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Molecular Characterization Of Blandm And Blaoxa-48 Gene In Carbapenam Resistant Klebsiella Species At A Tertiary Care Centre

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ABSTRACT

Introduction: Carbapenems are the last resort drugs used to treat multidrug resistant (MDR) bacterial infections. The incidence of carbapenem resistance is increasing across the globe. Treatment failure and eventually high mortality were reported among individuals with carbapenem resistant bacterial infections. The incidence of carbapenem-resistant *Klebsiella pneumoniae* (CRKP) infections is increasing globally. The bla_{NDM} is the predominant carbapenem-resistant gene in CRKP isolates. However, bla_{OXA-48} has also been reported to be increasing in recent days.

Aim And Objective: To study the molecular characterization of blaNDM and blaOXA-48 gene in carbapenam resistant *klebsiella* isolates.

Material And Methods: This was a Cross sectional study carried out in the Department of Microbiology for a period of 18 months i.e, November 2022 to May 2023. A total of 300 Klebsiella species from the isolates were tested collected from hospitalized and consultation patients were included in the study. The Antimicrobial susceptibility testing was performed according to the CLSI guidelines . The DNA extraction was done using the Qiagen DNA extraction kit and the resistant gene blaNDM and blaOXA-48 was detected using the PCR.

Results: A total of 300 Klebsiella species from the isolates were tested out of which Carbapenamses resistant kKbspp was observed to be 204(68%) and Carbapenamses sensitive Kbspp with 96 (32%) with the prevalence rate of 68%. The ratio of females was observed to be more as compared to the males with 64% and 36% respectively with the age group of 30-40 (38.7%) been affected the most. The maximum isolates were from urine (55%) and least for body fluid with 3%. The Ratio of Male/Female amongst Carbapenamses resistant klebsiella isolates was observed to be 32.9% and 67.1 % respectively. The age group 30-40 was the most commonly affected in Carbapenamses resistant klebsiella isolates with the urine cases most commonly found with 51.4%. The molecular characterization confirms BLANDM gene 48 (23.5%) and BLAOXA-48 with 57 (27.9%) was expressed.

Conclusion: CRKP is emerging as a serious threat among drug-resistant bacterial pathogens which would complicate the treatment of bacterial infections with available antibiotics. Performing regular surveillance studies in hospitals is very important to identify the circulating genes among carbapenem-resistant bacteria which will help to overcome the therapeutic challenges in treating the patients infected with CRKP.

Keywords: *CRKP, CLSI, DNA, blaNDM, blaOXA-48, PCR*

1. INTRODUCTION

In the recent years, one of the most issues of concern among healthcare systems is resistance to carbapenems among Enterobacteriaceae due to increasing morbidity and mortality among hospitalized patients. Carbapenems are considered as the last-line treatment of Enterobacteriaceae infections and resistance to them is a great challenge for clinicians [1].

Klebsiella pneumoniae belonging to *Klebsiella spp.* is one of the important species of *Enterobacterale.* As one of the most common opportunistic pathogens, it is also a major cause of hospital associated infections, ranking in the top three causative agents in most hospital settings [2]. The extended β-lactams and carbapenem are high-efficiency broad-spectrum antibiotics with high sensitivity to *Enterobacterale* and are commonly used to treat *K. pneumoniae* infections. Therefore, with the antimicrobial agents being extensively used in clinical therapy, extended-spectrum β-lactam (ESBL)-producing and carbapenem-resistant *K. pneumoniae* (CRKp) have rapidly developed and disseminated, leading to subsequently increased morbidity and mortality [3,4].

One of the most important emerging carbapenem-resistant bacteria is *Klebsiella pneumoniae* (*K. pneumoniae*) which is an opportunistic pathogen which accounts for many of nosocomial infections including urinary tract infections, pneumonia, and septicemia. Three main classes of carbapenemases were introduced including class A or serine protease, particularly the *K. pneumoniae* carbapenemase (KPC) that was mostly identified in *K. pneumonia* [5-7]. KPC is able to hydrolyze penicillins, carbapenems, cephalosporins and aztreonam. Class B metallo-beta-lactamase (MBL) is sensitive to metalic ion chelator like ethylenediaminetetraacetic acid (EDTA) because it is zinc dependent. New Delhi metallo-β-lactamase (NDM), imipenemase (IMP) and Verona integrin-encoded metallo-β-lactamase (VIM) are the most important enzymes in this class [8]. Recently, NDM-1 has spread widely in the world. Class D, oxacillinase (OXA), has different variants by deletions and substitutions in a few amino acids in these types of enzymes which cause variations in hydrolyzing penicillins and carbapenems.

The increase of carbapenem-resistant *Kp* (CRKP) represents an unquestionable threat to the health of hospitalized patients globally, with a high mortality rate compared to patients infected with carbapenem-susceptible *Kp*. Carbapenems are often used as the last line defence to treat nosocomial infection caused by extended spectrum β-lactamases (ESBL) producing Gram-negative bacteria. However, selective pressure from the overuse or misuse of carbapenems has resulted in the emergence of carbapenem-resistant *Enterobacteriaceae* (CRE) [5.6]. Within the increasing number of reported CRE cases worldwide, carbapenem-resistant *Klebsiella pneumoniae* (CRKP) takes precedence as the predominant isolate [9].

These genes can spread within or between different bacterial species through horizontal transfer of plasmids, conjugative transposons, or integrons [10]. As a result, carbapenem resistance in GNB is a major public-health concern worldwide. The most common carbapenemases identified in GNB include oxacillinases (OXA), *Klebsiella pneumoniae* carbapenemase (KPCs), and metallo-beta-lactamases (MBLs), including New Delhi metallo-β-lactamase (NDM) and Verona integron-encoded metallo-beta-lactamase imipenemase (VIM) [11,12]. These enzymes can break down carbapenem antibiotics, and develop resistance not only to carbapenems, but also to many other beta-lactam antibiotics, such as penicillins, cephalosporins, and monobactams [13,14].

Carbapenems such as imipenem, meropenem, and biapenem represent the first-line treatment of serious infections caused by multi-resistant Enterobacteriaceae including *Klebsiella pneumoniae* (*K. pneumoniae*) and *Escherichia coli* (*E. coli*) [14]. Whereas carbapenems can be hydrolyzed by carbapenemase in carbapenem-resistant *K. pneumoniae* (CRKP) [15], which results in resistance to β-Lactam antibiotics including carbapenem. Carbapenemases can be divided into Ambler class A β-lactamases (e.g. *Klebsiella pneumoniae* carbapenemases (KPC)), class B metallo-β-lactamases (MBLs), verona integrin-encoded metallo-β-lactamase (VIM), New Delhi metallo-β-lactamase (NDM) type, and Class D Enzymes of the OXA-48 type [13].

Due to increasing risk of infections caused by carbapenem-resistant *K. pneumoniae* strains and lack of comprehensive local information, studying the frequency of resistant genes and identifying appropriate antibiotics are essential for the control of such infections. The present study aimed to investigate the antibiotic susceptibility pattern of *K. pneumoniae* isolates and determine the frequency of carbapenemase producing *K. pneumoniae* obtained from Iranian hospitalized patients by phenotypic and genotypic method [16]. Therefore the present study was undertaken to study the molecular characterization of blaNDM and blaOXA-48 gene in carbapenam resistant *klebsiella species* at a tertiary care centre.

