. carbapenemase production) is very important in deciding the appropriate treatment schedule. Detection of the resistance mechanisms is always a serious challenge to the clinical laboratories [19]. The treatment of patients with serious Gram negative infection must be both prompt and correct. Numerous studies have demonstrated that mortality

risk is significantly increased when the antibiotic regimen does not adequately cover the infecting pathogen [3].

Enterobacteriaceae are among the leading causes of nosocomial infections [20]. Early identification of KPC-producing bacteria with *in vitro* testing is of paramount importance to the success of infection control efforts [13]. In the appropriate setting, active surveillance can improve infection control by detecting colonization and preventing horizontal spread [21].

CRE are known to harbor additional drug-resistance genes to other antimicrobial drug classes, which may also be carried on mobile genetic elements. *K. pneumoniae* sequence type 258 strains are KPC-producing clones that harbor Tn4401-bearing plasmids. These clones are highly effective in plasmid transfer across bacteria and are known to carry other plasmid-based antimicrobial drug resistance genes such as those that encode resistance to trimethoprim/sulfamethoxazole, aminoglycosides, and fluoroquinolones [22].

On 23rd August 2011, the Disease Daily reported an outbreak of an infection caused by a *Klebsiella pneumoniae* carbapenemase producing *Klebsiella pneumoniae* among patients at Panama's Social Security Hospital. The death toll rose to 50 with 71 patients infected within a month [23]. In the same year, U.S National Institutes of Health Clinical Center experienced an outbreak of Carbapenem Resistant *Klebsiella pneumoniae* that affected 18 patients, 11 of whom died. Integrated genomic and epidemiological analysis traced the outbreak back to three independent transmissions from a single patient who was discharged 3 weeks before the next case became clinically apparent [24].

The term "carbapenem" is defined as the 4:5 fused lactam ring of penicillins with a double bond between C-2 and C-3 and substitution of carbon for sulfur at C-1. The stereochemistry of the hydroxyethyl side chain of carbapenem is a key contributor of carbapenems and is important for activity [25]. Carbapenems like other members of β -lactams, are not easily diffusible through the bacterial cell wall [26].

Carbapenems are unique because they are relatively resistant to hydrolysis by most β -lactamases, in some cases act as "slow substrates" or inhibitors of β -lactamases and still target Penicillin Binding proteins (PBPs) [25].

The carbon atom at C-1 position plays a major role in the potency, spectrum of carbapenems and in their stability against β -lactamases. Also the strategically positioned hydroxyethyl side chain aids in resistance to hydrolysis by β -lactamases. The *trans* configuration the β -lactam ring at C-5 and C-6 results in the stability against β -lactamases [25].

Carbapenem-resistant *Klebsiella pneumoniae* (CRKP) is resistant to almost all antimicrobial agents, is associated with substantial morbidity and mortality, and poses a serious threat to public health. The ongoing worldwide spread of this pathogen emphasizes the need for immediate intervention [27].

2.0 MATERIAL AND METHODS

2.1 Ethical approval

Ethical approval was gotten from the ethical committee of Kaduna state Ministry of Health.

2.2 Sample Collection and Inoculation

A total of 150 samples of sputum, urine and wound swab were collected from patients sent to Microbiology laboratory of the selected hospitals in Zaria using convenience sampling technique. All clinical samples were collected and processed according to standard operating procedure. The samples were then inoculated on MacConkey agar and incubated overnight at 37°C.

2.3 Cultural Identification

The isolates were identified by their morphological characteristics on MacConkey agar. Isolates that appear as pink mucoid colonies on MacConkey after incubation at 37°C for 18 - 24hours were processed for Gram staining.

2.4 Biochemical characterization.

Indole production, Methyl Red - Voges-Proskauer test, Citrate utilisation test, Urease test, Glucose, Lactose, Sucrose fermentation and Hydrogen sulphide production using TSI Agar, Motility, Aesculin hydrolysis [28].

2.5 Antibiotic Susceptibility Test

Biochemically identified isolates of *Klebsiella pneumoniae* were standardized and subjected to antibiotics susceptibility test on Mueller Hinton agar by modified Kirby-Bauer disc diffusion technique using the following antibiotic discs: Tetracycline (30µg), Ciprofloxacin (5µg), Chloramphenicol (30µg), Cefotaxime (30µg), Ampicillin (30µg), Cotrimoxazole [Trimethoprim-Sulfamethoxazole] (1.25/23.75 µg), Gentamicin (10µg) and Imipenem (10µg).

