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Prevalence and pattern of multidrug resistant Gram-negative bacilli isolated from patients in the intensive care unit of a tertiary care hospital in Coastal Karnataka

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ABSTRACT

Introduction: Infections due to Gram negative bacilli (GNB) are the leading cause of mortality in ICU patients and are associated with higher morbidity rates, longer hospital stays and increased healthcare expenditures. Infections due to GNB in the ICU is about 2 to 5 times higher than in the general in-patient hospital population. This study aims to look at the prevalence of multi drug resistant gram-negative bacilli and proportion of ESBL producers in the MICU and to determine susceptibility patterns of GNB isolated, to various antibiotics.

Materials and Methods: A total of 616 samples were collected from 396 patients admitted to the MICU during the 4-month study period. After the samples were inoculated and identified, the gram-negative isolates were subjected to Antibiotic susceptibility testing using Kirby Bauer Disc Diffusion technique with 17 different antibiotic disks. Strains showing decreased sensitivity to Ceftazidime/Cefotaxime were screened for ESBL production.

Results: Among the 616 samples tested, 149 (24.2%) samples showed growth of Gram-negative bacteria exclusively. Total number of GNB's isolated were 173 due to some samples showing polymicrobial growth. The most common GNB found was *E. coli* (27.7%) which was followed by Klebsiella pneumonia at 26.0% and Acinetobacter baumannii at 18.5%. 64.2% of all GNB's were Multi Drug Resistant which included 75% *E. coli*, 71.1% Klebsiella pneumoniae and 84.4% Acinetobacter baumannii.

Conclusions: The study shows that the MDR GNB infections are on the rise in the ICU with GNBs being highly resistant to many previously effective first line antibiotics like Penicillins, newer Cephalosporins and Fluoroquinolones with susceptibility rates below 25% and even 0% for earlier generation Cephalosporins.

1. Introduction

Infections due to Gram negative bacilli (GNB) are the leading cause of mortality in ICU patients and are associated with higher morbidity rates, longer hospital stays and increased healthcare expenditures.[1] Gram negative bacilli are the most common cause of urinary tract infections, blood stream infections, respiratory tract infections and sepsis.[2] Infections due to GNB in the Intensive Care Unit is about 2 to 5 times higher than in the general in-patient hospital population.[3]

Gram negative bacilli are highly efficient at up-regulating or acquiring genes that code for mechanisms of antibiotic drug resistance, especially in the presence of antibiotic selection pressure. They use multiple mechanisms against the same antibiotic or use a single mechanism to affect multiple antibiotics. In addition to the threat of developing antibiotic resistance, there is a reduction in the discovery and development of new antibiotics.[4] Several factors like overcrowding of patients with high levels of disease acuity in relatively small specialised areas of the hospital increases the likelihood of person-to-person transmission of

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microorganisms. Imperfect infection control practices and use of excessive invasive devices also contribute to the development of high antimicrobial resistance.[5]

Multiple Drug Resistance (MDR) is defined as non-susceptibility to at least one agent in three or more antimicrobial categories.[6] Frequent use of broad-spectrum antibiotics results in the selection of resistant strains. Thus, the ICU patient frequently experiences infections by resistant pathogens which pose major clinical problems despite the introduction of new and potent antibiotics.[7]

The predominant mechanism for resistance to the β-lactam antibiotics in gram-negative bacteria is the production of β-lactamase. The production of extended-spectrum β-lactamases (ESBLs) is an important mechanism which is responsible for the resistance to the third-generation cephalosporins.[8] The genes for the ESBL enzymes are plasmid borne and have evolved from point mutations, thus altering the configuration of the active site of the original and long known β-lactamases.[9]

The problems which are associated with ESBLs include multi drug resistance, difficulty in detection and treatment, and increased morbidity and mortality. Awareness and the detection of these enzymes are necessary for optimal patient care.

Hence, this study aims to look at the prevalence of multidrug resistant gram-negative bacilli and ESBL producers among patients in the ICU and to determine susceptibility pattern of GNB to various antibiotics from different classes which will help in deciding optimum empirical therapy for critically ill patients

2. Materials and Methods

This prospective observational study was conducted after obtaining approval from the Institutional Ethics Committee. It included all adult patients aged 18 years and above who were admitted in the medical intensive care unit (MICU) of a tertiary care teaching hospital during the 4-month study period.