2. MATERIAL AND METHODS

This was a Cross sectional study carried out in the Department of Microbiology for a period of 12 months i.e, November 2022 to May 2023. A total of 300 Klebsiella species from the isolates were tested collected from hospitalized and consultation patients were included in the study. The Antimicrobial susceptibility testing was performed according to the CLSI guidelines . The DNA extraction was done using the Qiagen DNA extraction kit and the resistant gene blaNDM and blaOXA-48 was detected using the PCR.

Processing in laboratory

All samples were collected and processed according to the standard laboratory protocols. All the bacteria isolated were identified by standard biochemical tests and antimicrobial susceptibility testing was performed as per CLSI guidelines [17].

Screening test

Disc diffusion method: A carbapenem intermediate or resistant result should always raise the suspicion of possible carbapenemase production, as should reduce carbapenem susceptibility within the susceptible range in isolates of members of the family

1. **Confirmatory test**

Commercial Carba NP (cCarba NP): The RAPIDEC CARBA NP test detects carbapenem hydrolysis by carbapenemase-producing Enterobacteriaceae and Pseudomonas aeruginosa grown in culture. Hydrolysis acidifies the medium which results in a color change of the pH indicator – indicating the presence of a carbapenemase.

Testing the culture susceptibility towards novel β- lactam / β lactamase inhibitor combination drugs:

1. **Ceftazidime- avibactum >21/<20 (S/R)**
2. **Meropenam – vaborbactum >21/<19 (S/R)**

All above novel β- lactam drugs are FDA approved.

Inclusion criteria

1. All consecutive non duplicate isolates of *Klebsiella species* from clinical samples
2. Patient who gave consent
3. Patient of all age group and gender were included.

Exclusion criteria

1. Duplicate or repeated samples.
2. Patient who did not give consent were excluded from the study

Antibiotic Susceptibility Tests

The samples were assessed for their vulnerability by disc diffusion technique (DDT) as per the CLSI guidelines 2024. The subsequent discs of antibiotics (drug concentrations in µg) were used: like Ampicillin(10), Ampicillin/ Sulbactam (10/20), Gentamycin (30), Cefoxitin (30), Amikacin (30), Ciprofloxacin (10), Meropenem (10), Ceftazidime(30), Ceftazidime/ clavunalate(30/10), Piperacillin/ tazobactam(100/10), Ceftriaxone(30), Nitrofurantoin(30), Tigecycillin(15) and fosfomycin (20).

Methods for detection of carbapenamses production

The phenotypic detection of carbapenemases can be difficult using standard methods, as there is a considerable variation in the MICs for carbapenems. The highest MICs are usually recorded for ertapenem, with meropenem and/or imipenem Minimum inhibitory concentration (MICs) that are lower and sometimes even in the susceptible range(1 mg/liter [CLSI] and 2 mg/liter for carbapenem resistant [EUCAST]). Reliable phenotypic tests are available only for some carbapenemases and usually require 2 to 24 hr.

3. GENOTYPIC METHOD

MOLECULAR METHODS: For the detection of the gene blaNDM and blaOXA gene the chromosomal DNA from the clinical strains of *E.coli* was extracted. The DNA extraction was carried out using a commercial available DNA extraction kit (Qiagen DNA Extraction Kit) as indicated by the manufacturer's instructions.

The extracted DNA was run in PCR for its extension according to standard method.

Fig No.1 The DNA Extraction Reagents

DNA extraction and PCR method

- Total genomic DNA was extracted from all the ESBL positive isolates using a DNA extraction kit according to the manufacturer's instructions. Amplification and detection of the considered gene was done by the PCR method using specific primers.
- The primers were purchased from "Saha gene' and was reconstituted with sterile double distilled water based on the manufacturer's instruction.

Fig No. 2: Primers for NDM gene

Fig No.3: Primers of OXA gene

Polymerase Chain Reaction (PCR)

- The amplification of the blaNDM and blaOXA gene sequence was performed using PCR**.**

TARGET GENE	PRIMER	LENGTH BASE PAIR
blaNDM	**Forward-5; -**GCAGCTTGTCGGCCATGCGGGC **-3'** **Reverse- 5' -** GTCGCGAAGCTGAGCACCGCAT**-3'**	**782 [18]**

Table 1: Primers used for *bla*NDM gene

TARGET GENE	PRIMER	LENGTH BASE PAIR
***Bla*OXA-48**	**Forward-5' -** GCGTGGTTAAGGATGAACAC**-3'** **Reverse-5'-**CATCAAGTTCAACCCAACCG **-3'**	**438 [18]**

Table 2: Primers used for *bla*OXA-48 gene

Polymerase Chain Reaction (PCR)

For the PCR amplification, 2 µl of template DNA was added to 18 µl reaction containing 10 µl of Qiagen master mix, 2 µl of primer mix (1 µl each of the respective forward and reverse primers) and 6 µl of molecular-grade water.

The cyclic conditions for blaNDM gene, initial denaturation at 95 °C for 15 min, 30 cycles of 94 °C for 30 s, 59 °C for 1 min 30 s and 72 °C for 1 min 30 s were followed by extension of 72 °C for 10 min.

The PCR cycling conditions

Step	**Program** **blaNDM** **Time** **Temperature**	**Cycles**
Initial denaturation	15 min 95 ºC	
Denaturation	30 s 94 ºC	
Annealing	1 min30 s 59 ºC	30
Extension	1 min 30 s 72º C	
Final extension	10 min 72º C	

Table No. 4 : The PCR cycling conditions to amplify blaNDM gene fragments.

Step	**Program** **BlaOXA-48** **Time** **Temperature**	**Cycles**
Initial denaturation	15 min 95 ºC	
Denaturation	30 s 94 ºC	
Annealing	1min 30 s 52 ºC	30
Extension	1 min 30 s 72º C	
Final extension	1 min 30 s 72º C	

Table No. 5 : The PCR cycling conditions to amplify blaOXA-48 gene fragments

For acquired blaOXA genes, the initial denaturation was at 95 °C for 15 min, 30 cycles of 94 °C for 30 s, 52 °C for 1 min

30 s and 72 °C for 1 min 30 s, followed by extension of 72 °C for 1 min 30 s. The cyclic conditions for blaCTX gene, initial denaturation at 95 °C for 15 min, 30 cycles of 94 °C for 30 s, 59 °C for 1 min 30 s and 72 °C for 1 min 30 s were followed by extension of 72 °C for 10 min.

The Agarose gel preparation and visualized by Gel Doc™ EZ Gel Documentation System

- The Agarose Gel Electrophoresis was performed in order to identify the Purified PCR Product which was previously identified by its amplified DNA fragments.
- The resulting PCR product was subjected to 1 % agarose gel electrophoresis and visualized by Gel Doc™ EZ Gel Documentation System (Bio-Rad Laboratories Inc., Hercules, CA, USA).
- A 1 kb DNA Ladder (Thermo Fisher Scientific ™, Waltham, MA, USA) was used as the marker to evaluate the PCR product of the sample.