Briefly, the inocula were standardized by using a sterilized wire to pick four or five isolated colonies of the test organism and then suspending the organism in 2ml sterile normal saline. The suspension was then mixed properly and the turbidity was adjusted to a 0.5 McFarland standard. A sterile swab was dipped into the inoculum tubes and then excess fluid was removed by rotating the swab against the side of the tube. The Mueller Hinton agar was then inoculated by streaking the swab stick three times over the surface of the agar, rotating the plate approximately 60° each time to ensure even distribution of the inocula. The plates were allowed to set at room temperature for 3-5minutes for the surface of the agar to dry.

Using a sterile forcep the disks were placed one at a time on the plates and pressed gently to ensure complete contact with the agar surface. The plates were then allowed to set at room temperature for 5minutes before incubation at 37°C for 24hours. The sizes of the zone of inhibition were measured with the aid of a ruler to the nearest millimetre. Using the published CLSI guidelines, the susceptibility or resistance of the organism to each of the drug tested was determined (CLSI, 2015).

Isolates resistant to Imipenem was screened for carbapenemase production by the Cloverleaf test/Modified Hodge Test as recommended by the Clinical Laboratory Standards Institute [29].

2.6 Detection of carbapenemase production using Cloverleaf test or Modified Hodge Test (MHT)

This test is based on the inactivation of a carbapenem by either whole cells or cell extracts of the test organisms, which enables a carbapenem susceptible indicator strain (*Escherichia coli* ATCC 25922) to extend growth towards a carbapenem disk, along the streak of inoculum of the test strain.

A 0.5 McFarland standard suspension of the indicator organism (*Escherichia coli* ATCC 25922) was Prepare in normal saline and then a 1:10 dilution of it in normal saline was inoculated on Mueller Hinton Agar plate as a lawn. The plate was allowed to dry for 3 to 10 minutes. Imipenem disk was then placed at the middle of the inoculated Mueller Hinton Agar plate. Using a sterile loop 3 to 5 colonies of test isolates grown overnight were picked and inoculated in a straight line out from the edge of the disk. Following incubation at 37°C for 16 to 20 hours, the MHA plate was examined for enhanced growth of the indicator organism around the test isolates at the intersection of the streak and the zone of inhibition. Enhanced growth of the indicator organism (*Escherichia coli* ATCC 25922) means the test isolate is positive for carbapenemase production while no enhanced growth of the indicator organism means the isolate is negative for carbapenemase production [29].

3.0 RESULTS AND DISCUSSION

Out of the 150 clinical samples collected from selected hospitals in Zaria comprising of 68 urine samples, 44 wound swabs and 38 sputum samples, 19 *Klebsiella pneumoniae* were isolated giving a prevalence of 12.67%.

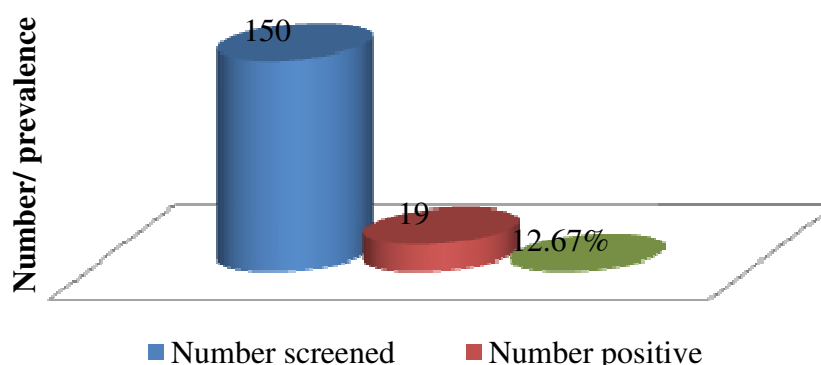


Figure 1: Prevalence of *Klebsiella pneumoniae* isolated from clinical samples in Zaria.

Result of the antibiotic susceptibility pattern of the isolates is presented in Figure 2. All the isolates screened were resistant (100%) to Ampicillin and Cefotaxime. The isolates screened showed 5.3%, 21.1%, 36.8% and 42.1% resistance to Imipenem, Gentamicin, Ciprofloxacin and Chloramphenicol respectively. A moderately high and high resistance to Tetracycline (57.9%) and Cotrimoxazole (78.9%) respectively were recorded in this study.

High level of susceptibility was demonstrated to Imipenem (94.7%). The high level of susceptibility demonstrated to Imipenem, Gentamicin and Ciprofloxacin in this study agrees with the study of [34,35,36]. The high susceptibility level (94.7%) to Imipenem recorded in this study is lower than that recorded [37] where they reported a 100% susceptibility of *Klebsiella pneumoniae* to Imipenem in Lagos. [38] reported 6-9% resistance of *Klebsiella pneumoniae* to Imipenem in Kano.