2.1. Lab methods

Clinical samples such as blood, urine, wound discharge/pus and respiratory secretions were aseptically collected using sterile containers and transported to the Microbiological laboratory. Samples were inoculated onto MacConkey agar and 5% Sheep blood agar and incubated at 37^oC for 24 hours. Identification of bacteria was done using colony characteristics, gram stain and different biochemical tests like Indole test, MRVP test, Catalase test, H_2S production test, Citrate utilization test, Urease test, Sugar fermentation test, Ornithine test, Decarboxylase test, OF test (Oxidative fermentation), and PPA test (Phenyl pyruvic deaminase).

The Kirby-Bauer disk diffusion method was used to test antimicrobial susceptibility (in Mueller-Hinton agar medium) and interpreted following CLSI 2019 guidelines.[10] The antibiogram disks that was used includes Ampicillin (10μg), Amoxiclav (10/20μg) Gentamicin (10μg), Amikacin (30μg), Trimethoprim- sulfamethoxazole (25μg), Chloramphenicol (30mg), Cefotaxime (30μg), Ceftazidime (30μg), Aztreonam (30μg), Piperacillin-Tazobactam (100/10μg), Ciprofloxacin (5μg), Levofloxacin (5μg), Imipenem (10 μg) and Meropenem(10μg).[11]

2.2. Phenotypic characterization

Strains showing decreased sensitivity to Ceftazidime/ Cefotaxime were screened for ESBL production as per CLSI guidelines 2019.

Test was done by using both ceftazidime (30 μg) disk alone and the combination of clavulanic acid (30 μg/10 μg). Disks were placed 25 mm apart from each other on Mueller-Hinton agar inoculated with 0.5 McFarland suspension of the test isolate. A difference of more than or equal to 5 mm in zone diameter between both discs was interpreted as ESBL producer. Quality control was done by testing with the American Type Culture Collection (ATCC) strains like *Klebsiella pneumoniae* ATCC 700603 and *E. coli* ATCC 25922.

2.3. Statistical analysis and interpretation

Data was entered, and analysed using SPSS version 23 software (Armonk, NY: IBM Corp. 2015.)

3. Results

A total number of 396 patients were included in the study who were admitted in the MICU during the study period, of which 261(65.9%) were males and 135 (34.1%) were females. Males outnumbered females by almost 2 to 1.

The patients were divided into 4 age groups. 30 (7.6%) patients were in the age group 18-30 years, 92 (23.2%) were 31-50 years, 184 (46.5%) of them were 51-70 years old and 90 (22.7%) were 71-90 years old. Almost half of the patients were in the 51-70 age group.

A total of 616 samples were collected from 396 patients and Urine was found to be the most frequently collected sample at 48.2 % which was followed by blood at 26.1%. More than one-third of all samples showed some growth. 149 (24.2%) samples showed growth of Gram-negative bacteria exclusively. (Table 1)

From 149 samples showing exclusive growth of GNB, 173 GNB were isolated due to some samples showing polymicrobial growth. Among the Respiratory samples, i.e., Sputum and ET Tip, most common organism was Acinetobacter baumannii (40%). In both Blood & Urine, the most common pathogen isolated was *E. coli* at 34.4% and 46.5% incidence rate respectively. In Pus, *Klebsiella pneumoniae* was most abundant at 33.3% and in Wound swab, it was Pseudomonas aeruginosa at 42.9%. (Table 2)

An antibiogram was prepared for Gram-negative bacteria with n>5. *E. coli* was most sensitive to Amikacin (75%) and Imipenem (73%). *Klebsiella pneumoniae* also followed the same pattern and showed highest sensitivity to Amikacin and Imipenem at 53.3% and 48.9% respectively albeit the proportion of Resistant strains were higher.

Acinetobacter baumannii too had high amount of MDR strains and Cotrimoxazole & Amikacin/Gentamicin were effective only in 34.3% and 31.2% cases respectively.

Amikacin was highly efficacious for Pseudomonas aeruginosa (80%), followed by Imipenem/Meropenem in 72% cases. Klebsiellla oxytoca was sensitive to Amikacin and Cotrimoxazole 60% of the time.

High rate of resistance is seen to Ampicillin and first, second and third generation cephalosporins due to intrinsic resistance. There is no discernable difference between the three generations of cephalosporins and all organisms are highly resistant to them. (Table 3)

Multiple Drug Resistance (MDR) is defined as non-susceptibility to at least one agent in three or more antimicrobial categories.[6] Based on this definition, 111 organisms out of a total 173 GNB are Multi Drug Resistant (64.2%). 36/48 (75%) *E.coli* specimens, 32/45 (71.1%) *Klebsiella pneumoniae* and 27/32 (84.4%) *Acinetobacter baumannii* specimens are MDR.