Statistical analysis

The categorical data was entered in the Microsoft excel and Master chart was prepared and analyzed by Chi square using standard deviation & calculating proportion.

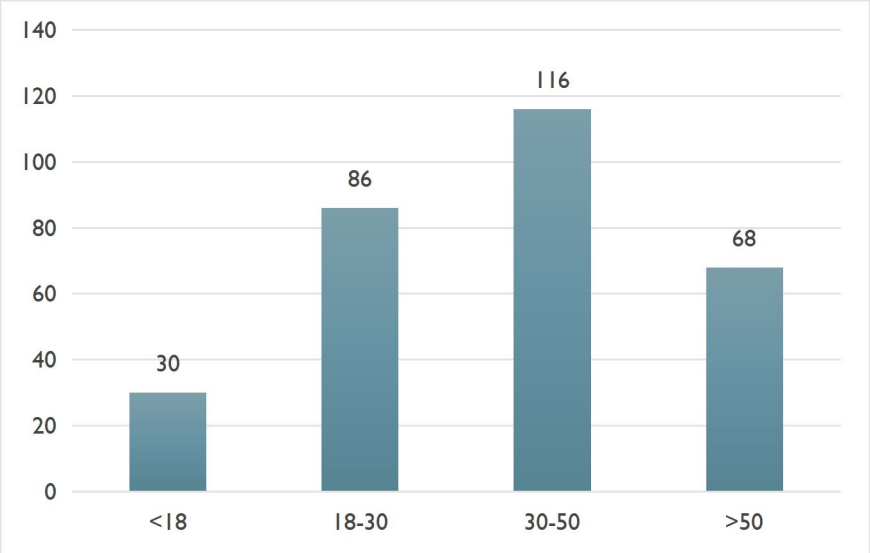
4. RESULTS

In the present study a total of 300 Klebsiella species from the isolates were tested out of which Carbapenamses resistant kKbspp was observed to be 204(68%) and Carbapenamses sensitive Kbspp with 96 (32%) with the prevalence rate of 68%.

Age group	No. of patients	Percentage
<18	30	10%
18-30	86	28.7%
30-50	116	38.7%
>50	68	22.6%

Table No. 6: Age wise distribution of amongst klebsiella positive isolates

The ratio of females was observed to be more as compared to the males with 64% and 36% respectively.



Graph No.1: Graphical representation of Age wise distribution of amongst klebsiella positive isolates

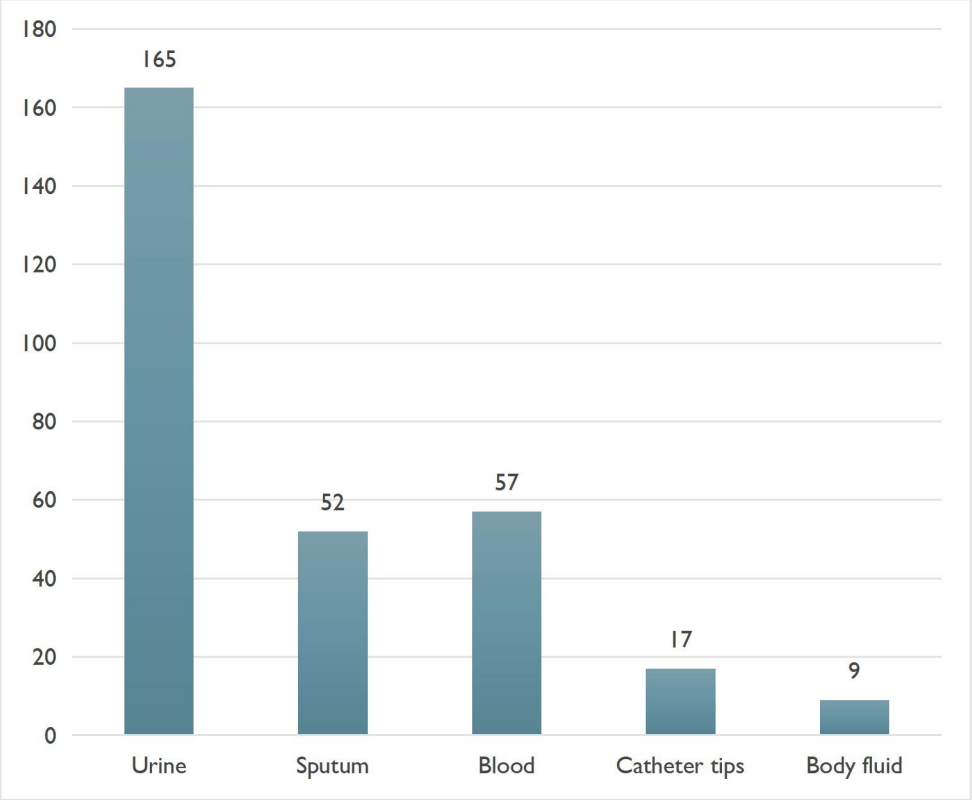
In the present study the maximum number was recorded in the age group of 30-40 (38.7%) years of age followed by 18-30

years with 28.7% and least in and below 18 years with 10%.

Sample	No. of patients	Percentage
Urine	165	55%
Sputum	52	17.3%
Blood	57	19%
Catheter tips	17	5.7%
Body fluid	9	3%

Table No. 7: Isolate of Klebsella in different samples

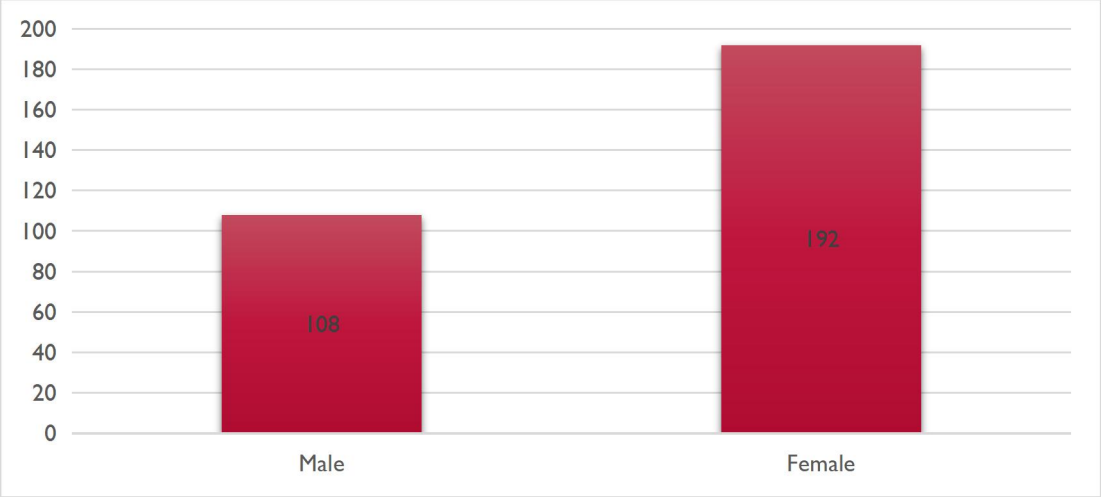
The maximum isolates were from urine (55%) and least for body fluid with 3%.