Antibiotic resistance has no border to cross especially in setting where proper infection control is not in practice. It doesn't discriminate between the specimen from which the organism was isolated or even the gender and age of the patient from which it was isolated as demonstrated by the isolates screened in this study.

Prevalence of carbapenem resistant *Klebsiella pneumoniae* in Zaria is shown in Figure 3. Out of 19 *Klebsiella pneumoniae* isolates from 150 clinical samples, 1 was intermediately resistant (non-susceptible) to imipenem giving a prevalence of 5.26%.

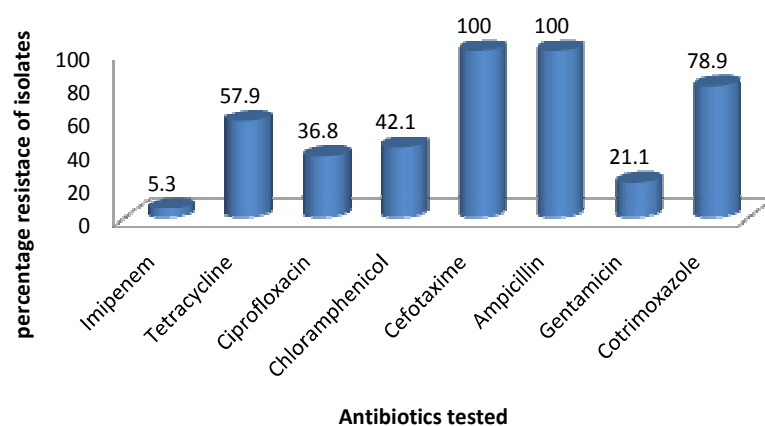


Figure 2: Percentage resistance of the isolates to the antibiotics tested.

The prevalence of carbapenem resistant *Klebsiella pneumoniae* in this study is 5.26%. The low prevalence of carbapenem resistant *Klebsiella pneumoniae* and low level of resistance (5.3%) demonstrated by the isolates to Imipenem in this study could be due to the fact that (i) Imipenem (and other carbapenems) usage is still low in Nigeria (ii) they are expensive as such they are not subjected to abuse. (iii) They are not readily available and are reserved for life threatening Gram negative infections (iv) they are administered intravenously (v) they are not frequently prescribed.

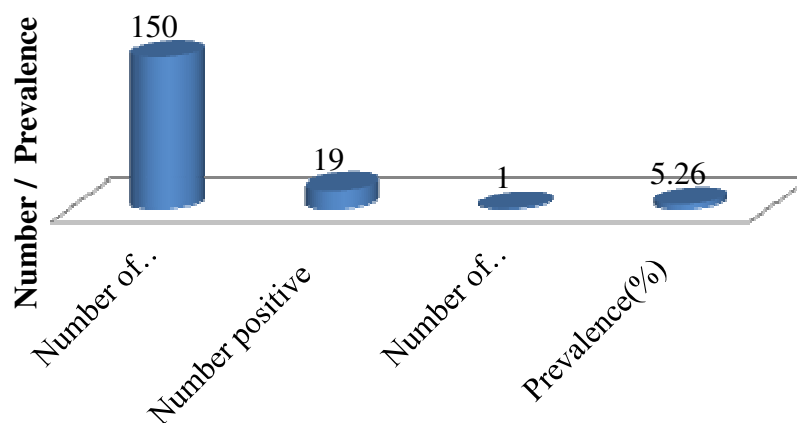
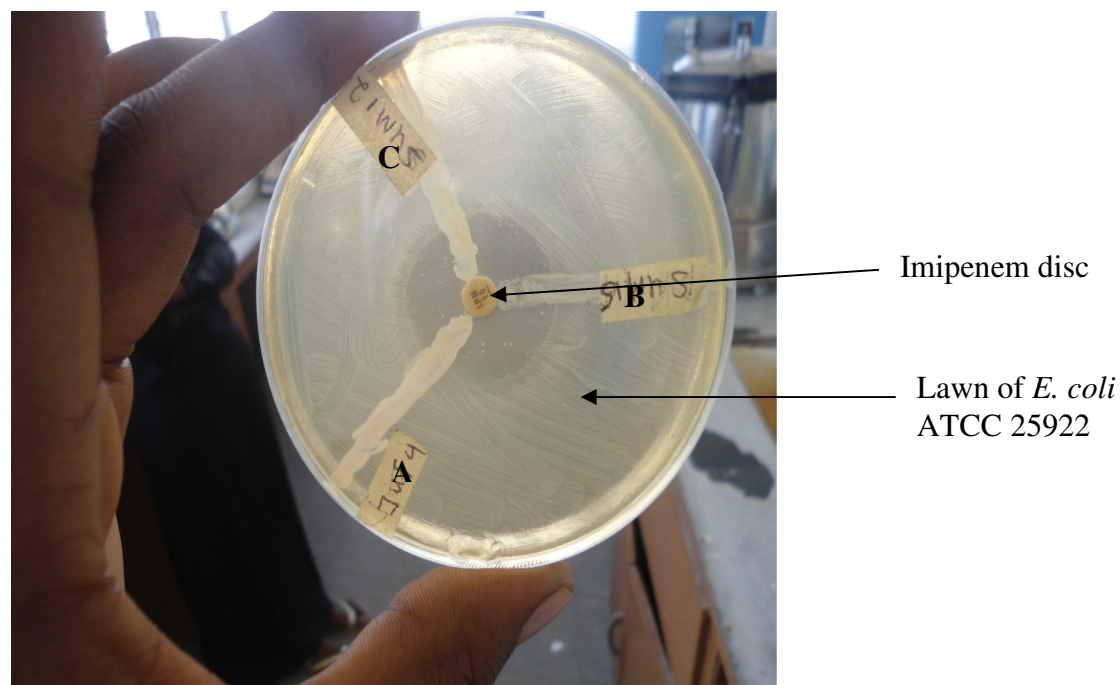