Strains of *Klebsiella pneumoniae, Klebsiella oxytoca, E.coli* and Proteus mirabilis showing decreased sensitivity to Cefotaxime/Ceftazidime were tested for ESBL Production as per CLSI guidelines. A total of 79 strains of these 4 organisms showed decreased sensitivity to Cefotaxime/Ceftazidime - 39 *E.coli*, 37 *Klebsiella pneumoniae*, 3 *Klebsiella oxytoca* and 0 Proteus mirabilis.

Based on Kirby Bauer Disc Diffusion method, there were 21 ESBL producers out of 79, i.e 11/39 *E.coli* and 10/37 *Klebsiella pneumoniae*. (Figure 1)

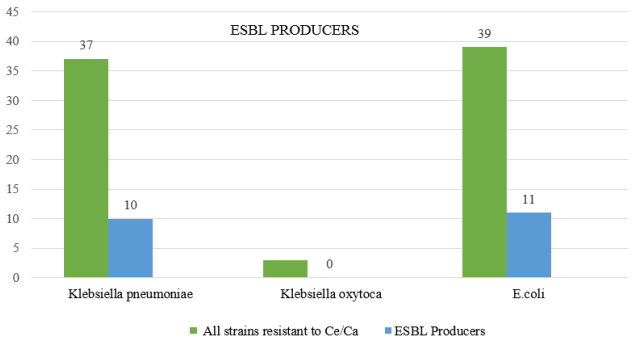

Fig. 1: Proportion of ESBL producers

4. Discussion

Gram-Negative Bacteria are the leading causes of infection and subsequent death in the ICU. This can be attributed to Antibiotic resistance which can be due to a great number of factors like therapy with Broad spectrum antibiotics, frequent invasive procedures, prolonged hospital stay and other co-morbid conditions.

Among the 396 patients who were admitted to the MICU during the study period, 65.9%were males and 34.1% were females with a Male to Female ratio of 1.93. Other studies also had a male preponderance with Sahoo et al.[12] reporting a Male to Female ratio of 1.46:1, Garland et al.[13] reported a ratio of 1.75 and Jamshidhi et al.[14] reported an M:F ratio >2. This could be possibly due to the fact that men are more likely to suffer from chronic conditions needing ICU admission due to lifestyle choices like dangerous occupations, heavy drinking and smoking.

The majority of the patients i.e., 184 (46.5%) were in the age group 51-70 years followed by 92 people (23.2%) in the 31-50 years age group. Wise et al.[15] reported a median age of ICU admission in South Africa at 38 years which is in contrast to our findings. A study by Qadeer et al.[16] in Pakistan agrees with our findings and their study shows approximately 41.5% ICU admissions in the age group 50-69 years and 23% in the age group 30-49 years.

Urine was the most commonly collected sample which accounted for 48.2% of all collections, followed by blood at 26.1% and ET Tip at 11.7%. This is in contrast to a study done by Balakrishnan et al.[17] who reported blood sample collection at 58.3%, followed by urine at 14.1%. Another study by Moolchandani K et al.[18] reported Tracheal exudate and sputum as the most commonly collected samples.

The most common GNB found in the MICU was *E. coli* and it accounted for 27.7% of the total GNB which was followed by Klebsiella pneumonia at 26.0% and *Acinetobacter baumannii* at 18.5%. Balakrishnan et al.[16] also reported *E. coli* (27.7%) as the most common GNB, but it was followed by A. baumannii (24.7%) and then K. pneumoniae (19.8%). In contrast to our study, Bhatta et al.[19] reported K. pneumoniae as the most GNB most isolated at 39.8%, followed by *E. coli* at 35.9% and *A. baumannii* at 14.8%. In a study from Nepal, Siwakoti et al[20] reported Acinetobacter spp (38%) as most commonly isolated organism followed by *Klebsiella pneumoniae* (29%) and Pseudomonas spp (22%).