Graph No.2: Graphical representation of Isolate of Klebsella in different samples

Gender	No of patients	Percentage
Male	108	36%
Female	192	64%

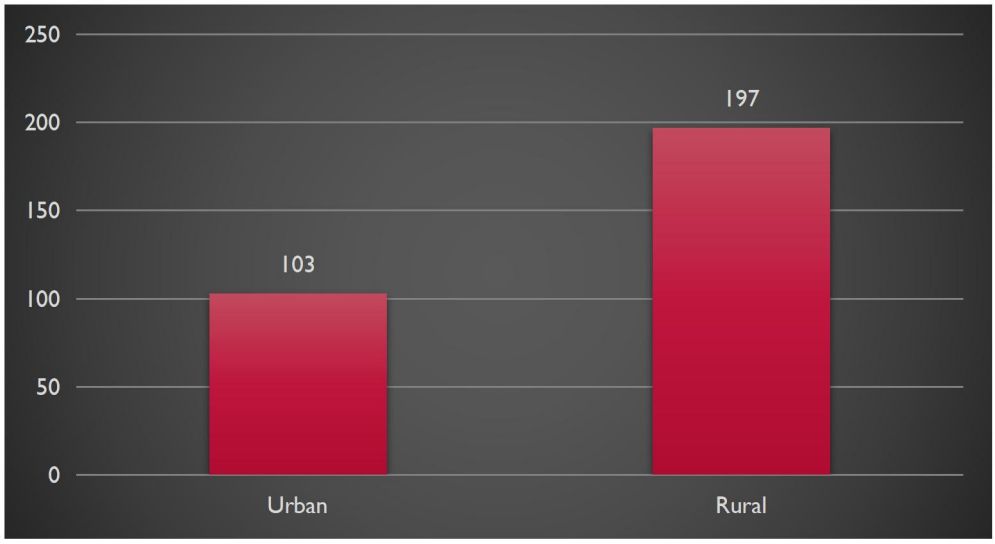
Table No. 8: Ratio of Male/Female amongst Klebsiella positive isolates



Graph No.3: Graphical representation of Ratio of Male/Female amongst Klebsiella positive isolates

Demographic profile	No. of patients	Percentage
Urban	103	34.3%
Rural	197	65.7%

Table No. 9: Sociodemographic Profile of Klebsiella positive Isolates

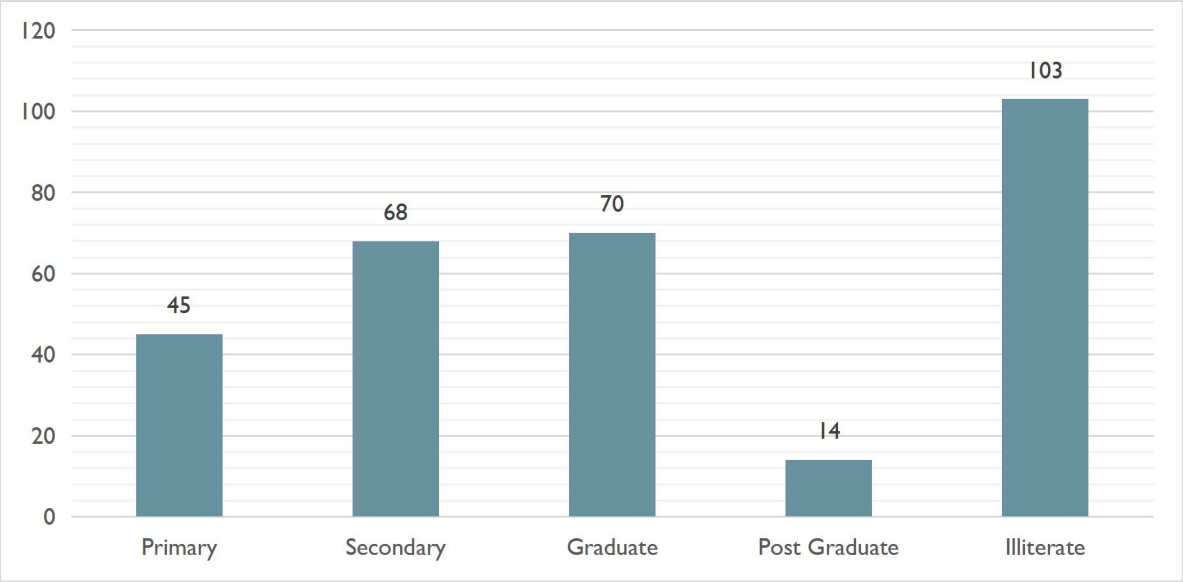


Graph No.4: Graphical representation of Sociodemographic Profile of Klebsiella positive Isolates

Eduction	No. of patients	Percentage
Primary	45	15%
Secondary	68	22.7%
Graduate	70	23.3%
Post graduate	14	4.7%
Illiterate	103	34.3%

Table No. 10: Educational Profile of Klebsiella positive Isolates

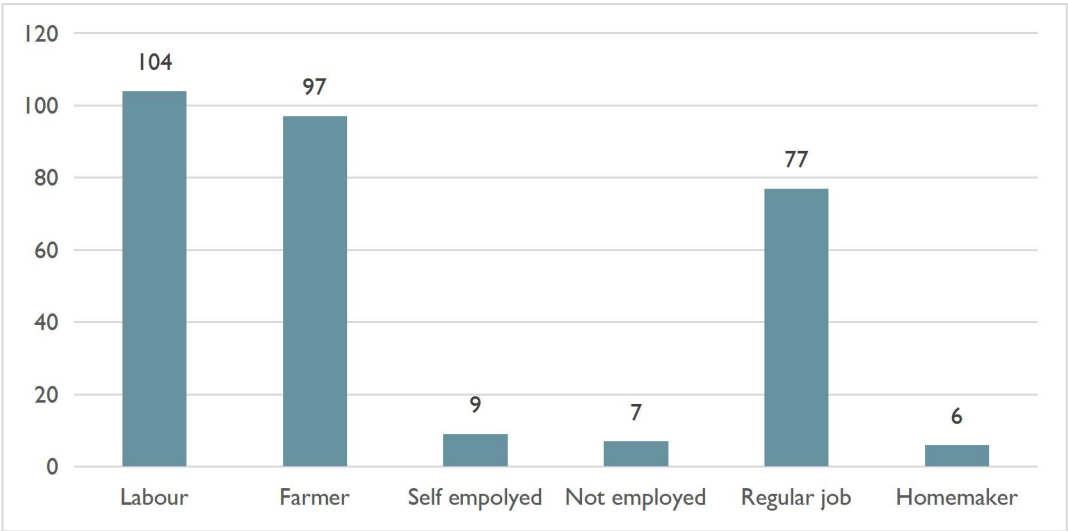
It was also noted that in the rural area (65.7%) cases were recorded and urban with 34.3%. In the present study the illiterate were found to be the most with 34.5%, followed by graduates with 23.3 % and least for post graduates with 4.7%.