Figure 3: Prevalence of carbapenem resistant *Klebsiella pneumoniae* isolated from clinical samples in Zaria.

Emergence and spread of carbapenemases account for the resistance of bacteria to carbapenems which were the "drug of last resort" in the treatment of infection caused by multidrug resistant Gram negative bacteria. The only treatment option that remains potentially toxic to carbapenems resistant bacteria is polymyxin B and colistin [30] and Tigecycline [31]. Due to the increase and spread of carbapenems resistant bacteria, in a 2013 Threat Report on Antimicrobial Resistance, the CDC prioritized CRE as an urgent threat (the highest level), requiring concerted commitment and action, and noted that ≈50% of hospitalized patients with bloodstream infection caused by CRE die from the infection [32,33]. As such it is necessary to know the prevalence of carbapenems resistance in the clinical isolates. Failure to identify

222 them may lead to inappropriate therapy, treatment failure, spread of KPC producing organisms among
 223 patients and may result in increased mortality.
 224 According to CLSI [29], Carbapenemase-producing isolates usually test intermediate or resistant to one
 225 or more carbapenems and usually test resistant to one or more agents in cephalosporin subclass III (e.g.
 226 Cefotaxime). The isolate with the above definition was then screened for KPC production using the
 227 Modified Hodge test (Clover leaf test). Since the isolate shows no enhanced growth of the indicator strain
 228 (*Escherichia coli* ATCC 25922) it is negative for carbapenemase production.
 229



230 Plate I: Result of test for the detection of *Klebsiella pneumoniae* carbapenemase production using
 231 Modified Hodge Test (Cloverleaf test). A, B and C are the test isolates.
 232
 233