In our study, the most common GNB isolated from Urine and blood is *E. coli* at 46.5% and 34.4% incidence respectively. The most common GNB in Respiratory secretions is *A. baumannii* at 40% and 46% in Sputum and ET Tip respectively. Most common GNB in Pus is K. pneumoniae (33.3%) and in Wound swab its *P. aeruginosa* (42.9%). Balakrishnan et al and Mohammadi-mehr et al.[21] have reported *E. coli* as most commonly found in Urine, K. pneumoniae in Blood and *A. baumannii* in Respiratory secretions.

From the antibiogram prepared, it's evident that the strains of *K. pneumoniae, A. baumannii*, *P. aeruginosa* and

Table 1: Profile of samples from MICU

Sample	Frequency n (%)	Samples showing growth	Samples showing growth of GNB exclusively
Urine	297 (48.2%)	97 (45.1%)	65 (43.6%)
Blood	161 (26.1%)	53 (24.6%)	30 (20.1%)
ET tip	72 (11.7%)	34 (15.8%)	26 (17.4%)
CSF	28 (4.5%)	0 (0%)	0 (0%)
Sputum	21 (3.4%)	10 (4.6%)	10 (6.7%)
Wound swab	12 (1.9%)	12 (5.6%)	10 (6.7%)
Ascitic fluid	12 (1.9%)	0 (0%)	0 (0%)
Pus	9 (1.5%)	8 (3.7%)	8 (5.3%)
Pleural fluid	3 (0.5%)	0 (0%)	0 (0%)
BAL	1 (0.2%)	1 (0.5%)	0 (0%)
Total	616 (100%)	215 (34.9%)	149 (24.2%)

Table 2: Pattern of Gram-Negative Bacteria isolated from different samples

Gram Negative Bacilli	Sputum n (%)	ET Tip	Blood	Pus	Wound swab	Urine	Total n=173
Escherichia.coli	1 (10)	1 (2.7)	11 (34.4)	-	2 (14.3)	33 (46.5)	48
Klebsiella pneumoniae	3 (30)	9 (24.3)	9 (28.1)	3 (33.3)	4 (28.6)	17 (24.0)	45
Acinetobacter baumannii	4 (40)	17 (46)	5 (15.6)	-	1 (7.1)	5 (7.0)	32
Pseudomonas aeruginosa	1 (10)	7 (19)	2 (6.2)	2 (22.2)	6 (42.9)	7 (9.8)	25
Klebsiella oxytoca	1 (10)	1 (2.7)	-	-	-	3 (4.2)	5
Citrobacter freundii	-	-	-	-	-	3 (4.2)	3
Proteus vulgaris	-	-	-	1 (11.1)	-	2 (2.8)	3
Citrobacter koseri	-	-	-	1 (11.1)	1 (7.1)	1 (1.4)	3
Proteus mirabilis	-	-	1 (3.1)	1 (11.1)	-	-	2
Stenotrophomonas maltophilia	-	1 (2.7)	-	-	-	-	1
Salmonella enterica	-	-	1 (3.1)	-	-	-	1
Kingella denitrificans	-	1 (2.7)	-	-	-	-	1
Enterobacter spp	-	-	1 (3.1)	-	-	-	1
Elizabethkingia meningoseptica	-	-	1 (3.1)	-	-	-	1
Burkholderia pseudomallei	-	-	-	1 (11.1)	-	-	1
Burkholderia cepacia	-	-	1 (3.1)	-	-	-	1
Total	10	37	32	9	14	71	173

K. oxytoca isolated from the MICU are 100% resistant to Ampicillin due to intrinsic resistance and only 10.4% of *E. coli* are sensitive. Susceptibility of all generation cephalosporins ranged from 3.1% to 60% with sensitivity mostly lying below 20%. Nitrofurantoin ranged from 3.1% to 50% making it ineffective against most GNB.

E. coli was least susceptible to Ampicillin (10.4%), followed by Cephalosporins, followed by Fluoroquinolones, Cotrimoxazole, then Nitrofurantoin, Piptaz and most susceptible to Imipenem with 73%. This is in contrast to a study by Saravanan et al.[22] where Cephalosporins are more effective than Cotrimoxazole and Fluoroquinolones for *E. coli* infections.