Graph No.5: Graphical representation of Educational Profile of Klebsiella positive Isolates

Occupation	No. of patients	Percentage
Labour	104	34.6%
Farmer	97	32.3%
Self employed	9	3%
Not employed	7	2.3%
Regular job	77	25.7%
Homemaker	6	2%

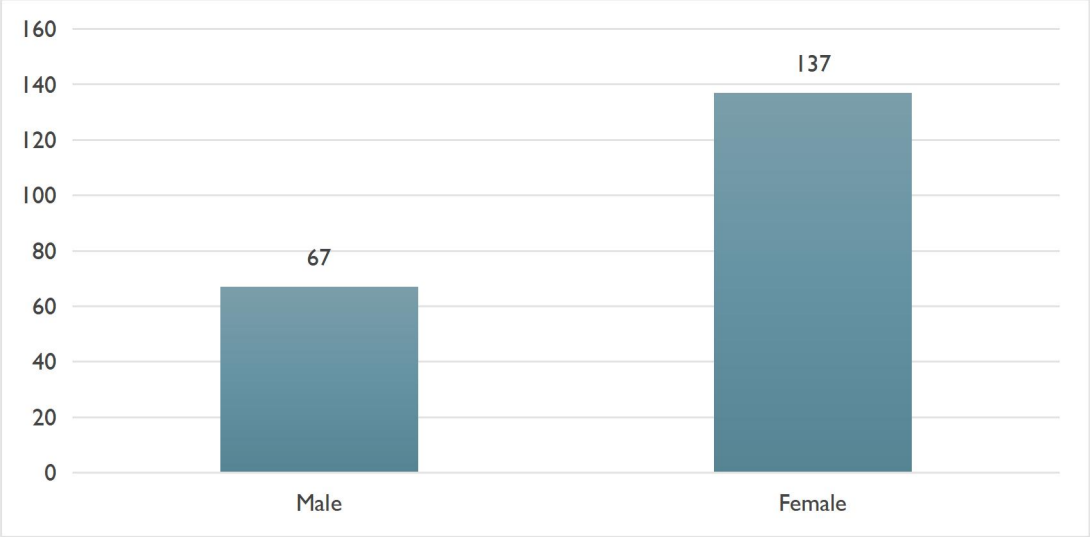
Table No. 11: Occupational Profile of Klebsiella positive Isolates



Graph No.6: Graphical representation of Occupational Profile of Klebsiella positive Isolates

Gender	No. of patients	Percentage
Male	67	32.9%
Female	137	67.1%

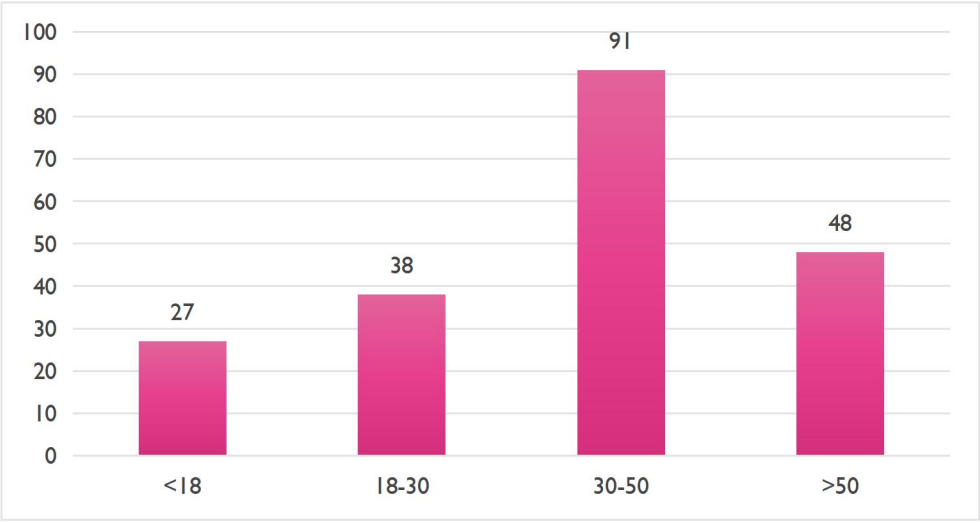
Table No. 12: Ratio of Male/Female amongst Carbapenamses resistant klebsiella isolates



Graph No.7: Graphical representation of Ratio of Male/Female amongst Carbapenamses resistant klebsiella isolates

Age group	No. of patients	Percentage
<18	27	13.2%
18-30	38	18.7%
30-50	91	44.6%
>50	48	23.5%

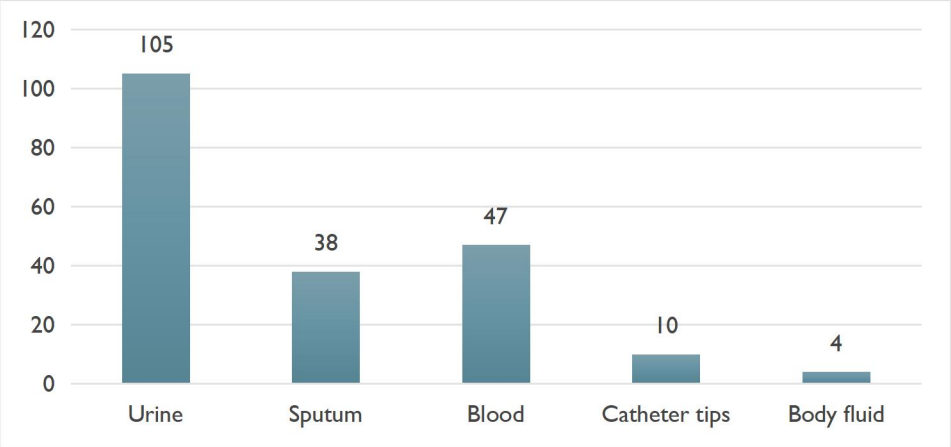
Table No. 13: Age wise distribution Carbapenamses resistant klebsiella isolates



Graph No.8: Graphical representation of Age wise distribution Carbapenamses resistant klebsiella isolates

Sample	No. of patients	Percentage
Urine	105	51.4%
Sputum	38	18.7%
Blood	47	23%
Catheter tips	10	4.9%
Body fluid	4	2%

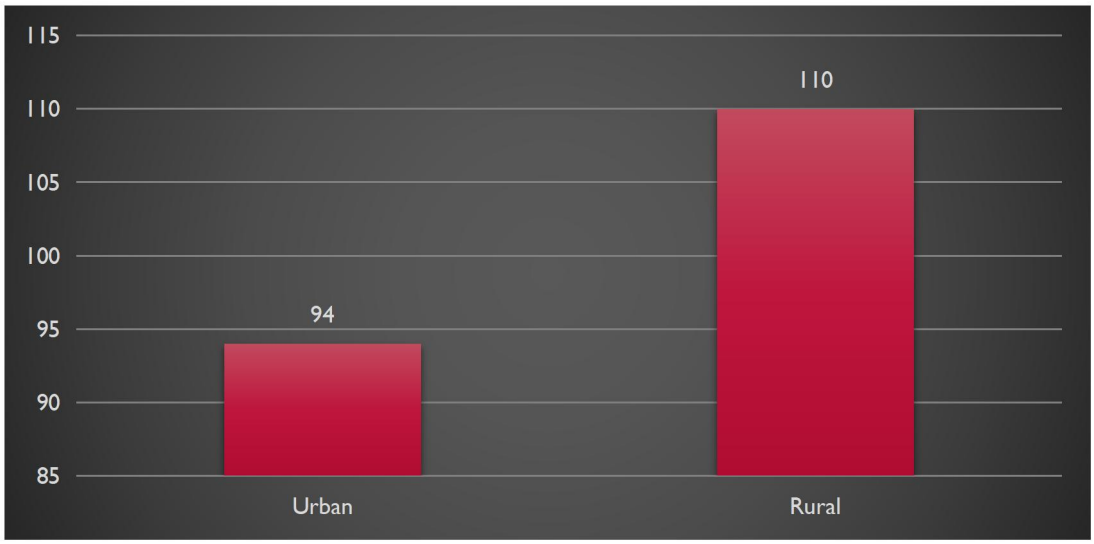
Table No. 14: Isolate of Carbapenamses resistant klebsiella in different samples