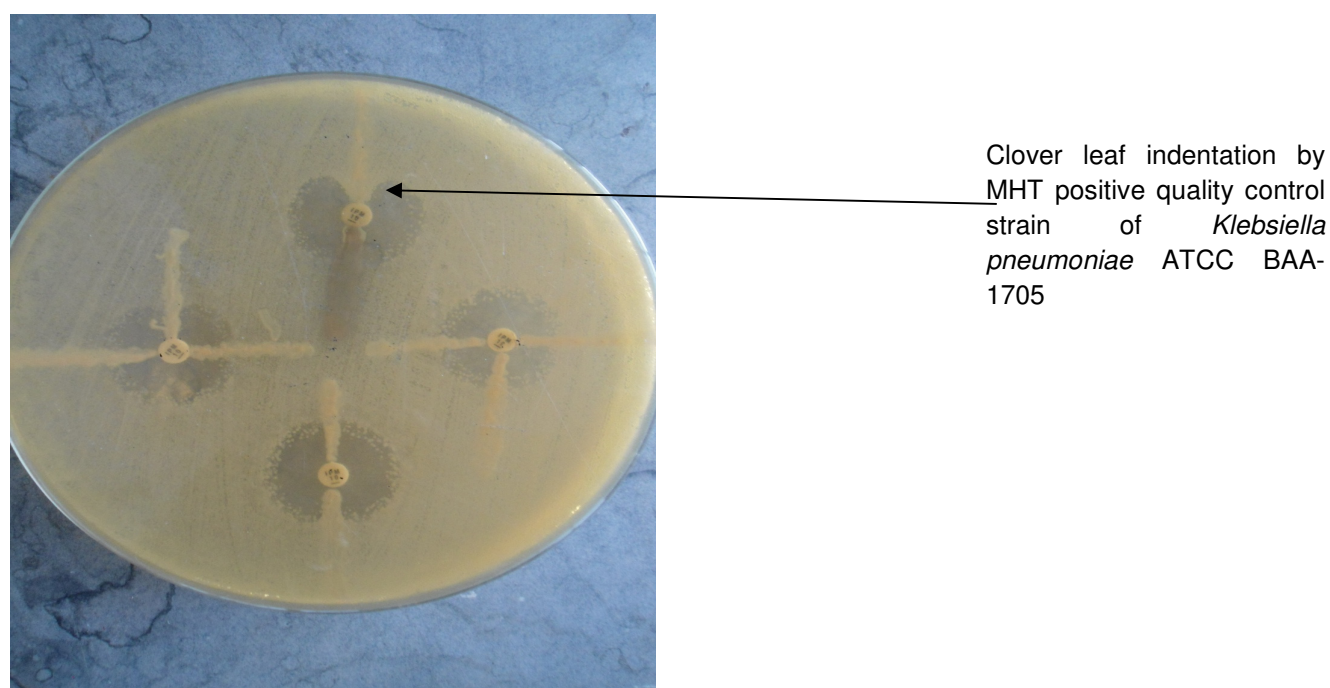


Plate II: Result of the Modified Hodge Test using the positive control strain and 9 of the isolates.

The prevalence of *Klebsiella pneumoniae* carbapenemase (KPC) producing *Klebsiella pneumoniae* in Zaria is presented in Figure 4. Only one out of the 19 isolates screened was intermediately resistant to Imipenem. This isolate gave a negative Modified Hodge Test hence the prevalence of KPC producing *Klebsiella pneumoniae* in this study is 0%.

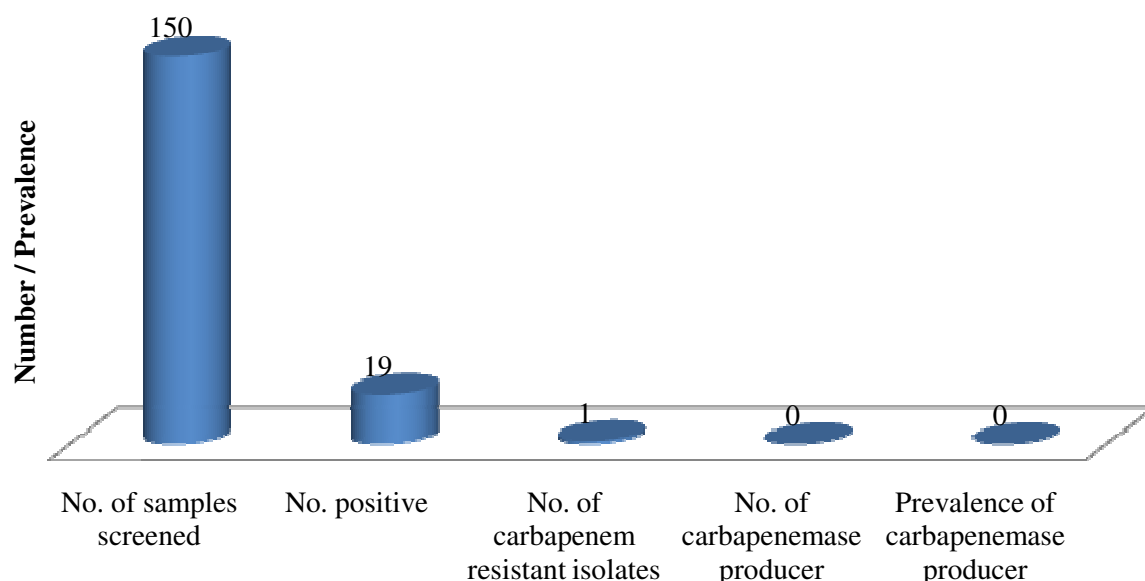


Figure 4: Prevalence of *Klebsiella pneumoniae* carbapenemase (KPC) producing *Klebsiella pneumoniae* in Zaria.

Klebsiella pneumoniae carbapenemase (KPC) production is one of the mechanisms of resistance used by *Klebsiella pneumoniae* to resist Imipenem. In this study the isolate that was resistant to Imipenem and Cefotaxime (a third generation Cephalosporin) was screened for carbapenemase production using the Modified Hodge Test as recommended by [19]. This isolate was found to be a non *Klebsiella pneumoniae* carbapenemase (KPC) producer, giving a prevalence of 0.0% for KPC producing *Klebsiella pneumoniae* in this study. This suggests that the resistance is either due to porin loss which limits the entry of the carbapenems into the cell thereby resulting in decreased outer membrane permeability or over expression of β -lactamases (such as AmpC β -lactamases and ESBLs) possessing low-level carbapenemase activity [19].