Klebsiella pneumoniae also followed the same pattern but with 53.3% sensitivity to Amikacin. *Acinetobacter baumannii* shows low susceptibility across all antibiotic classes with it being most susceptible to Cotrimoxazole (34.3%), then Aminoglycosides (31.2%) and intrinsically

Table 3: Proportion of Gram-negative organisms susceptible to different antibiotics

Antibiotics	*E. coli* n = 48 (%)	*Klebsiella pneumoniae* n = 45 (%)	*Acinetobacter baumannii* n = 32 (%)	P.aeruginosa n = 25 (%)	Klebsiella oxytoca n = 5 (%)
Ampicillin	5 (10.4)	0	0	0	0
Gentamicin	29 (60.4)	20 (44.4)	10 (31.2)	17 (68.0)	2 (40.0)
Amikacin	36 (75.0)	24 (53.3)	10 (31.2)	20 (80.0)	3 (60.0)
Cefazolin	7 (14.6)	7 (15.5)	0	0	2 (40.0)
Cefuroxime	7 (14.6)	7 (15.5)	0	0	2 (40.0)
Ceftriaxone	6 (12.5)	5 (11.1)	1 (3.1)	0	1 (20.0)
Cefotaxime	9 (18.8)	7 (15.5)	1 (3.1)	1 (4.0)	2 (40.0)
Ceftazidime	-	-	-	15 (60.0)	-
Cefoperazone/sulbactam	30 (62.5)	19 (42.2)	7 (21.9)	18 (72.0)	2 (40.0)
Aztreonam	-	-	-	17 (68.0)	-
Nitrofurantoin	24 (50.0)	6 (13.3)	1 (3.1)	3 (12.0)	1 (20.0)
Piperacillin/Tazobactam	32 (66.6)	19 (42.2)	6 (18.8)	19 (76.0)	2 (40.0)
Ciprofloxacin	12 (25)	12 (26.6)	5 (15.6)	15 (60.0)	2 (40.0)
Levofloxacin	12 (25)	13 (28.9)	7 (21.9)	14 (56.0)	2 (40.0)
Imipenem	35 (73)	22 (48.9)	4 (12.5)	18 (72.0)	2 (40.0)
Meropenem	34 (71)	19 (42.2)	4 (12.5)	18 (72.0)	2 (40.0)
Cotrimoxazole	22 (45.9)	16 (35.5)	11 (34.3)	-	3 (60.0)

resistant to second generation cephalosporins. With such high resistance rates, last resort antibiotics have to be used like Tigecycline/Colistin. Pseudomonas aeruginosa is highly susceptible to Amikacin (80%), then Piptaz (76%), Carbapenems and Cefperazone/sulbactam (72%).

In this study, 111 organisms out of a total 173 GNB are Multi Drug Resistant (64.2%). 75% *E.coli* specimens, 71.1% *Klebsiella pneumoniae* and 84.4% *Acinetobacter baumannii* specimens are MDR. This is in accordance with a study by Bhatta et al which shows 78.26% *E.coli*, 70.58 *K.pneumoniae* and 89.47% A.baumannii to be MDR. Panta et al.[23] also reported similar figures with overall MDR count for GNB at 67.9%. while Siwakoti S et al. reported a lower rate of 47% MDR GNB.

Strains of *Klebsiella pneumoniae, Klebsiella oxytoca*, *E.coli* and Proteus mirabilis showing decreased sensitivity to Cefotaxime/Ceftazidime were tested for ESBL A total of 79 samples of these 4 organisms showed decreased sensitivity to Cefotaxime/Ceftazidime - 39 *E.coli*, 37 *Klebsiella pneumoniae*, 3 Klebsiella oxytoca and 0 Proteus mirabilis.

Out of the 79 samples, a total of 21 were ESBL producers (26.6%) which included 28.2% of all *E.coli* and 27% of *Klebsiella pneumoniae*. *K.oxytoca* was negative for ESBL production.

A study by Rodriguez et al.[24] showed the overall ESBL prevalence for *E.coli* as 25% and in *K.pneumoniae* as 26% which is in accordance with our study. Another study by Sahoo et al. showed much higher rate of ESBL Production for *E.coli* and *K.pneumoniae* at 44% and 43.1% respectively. A study by Xiong Z et al.[25] showed similar *E.coli* ESBL prevalence at 23.6% but much higher *K.pneumoniae* ESBL prevalence at 51%.

In other studies, done in Indian centres, the percentage of ESBL producers is anywhere from 22 to 75%[26–28] while in Japan, the prevalence of ESBL producing *E.coli* is 0.1% according to a study by Yagi et al.[29]

5. Conclusion

In this study, out of 616 samples tested, 149 samples showed growth of GNB and 173 GNB were isolated from them due to some samples showing polymicrobial growth. *E. coli* was the most commonly isolated organism at 27.7%, followed by *K. pneumoniae* with 26% and *A. baumannii* at 18.5%.