Graph No.9: Graphical representation of Isolate of Carbapenamses resistant klebsiella in different samples

Demographic profile	No. of patients	Percentage
Urban	94	46%
Rural	110	54%

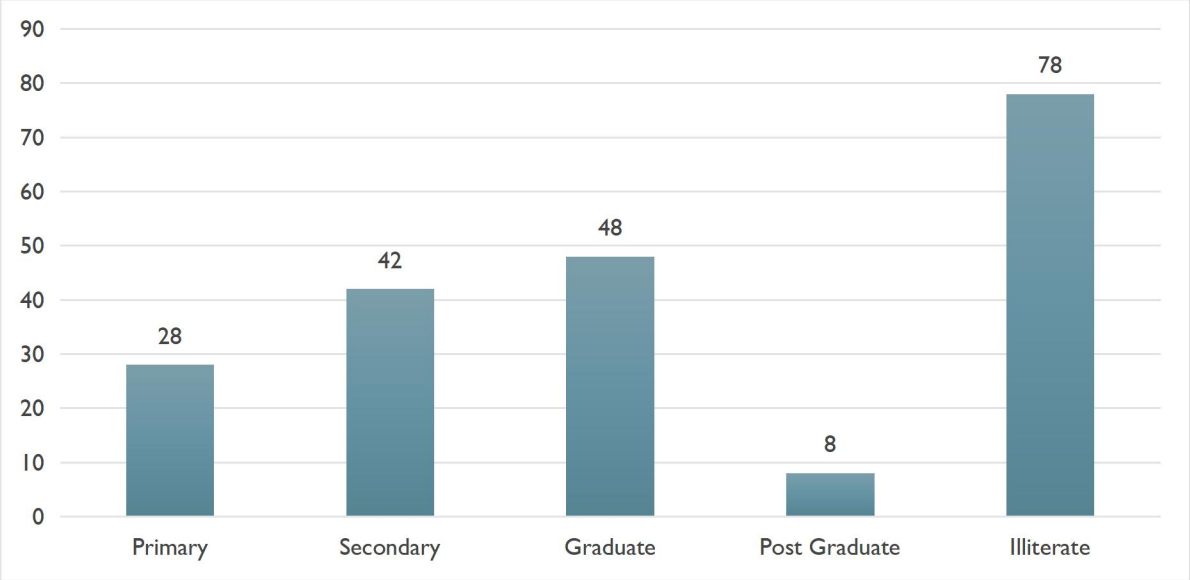
Table No. 15: Sociodemographic Profile of Carbapenamses resistantklebsiella in different samples



Graph No.10: Graphical representation of Sociodemographic Profile of Carbapenamses resistantklebsiella in different samples

Eduction	No. of patients	Percentage
Primary	28	13.8%
Secondary	42	20.5%
Graduate	48	23.5%
Post graduate	8	4%
Illiterate	78	38.2%

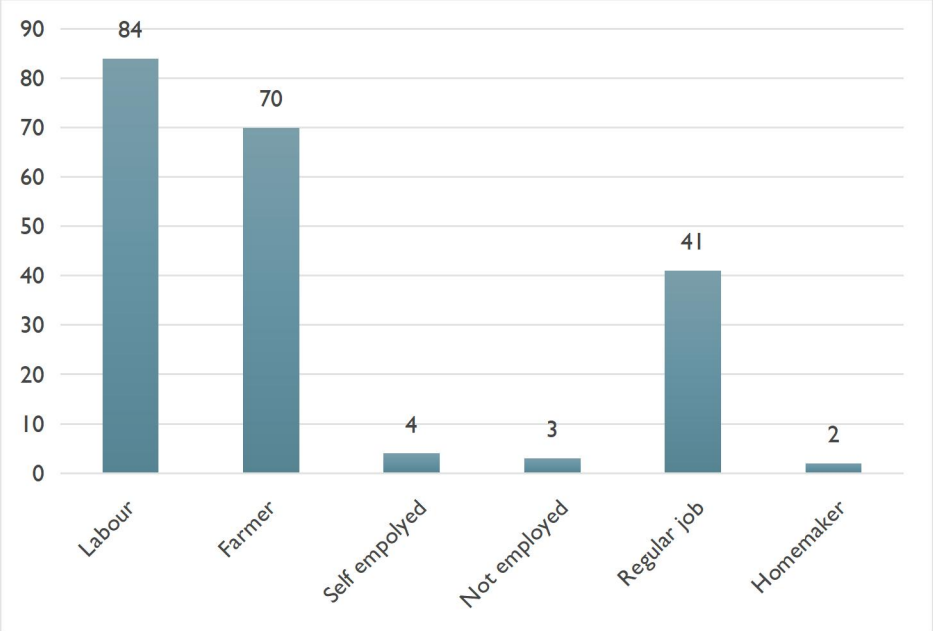
Table No.16: Educational Profile of Carbapenamses resistant klebsiella



Graph No.11: Graphical representation of Educational Profile of Carbapenamses resistant klebsiella

Occupation	No. of patients	Percentage
Labour	84	41.2%
Farmer	70	34.3%
Self employed	4	2%
Not employed	3	1.4%
Regular job	41	20.1%
Homemaker	2	1%

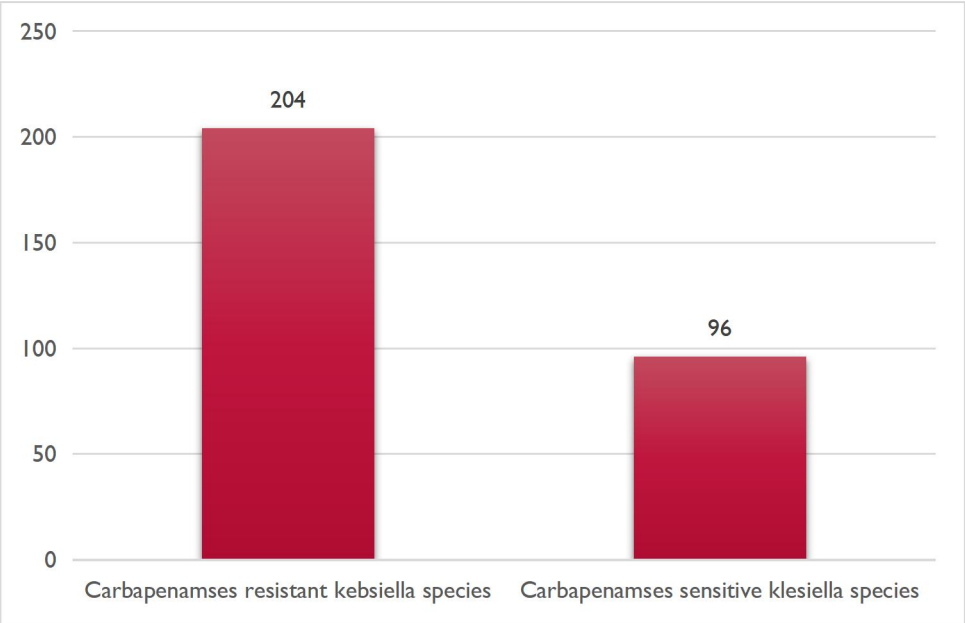
Table No. 17: Occupational Profile of Carbapenamses resistant klebsiella