The prevalence of KPC producing *Klebsiella pneumoniae* observed in this study (0.0%) is lower than a prevalence of (29.9%) reported by [31] among patients in intensive care unit and surgical wards of tertiary health care centers in Kano. The reason for the higher prevalence in their study is because they were dealing with hospitalized patients who form one of the populations at risk of harbouring KPC organisms. [39] reported that 10.2% of the 28 carbapenem resistant isolates screened for carbapenemase production by MHT were MHT positive (*Klebsiella pneumoniae* carbapenemase (KPC) producer) in Maiduguri.

Carbapenems resistance traits such as decreased outer membrane permeability, over expression of β -lactamases, production of cephalosporinase and porin loss are not transferable, unlike most of the carbapenemase genes. This explains why carbapenem-resistant isolates that do not produce carbapenemases are considered to be much less important from a public health perspective than

carbapenemase producers. The spread of carbapenemase producers is by far the most important current clinical issue in antibiotic resistance in Gram-negatives, and must be strictly controlled [40].

4.0 CONCLUSION

The discovery of carbapenems was a major breakthrough in infectious disease therapeutics because of their ability to inhibit Penicillin Binding Protein (PBP) and β -lactamase. The carbapenems are regarded as the agents of "last resort" for many complicated bacterial infections. As Multidrug resistant pathogens continue to emerge, there is need to screen isolates for resistance to carbapenem and confirm them by Modified Hodge Test.

Antibiotic resistance is on the increase in Nigeria and worldwide. The prevalence of carbapenem resistant *Klebsiella pneumoniae* in Zaria according to this study is 5.26% while that *Klebsiella pneumoniae* carbapenemase producer was 0.0%. The low level of resistance recorded for Imipenem is an indication that it still remains one of the antibiotics of "last resort" for infections caused by multidrug resistant pathogens. The occurrence of carbapenem resistant organism is on the increase even though it remains low and is less common when compared to the occurrence of extended-spectrum β -lactamase (ESBL) and AmpC producing organisms.

The Modified Hodge Test is a readily available confirmatory test for carbapenemase production. It can be performed in many clinical microbiology laboratories. Since it is less expensive and requires less expertise. Studies have shown that MHT is very sensitive and reliable for the detection of carbapenemases.

CONSENT

All authors declare that written informed consent (or oral consent in some cases) was obtained from the patient (or other approved parties) for publication of this case report and accompanying images.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards.

REFERENCES

1. Jesudason MV, Kandathil AL, Balaji V. Comparison of two methods to detect carbapenemase and metallo- β -lactamase production in clinical isolates. Indian Journal of Medical Research, 2005;121:780-783
2. Kimberly DB. Are all carbapenems the same? *Healio: infectious disease news*. pharmacology consult. University of Minnesota Medical Center, Fairview, Minneapolis; 2008.
3. James JR. The role of carbapenem in initial therapy for serious Gram negative infection. Critical care, 2008;12(4):5.
4. Walsh TR. Emerging carbapenemases: A global perspective. International Journal of Antimicrobial Agents, 2010;36(3):8-14.
5. Cornaglia G, Rossolini GM. The emerging threat of acquired carbapenemases in Gram-negative bacteria. Clinical Microbiological Infection, 2010;16:99-101.
6. Yigit H, Queenan AM, Anderson GJ, Domenech-Sanchez A, Biddle JW, Steward CD. *et al*. Novel carbapenem-hydrolyzing beta-lactamase KPC-1 from a carbapenem-resistant strain of *Klebsiella pneumoniae*. Journal of Antimicrobial Agents and Chemotherapy, 2001;45:1151-1161.
7. Paterson DL, Bonomo RA. Extended-Spectrum β -Lactamases: a Clinical Update. Clinical Microbiology Reviews, 2005;18(4):657-686.
8. Ryan SA, Kerri AT, Saarikka S, Michael P, Kristie JJ, Daniel JM. Emergence of *Klebsiella pneumoniae* Carbapenemase (KPC)-Producing Bacteria. Southern Medical Journal, 2011;104(1):40-45.
9. Oshun P, Ogunsola F. Carbapenem resistant *Klebsiella pneumoniae* at the Lagos University teaching hospital, Lagos, Nigeria. Epidemiology of MDR-Gram-negatives. 22nd European Congress of Clinical Microbiology and Infectious Diseases (ECCMID). 31.03.2012 - 03.04.2012.