64.2% of all GNB isolated were MDR which included 84.4% of *A. baumannii,* 75% of *E. coli* and 71.1% of *K. pneumoniae*. 28.2% of *E. coli* and 27% of *Klebsiella pneumoniae* were ESBL producers.

GNB are highly resistant to many previously effective first line antibiotics like Penicillins, Cephalosporins and Fluoroquinolones with susceptibility rates below 25% and even 0% for earlier generation Cephalosporins. The antibiogram prepared from the data collected shows good susceptibility to aminoglycosides like Amikacin and Gentamicin and Carbapenems like Imipenem and Meropenem and poor susceptibility to all the others.

These findings can aid in antibiotic stewardship programs and help clinicians in deciding appropriate empirical therapy. It shows that MDR GNB infections are on the rise in ICU and physicians must be judicious while prescribing antibiotics.

6. Source of Funding

None.

7. Conflicts of Interest

None.

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References

1. Hamishehkar H, Shadmehr P, Mahmoodpoor A, Mashayekhi SO, Maleki TE. Antimicrobial susceptibility patterns among bacteria isolated from intensive care units of the largest teaching hospital at the northwest of Iran. Braz. *J Pharm Sci [Internet]*. 2016;52(3):403–12.
2. Lockhart SR, Abramson MA, Beekmann SE, Gallagher G, Riedel S, Diekema DJ, et al. Antimicrobial resistance among Gram-negative bacilli causing infections in intensive care unit patients in the United States between 1993 and. *J Clin Microbiol*. 2004;45(10):3352–9. doi:10.1128/JCM.01284-07.
3. Dasgupta S, Das S, Chawan NS, Hazra A. Nosocomial infections in the intensive care unit:Incidence, risk factors, outcome and associated pathogens in a public tertiary teaching hospital of Eastern India. *Indian J Crit Care Med*. 2015;19(1):14–20. doi:10.4103/0972-5229.148633.
4. Peleg AY, Hooper DC. Hospital-acquired infections due to gram-negative bacteria. *N Engl J Med*. 2010;362(19):1804–13. doi:10.1056/NEJMra0904124.
5. Mehrad B, Clark NM, Zhanel GG, Lynch JP. Antimicrobial resistance in hospital acquired gram-negative bacterial infections. *Chest*. 2015;147(5):1413–21. doi:10.1378/chest.14-2171.
6. Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, et al. Multidrug-resistant, extensively drug resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin Microbiol Infect*. 2012;18(3):268–81. doi:10.1111/j.1469-0691.2011.03570.x.
7. Gould IM. Risk factors for acquisition of multiple drug resistant Gram-negative bacteria. *Eur J Clin Microbiol Infect Dis*. 1994;13(Suppl 1):30–8. doi:10.1007/BF02390682.
8. Umadevi S, Kandhakumari G, Joseph NM, Kumar S, Easow JM, Stephen S, et al. Prevalence and antibiogram of ESBL producers. *J Clin Diagn Res*. 2011;5(2):236–9.
9. Bradford PA. Extended-Spectrum β-Lactamases in the 21st Century: Characterization, Epidemiology, and Detection of This Important Resistance Threat. *Clin Microbiol Rev*. 2001;14(4):933–51. doi:10.1128/CMR.14.4.933-951.2001.
10. Clinical and Laboratory Standards Institute (CLSI), Jan - 2019, Performance standards for antimicrobial susceptibility testing. Approved standard M100; 2019.
11. Balakrishnan S, Shaji N, Jakribettu RP. Antibiotic resistance pattern of gram-negative bacterial isolates from the clinical samples from critical care units of a tertiary care centre. *Int J Med Lab Res*. 2019;4(1):17–22.
12. Sahoo S, Otta S, Swain B, Kar SK. Detection and genetic characterization of extended-spectrum beta-lactamases producers in a tertiary care hospital. *J Lab Physicians*. 2019;11(3):253–8. doi:10.4103/JLP.JLP_31_19.
13. Garland A, Olafson K, Ramsey CD, Yogendran M, Fransoo R. Epidemiology of critically ill patients in intensive care units: a population-based observational study. *Crit Care*. 2013;17(5):212. doi:10.1186/cc13026.