Graph No.12: Graphical representation of Occupational Profile of

Carbapenamses Kebspp	No. of patients	Percentage
Carbapenamses resistant kKbspp	204	68%
Carbapenamses sensitivekKbspp	96	32%

Table No. 18: Carbapenamses resistant klebsiella



Graph No.13: Graphical representation of Carbapenamses sensitive and resistant kebsiella species

The labour class was the most affected with 34.6%. The Ratio of Male/Female amongst Carbapenamses resistant klebsiella isolates was observed to be 32.9% and 67.1 % respectively. The age group 30-40 was the most commonly affected in Carbapenamses resistant klebsiella isolates with the urine cases most commonly found with 51.4%.

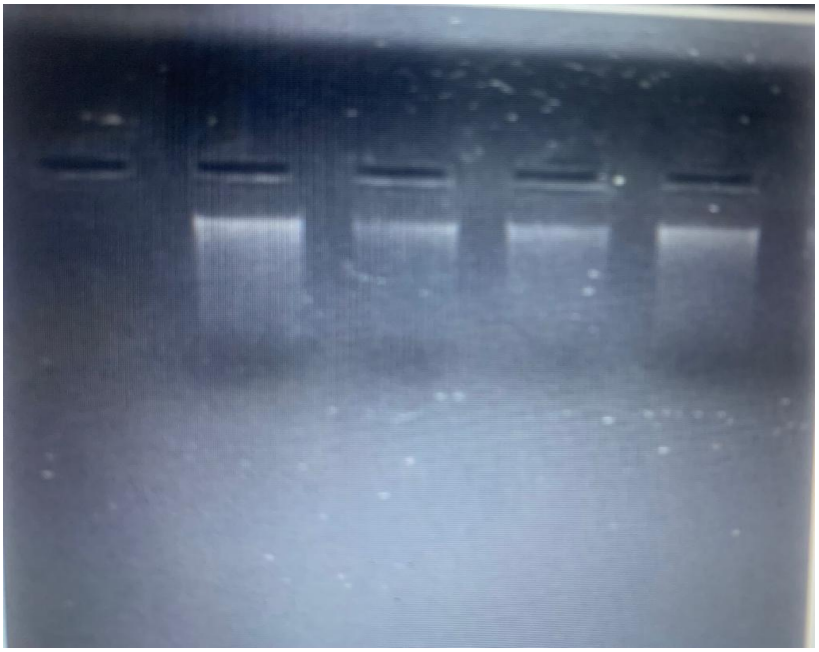


Fig No. 4: The DNA Extraction in Agarose gel

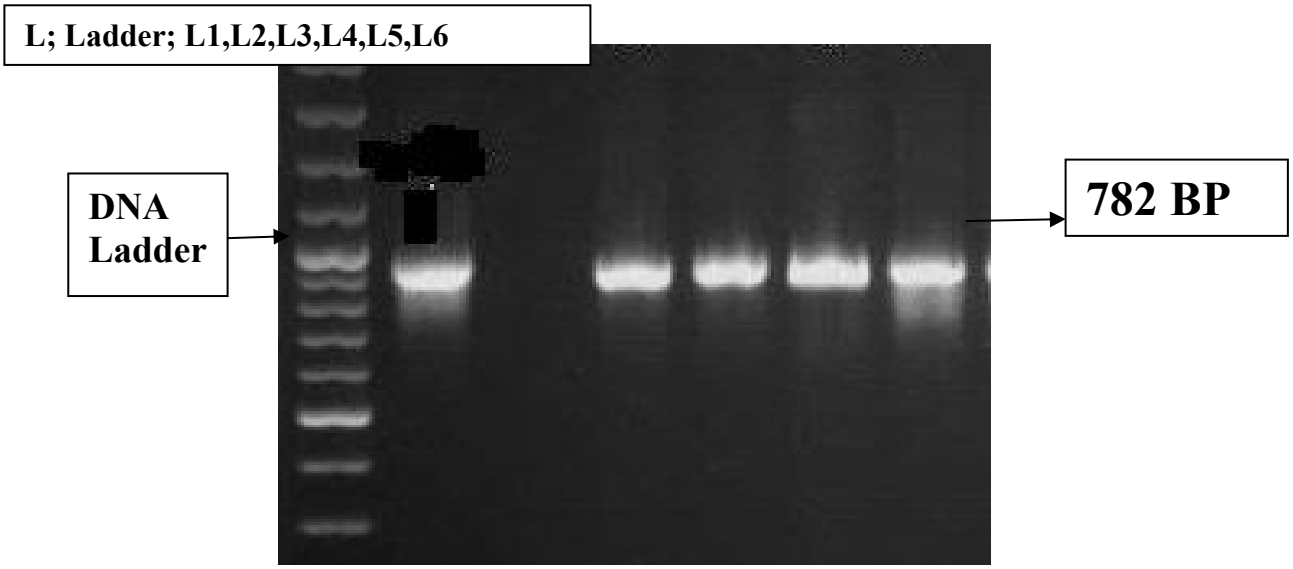


Fig No. 5: Gene *bla*NDM gene

L corresponds to the DNA Ladder; L1 corresponds to the positive Control; L2 Corresponds to the Negative Control to blaNDM gene; L3-L6

are the sample positive for blaNDM gene

L1,L2,L3,L4,L5,L6,L7,L8,L9,L10,L (Ladder)