10. Umadevi S, Kanhakumari G, Joseph NM, Kumar S, Eaow JM, Atephen S. *et al.* Prevalence and antimicrobial susceptibility pattern of ESBL producing Gram negative bacilli. *Journal Clinical diabetes Research*, 2011;5(2):236-239.
11. Galani I, Rekatsina PD, Hatzaki D, Plachouras D, Souli M, Giamarellou H. Evaluation of different laboratory tests for the detection of metallo β -lactamase production in *Enterobacteriaceae*. *Journal of Antimicrobial agents and Chemotherapy*, 2008;61:548-553.
12. Akinduti PA, Oluwaseun E, Motayo BO, Adeyakinu AF, Emerging Multidrug resistant Ampc Beta-Lactamase and Carbapenemase enteric Isolates in Abeokuta. *Nature and Science*, 2012;10(7):70-74.
13. Center for Disease Control and Prevention (CDC). Guidance for control of infections with carbapenem-resistant or carbapenemase-producing *Enterobacteriaceae* in acute care facilities. *Morbidity and Mortal Weekly Report*, 2009;58:256-260.
14. Nadkarni AS, Schliep T, Khan L, Zeana CB. Cluster of bloodstream infections caused by KPC-2 carbapenemase-producing *Klebsiella pneumoniae* in Manhattan. *American Journal of Infection Control*, 2009;37:121-126.
15. Gasink LB, Edelstein PH, Lautenbach E, Synnestvedt M, Fishman NO. Risk factors and clinical impact of *Klebsiella pneumoniae* carbapenemase-producing *K. pneumoniae*. *Infection Control Hospital and Epidemiology*, 2009;30:1180-1185.
16. Bratu S, Landman D, Haag R, Recco A, Eramo MA, Quale J. Rapid spread of carbapenem-resistant *Klebsiella pneumoniae* in New York City. *Archives of International Medicine*, 2005;165:1430-1435.
17. Patel G, Huprikar S, Factor SH, Jenkins SG, Calfee DP. Outcomes of carbapenem-resistant *Klebsiella pneumoniae* infection and the impact of antimicrobial and adjunctive therapies. *Infection Control and Hospital Epidemiology*, 2008;29:1099-1106.
18. Mathers AJ, Cox HL, Bonatti H, Kitchel B, Brassinga AKC, Wispelwey B. *et al.* Fatal cross infection by carbapenem-resistant *Klebsiella* in two liver transplant recipients. *Transplantation and Infectious Diseases*, 2009;11:257-265.
19. Valsan C, Chinnan JP, Sathivathy KA. Phenotypic detection of β -lactamases in enterobacteriaceae using a 12-disk procedure. *Journal of Academic and Clinical Microbiology*, 2013;15(1):7-10.
20. Hidron AL, Edwards JR, Patel J, Horan TC, Sievert DM, Pollock DA. *et al.* NSHN annual update: Antimicrobial-resistant pathogens associated with healthcare-associated infections: Annual summary of data reported to the national healthcare safety network at the centers for disease control and prevention, 2006-2007. *Infection Control and Hospital Epidemiology*, 2008;29:996-1011.
21. Kochar S, Sheard T, Sharma R, Hui A, Tolentino E, Allen G. Success of an infection control program to reduce the spread of carbapenem-resistant *Klebsiella pneumoniae*. *Infection control and Hospital Epidemiology*, 2009;30:447-452.
22. Munoz-Price LS, Quinn JP. The spread of *Klebsiella pneumoniae* carbapenemases: a tale of strains, plasmids, and transposons. *Clinical Infectious Diseases*, 2009;49:1739-1941. <http://dx.doi.org/10.1086/648078>.
23. Pinheiro L, KPC bacteria kills 50 in panama: mechanism of Antibiotic Resistance. *The Daily Disease*. August 23rd 2011.
24. Evan SS, Adrian MZ, Pamela JT, Frida S, NISC Comparative sequencing program, David KH *et al.* Tracking a hospital outbreak of Carbapenem Resistant *Klebsiella pneumoniae* with whole genome sequencing. *Science Translational Medicine*, 2012;4(148).
25. Papp-Wallace KM, Endimiani A, Taracila MA, Bonomo RA. Carbapenems: Past, Present, and Future. *Antimicrobial Agents and Chemotherapy*, 2011;55(11):4943-4960
26. Martinez-Martinez L, Extended-spectrum β -lactamases and the permeability barrier. *Clinical Microbiology Infection*, 2008;14(Suppl. 1):82-89.
27. Saidel-Odes L, Borer A. Limiting and controlling carbapenem-resistant *Klebsiella pneumoniae*. *Infection and Drug Resistance*, 2014;7:9-14.
28. Cowan ST, Steel KJ. *Manual for the Identification of Medical Bacteria* 3rd ed. / edited and rev. by G.I. Barrow and R.K.A. Feltham. Cambridge University Press. London; 2003.
29. Clinical and Laboratory Standards Institute (CLSI). Performance standards for antimicrobial susceptibility testing; twenty-fourth informational supplement, M100-S25, 2015;35(3):112-126.
31. Behera B, Mathur P, Das A, Kapil A, Sharma V. An evaluation of four phenotypic techniques for detection of metallo beta lactamase producing *Pseudomonas aeruginosa*. *Indian Journal of Medical Microbiology*, 2008;26(3):233-237.