14. Jamshidi M, Javadpour S, Eftekhari TE, Moradi N, Jomehpour F. Antimicrobial resistance pattern among intensive care unit patients. *Afr J Microbiol Res*. 2009;3(10):590–4.
15. Wise R, Vasconcellos KD, Skinner D, Rodseth R, Gopalan D, Muckart D, et al. Outcomes 30 days after ICU admission: the 30DOS study. *South Afr J Anaesth Analg*. 2017;23(6):139–44.
16. Qadeer A, Akhtar A, Ain QU, Saadat S, Mansoor S, Assad S, et al. Antibiogram of Medical Intensive Care Unit at Tertiary Care Hospital Setting of Pakistan. *Cureus*. 2016;8(9):809. doi:10.7759/cureus.809.
17. Balakrishnan S, Shaji N, Jakribettu RP. Antibiotic resistance pattern of gram-negative bacterial isolates from the clinical samples from critical care units of a tertiary care centre. *Int J Med Lab Res*. 2019;4(1):17–22.
18. Moolchandani K, Sastry AS, Deepashree R, Sistla S, Harish BN, Mandal J, et al. Antimicrobial Resistance Surveillance among Intensive Care Units of a Tertiary Care Hospital in Southern India. *J Clin Diagn Res*. 2017;11(2):DC01–7. doi:10.7860/JCDR/2017/23717.9247.
19. Bhatta B, Thapa R, Shahi S, Karki S, Bhatta Y, Das JK, et al. Isolates and their Antibiogram in Different Samples from a Tertiary Care Hospital. *Kathmandu Med J Shree Birendra Hosp*. 2015;14(1):1–8.
20. Siwakoti S, Subedi A, Sharma A, Baral R, Bhattarai NR, Khanal B, et al. Incidence and outcomes of multidrug-resistant gram-negative bacteria infections in intensive care unit from Nepal-a prospective cohort study. *Antimicrob Resist Infect Control*. 2018;7:114. doi:10.1186/s13756-018-0404-3.
21. Mohammadi-Mehr M, Feizabadi MM. Antimicrobial resistance pattern of Gram-negative bacilli isolated from patients at ICUs of Army hospitals in Iran. *Iran J Microbiol*. 2011;3(1):26–30.
22. Saravanan R, Raveendaran V. Antimicrobial resistance pattern in a tertiary care hospital: An observational study. *J Basic Clin Pharm*. 2013;4(3):56–63. doi:10.4103/0976-0105.118797.
23. Panta K, Ghimire P, Rai S, Mukhiya R, Singh RN, Rai G, et al. Antibiogram typing of gram-negative isolates in different clinical samples of a tertiary hospital. *Asian J Pharm Clin Res*. 2013;6(1):153–6.
24. Rodriguez M, Vera DE, Ramirez-Ronda CH, Saavedra S. Phenotypic confirmation of extended-spectrum B-lactamases (ESBL) in clinical isolates of Escherichia coli and Klebsiella pneumoniae at the San Juan Veterans Affairs Medical Center. *P R Health Sci J*. 2004;23(3):207–15.
25. Xiong Z, Zhu D, Zhang Y, Wang F. Extended-spectrum beta-lactamase in Klebsiella pneumoniae and Escherichia coli isolates. *Zhonghua Yi Xue Za Zhi*. 2002;82(21):1476–9.
26. Agrawal P, Ghosh AN, Kumar S, Basu B, Kapila K. Prevalence of extended-spectrum beta-lactamases among Escherichia coli and Klebsiella pneumoniae isolates in a tertiary care hospital. *Indian J Pathol Microbiol*. 2008;51(1):139–42. doi:10.4103/0377-4929.40428.
27. Aruna K, Mobashshera T. Prevalence of extended spectrum beta-lactamase production among uropathogens in South Mumbai and its antibiogram pattern. *EXCLI J*. 2012;11:363–72.
28. Dalela G. Prevalence of extended spectrum beta lactamase (ESBL) producers among gram negative bacilli from various clinical isolates in a tertiary care hospital at Jhalawar, Rajasthan, India. *J Clin Diagn Res*. 2012;6(2):182–7.
29. Yagi T, Kurokawa H, Shibata N, Shibayama K, Arakawa Y. A preliminary survey of extended-spectrum β- lactamases (ESBLs) in clinical isolates of Klebsiella pneumoniae and Escherichia coli in Japan. *FEMS Microbiol Lett*. 2000;184(1):53–56. doi:10.1111/j.1574-6968.2000.tb08989.x.

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