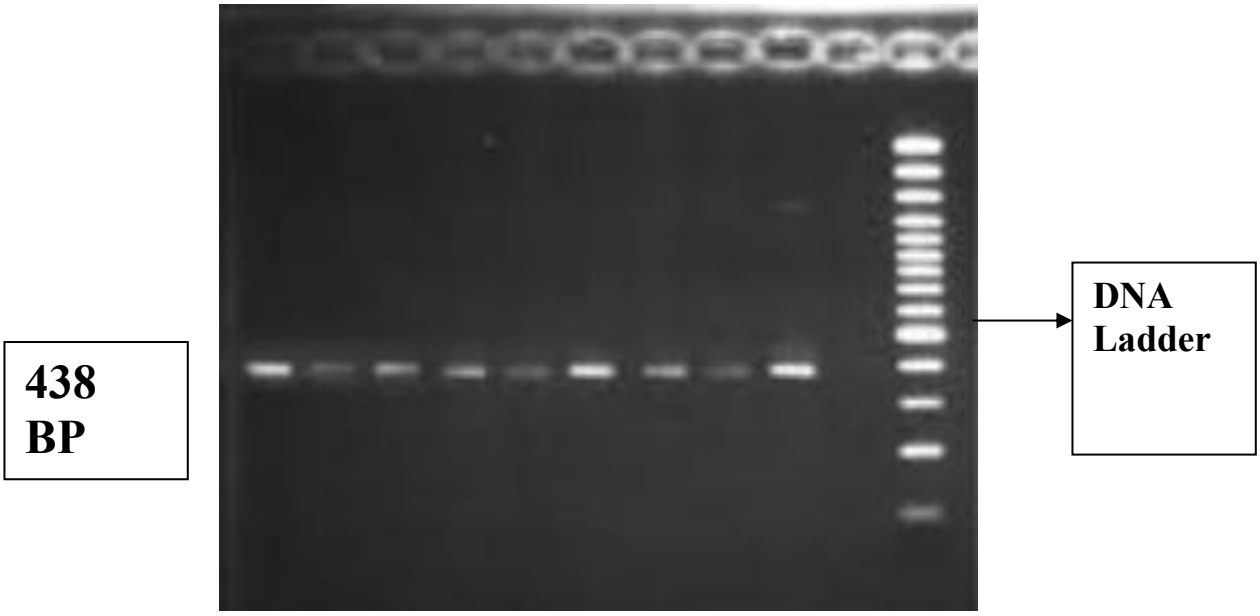


Fig No. 6: Gene *bla*OXA-48 gene

L1 corresponds to the positive Control; L2-L9 Corresponds to the sample positive for blaOXA-48 gene; L10 is the Negative Control to blaNDM gene; L corresponds to the DNA Ladder

5. DISCUSSION

Carbapenem-resistant Enterobacteriaceae (CRE) frequently cause infections in immunocompromised patients, leading to prolonged hospital stays and increased mortality Despite the introduction of new antibiotics for CRE infections, combating antibiotic resistance remains challenging due to the limited availability of effective treatments and the lack of comprehensive clinical data from large randomized controlled trials. Diagnosing, treating, and preventing CRE infections are significant challenges. Notably, carbapenem-resistant *Klebsiella pneumoniae* (CRKP) is identified as a critical-priority pathogen among CREs [4].

In the present study a total of 300 Klebsiella species from the isolates were tested out of which Carbapenamses resistant kKbspp was observed to be 204 (68%) and Carbapenamses sensitive Kbspp with 96 (32%) with the prevalence rate of 68%. This study was in accordance to the study conducted by Jennifer H Han et al where a total of 3846 *K. pneumoniae* cultures were identified, with an overall carbapenem resistance rate of 24.6%. There were significant differences in CRKP rates across geographic regions, with the highest in the West (42.2%) [19].

The ratio of females was observed to be more as compared to the males with 64% and 36% respectively. This study was in constrast to the study conducted by the other research investigator where there is a predominance of males (58%) over females (42%) [20].

In the present study the maximum number was recorded in the age group of 30-40 (38.7%) years of age followed by 18-30 years with 28.7% and least in and below 18 years with 10%. This study was in accordance to the other study where solation of Klebsiella pneumonia also the infection was observed to be more common in age group 41-60 years [20]. In the current study the maximum isolates were from urine (55%) and least for body fluid with 3%. This study was in support to the current study where the highest percentage of *Klebsiella pneumonia* were isolated were from pus (27.8%) followed by urine (22%), blood (8%) and sputum (8%) [20]. There was another study where urine was the most common isolated [21]. Factors such as dietary habits, food sources, and sanitation systems may contribute to the high prevalence of Kp carriage [22].

In the present study a total of 300 Klebsiella species from the isolates were tested out of which Carbapenamses resistant kKbspp was observed to be 204(68%) and Carbapenamses sensitive Kbspp with 96 (32%). There was another study similar to the present study where here was a prevalence of carbapenem resistance of nearly 25% among *K. pneumoniae* isolates from this large, LTACH-based surveillance study in the United States [19].

In the present study the molecular characterization confirms blaNDM gene with 48 (23.5%) and blaOXA-48 with 57 (27.9%) was expressed. In the current study the expression of blaOXA -48 gene was more as compared to the blaNDM gene. This was in constrast to the other study by Sarva Kamalakar et al., in 2024 where about 66.4 % of CRKP isolates harbored *bla*$_{NDM}$, 17.4 % harbored *blaOXA-48*, and 16.2 % harbored both *bla*NDM and blaOXA48 genes [23].

In India, carbapenem resistance is mainly due to *bla*NDM and *bla*OXA-48 enzymes. Other carbapenemase genes such as *bla*KPC, *bla*VIM, and *bla*IMP were rarely seen (Mohanty et al., 2017, Veeraraghavan et al., 2017). [24,25]. In another study, the bla_{OXA-48} gene was detected in 44.5 % of carbapenem-resistant isolates (Pawar et al., 2020). Which wa sin accordance to the current study [26].

There was another studies which were in support to the current study wherein 55% reported in Croatia by Šuto et al. [27], the 66.7% in South India by Remya et al. [28], and the 52% and 100% in Egypt and Iran, respectively, reported by El-Domany et al. [29]and Ghanbarinasab et al. [30]. These variations may be due to differences in sample size, study population, or geographical location.

The polymyxins are typically the last-line agents used for treatment of infections due to CRKP and are often critical for combination therapy regimens. These results emphasize the importance of healthcare setting–specific antibiotic susceptibility rates for antibiotic stewardship efforts and guidance of empiric treatment of patients at high risk for infections due to CRKP. In addition, increased resources and funding should be directed toward enhanced monitoring of colistin/polymyxin B resistance rates on a national basis [31]

The OXA-48 and NDM-1 carbapenemase genes are critically important due to their capacity to rapidly disseminate and induce high-level resistance to carbapenems, which significantly limit treatment options for infections caused by *Klebsiella pneumoniae*. Surveillance data from tertiary hospitals indicate a rising trend in carbapenem resistance, highlighting the urgent need for effective monitoring and control strategies to address the spread of these resistant strains [32].

It is a serious alarm in clinical settings that CRKP infections could limit the antibiotics for treatment and complicate the recovery of patients from the infections. Many studies reported hospital-acquired CRKP infections and their treatment failure. Infection Control Policies should be strictly implemented in hospitals to control the spread of infectious agents especially multidrug-resistant pathogens [33].

6. CONCLUSION

The infections caused by CRKP are a serious public health concern, especially in patients under treatment in hospital settings. Strict implementation of Infection Control Policies would reduce the carbapenem-resistant bacterial infections spreading to the community. Performing regular surveillance studies in hospitals is very important to identify the circulating genes among carbapenem-resistant bacteria which will help to overcome the therapeutic challenges in treating the patients infected with CRKP.

DECLARATIONS:

Conflicts of interest: There is no any conflict of interest associated with this study

Consent to participate: There is consent to participate.

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