31. Yusuf I, Rabi AT, Haruna M, Abdullahi SA, Carbapenem Resistant Enterobacteriaceae (CRE) in Intensive Care Units and Surgical Wards of Hospitals With No History Of Carbapenem Usage in Kano, North West Nigeria. *Nigerian Journal of Microbiology*, 2015;27(1):2612-218.
32. Centers for Disease Control and Prevention (CDC). Vital signs: carbapenem-resistant Enterobacteriaceae. Report no. 62. 2013a <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6209a3.htm>
33. Centers for Disease Control and Prevention (CDC). Antibiotic resistance threats in the United States. <http://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf>. 2013b.
34. Osundiya OO, Oladele RO, Oduyebo OO. Multiple Antibiotic Resistance (MAR) Indices of *Pseudomonas* and *Klebsiella* species Isolates in Lagos University Teaching Hospital. *African Journal of Clinical and Experimental Microbiology*, 2013;14(3):164-168.
35. Prado T, Pereira WC, Silva DM, Seki, LM, Carvalli APD'A. *et al.* Detection of extended – spectrum β -lactamase producing *K. pneumoniae* in effluents and sludge of a hospital treatment plant. *Letters in Applied Microbiology*, 2007;46:136-141.
36. Chikwendu CI, Amadi ES, Obi RK. Prevalence and antimicrobial resistance in *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* isolates from non-clinical urine samples. *New York Science Journal*, 2010;3(11):194-200. (ISSN: 1554-0200). (<http://www.sciencepub.net>).
37. Enwuru NV, Enwuru CA, Ogbornia SO, Adepoju-Bello AA. Metallo-B-Lactamase Production by *Escherichia coli* and *Klebsiella* Species Isolated From Hospital And Community Subjects in Lagos, Nigeria. *Nature Science*, 2011;9(11)
38. Yusuf I, Yushu'a M, Sherif AA, Getso MI, Yahaya H, Bala JA. *et al.* Detection of Metallo Beta Lactamases Among Gram Negative Bacteria Isolates From Murtala Muhammed Specialist Hospital, Kano And Al Madina Hospital Kaduna, Nigeria. *Bayero Journal of Pure and Applied Science*, 2012;5(2):84-88.
39. Mohammed Y, Zailani SB, Onipede AO. Characterization of KPC, NDM and VIM Type Carbapenem Resistance *Enterobacteriaceae* from North Eastern, Nigeria. *Journal of Biosciences and Medicines*, 2015;3:100-107.
40. Nordmann P, Gniadkowski M, Giske CG, Poirel L, Woodford N, Miriagou V. European Network on Carbapenemases. Identification and screening of carbapenemase-producing *Enterobacteriaceae*. *Clinical Microbiology and Infection*, 2012;18:432–438

APPENDIX

414
415



MINISTRY OF HEALTH AND HUMAN SERVICES
KADUNA STATE OF NIGERIA
ADDRESS: Independence Way, P.M.B. 2014, Kaduna.

MOH/ADM/744/VOL.1/333

19th OCT, 2015

NOTICE OF APPROVAL AFTER FULL COMMITTEE REVIEW

PREVALENCE OF CARBAPENEM RESISTANT KLEBSIELLA PNEUMONIAE IN CLINICAL SAMPLES FROM SOME SELECTED HOSPITALS IN ZARIA

Name of Principal Investigator:	HUSSEINI IBRAHIM MOHAMMED
Address of Principal Investigator:	Dept. of Microbiology Ahmadu Bello University Zaria, Kaduna State.
Date of receipt of Application	20 th Aug, 2015
Date of Ethical Approval	29 th Sept, 2015

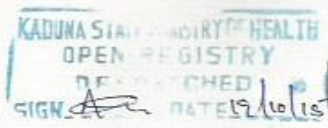
This is to inform you that the Research described in the submitted Protocol, the Consent forms, advertisements and other participant information materials have been reviewed and given full approval by the Health Research Ethics Committee (HREC).

If there is delay in starting the research or any change, inform the HREC so that the dates of approval can be adjusted accordingly.

However, Researcher is kindly requested to submit a copy of his/her findings to the State Ministry of Health, please.



TUMAN DANIEL ALI ESQ
SECRETARY
FOR: CHAIRMAN



KADUNA STATE MINISTRY OF HEALTH
OPEN REGISTRY
RECEIVED
SIGNATURE DATE 19/10/15

Phone No.: 08184078693

Website: <http://www/moh.kd.gov.ng>

Email: health@kds.gov.ng

416