Int.J.Curr.Microbiol.App.Sci (2020) *9*(1): 2577-2587

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 9 Number 1 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.901.292

Antibiotic Susceptibility Profiling among Gram Positive and Gram Negative Pathogens in North Bihar, India

B. K. Sharma* and Roy Sujata

Sharma Diagnostic, Darbhanga, Bihar, India

**Corresponding author*

Keywords

Cefepime + amikacin, Cefepime, Clinical isolates, Potentox, Susceptibility

Article Info

Accepted:
20 December 2019
Available Online:
20 January 2020

A B S T R A C T

This study was undertaken to determine the prevalence of Gram negative and Gram positive in various clinical samples collected during study and to analyze the antibiotic susceptibility patterns of various drugs against these isolates to find which drug offers the best solution against multidrug resistant Gram negative and Gram positive pathogens. In the current study, a total of 741 isolates were isolated from different clinical specimens between October 2018 to January 2019. Antibiotic susceptibility testing were carried out according to the recommendations of Clinical Laboratory Standards Institute (CLSI) guidelines. Out of 741 clinical isolates, 575 (77.59%) were of Gram negative and 166 (22.40%) were of Gram positive. Among Gram negative pathogens, (n=575), the highest occurrence of pathogens was found in urine samples (81.57%) followed by stool (17.04%), pus (0.35%) and others 1.04%, whereas Gram positive (n=166) isolates were more dominant in sputum (24.70%) followed by pus/swab (23.49%), throat (18.07%), vagina (9.04%), synovial fluid (1.2%), each of ear swab, aural fluid, conjuctival fluid contributed to 0.6% and others making 21.69%**.** Further analysis of pathogens (n=741), *Escherichia coli* (63.43%) was the most dominant pathogen followed by *Streptococcus pyogenes* (9.18%), *Streptococcus species* (8.77%), *Enterobacter species* (8.64%), *Proteus* species (3.78%), *Streptococcus haemolyticus* (3.10%), Klebsiella species (1.48%) *Staphylococcus* species (1.35%) and *Pseudomonas* species (0.27%). Our susceptibility data revealed that Potentox was the most active antibacterial agent with the majority of isolates displaying 88.66% susceptibility, which is 20.10-54.25% high compared to other tested drugs. Levofloxacin appeared to be second most active agent (68.56%) followed by cefepime plus tazobactam (58.30%), meropenem (45.75%) and amikacin (34.41%). From the above results, it is evident that Potentox has enhanced *in-vitro* antibacterial activity and exhibited 20 to 54 % superiority over other drugs. Therefore, it can be a better choice to treat the infections caused by drug-resistant Gram negative and Gram positive pathogens in the clinical settings, and can be an important empiric consideration as a drug of choice to carbapenem.

Introduction

Antibiotic resistance is a global health crisis which has emerged as one of the principal public health problems of the 21st century and it must be managed with the utmost urgency. According to a study of The US Centers for Disease Control and Prevention (CDC) estimates, antibiotic resistance is causing more than 2 million infections and 23,000 deaths each year in the United States at a direct cost of $20 billion and additional productivity loss of $35 billion (Neil, 2014; Vasoo *et al.,* 2015). It can occur as a natural selection process where nature empowers all bacteria with some degree of low-level resistance (Levy *et al.,* 2007; Neil, 2014; WHO, 2015). The overuse and misuse of antibiotics contributed the more rapid emergence of antibiotic-resistant bacteria and antibiotic resistant genes (ARGs), reducing their therapeutic potential against human and animal pathogens (Wright, 2010).

Aminoglycosides (AG) are broad spectrum antibiotics with high potency and have been used to treat many serious Gram-negative and some Gram-positive infections (Hermann, 2007). They exert their antibacterial activity by inhibiting protein synthesis via binding to the 16S rRNA and by disrupting the bacterial cell membrane integrity (Shakil *et al.,* 2008). Gram-negative bacteria are responsible for more than 30% of hospital-acquired infections and more than 40% of infections in patients in intensive care units (Peleg and Hooper, 2010; Kallen *et al.,* 2010). However, over the past few years, the emergence of resistant strains of *Pseudomonas* species, *Escherichia coli*, *Klebsiella* species, *Acinetobacter* species has reduced the potential of aminoglycosides in empiric therapies (Gad *et al.,* 2011; Randhawa *et al.,* 2004; Shahid and Malik, 2005). There are a number of aminoglycoside resistance mechanisms that include reduced uptake or decreased cell permeability (Garneau-Tsodikova and Labby, 2016), alteration of the ribosomal binding site by rRNA methylases (Galimand *et al.,* 2012), overexpression of efflux pump (Poole, 2004) and production of aminoglycoside-modifying enzymes (AMEs) (Miró *et al.,* 2013). In Gram negative organisms, resistance to aminoglycosides such as amikacin, tobramycin and gentamycin has been reported to vary from 32.6% to 83.6% (Shahid and malik 2005).

Cefepime is a fourth generation cephalosporin antibiotic, has broad spectrum activity and is less affected by the non hydrolytic barrier mechanism of resistance (Shrivastava and Chaudhary, 2009). However, in the past few years, it is being threatened because of increasing resistance (Dua *et al.,* 2011). Chong *et al.,* (2010) have reported 35.3% resistance of cefepime against gram-negative isolates. Chaudhary and Payasi (2015) have highlighted 55-74% resistance of cefepime against gram-negative pathogens.

With the global rise of antibiotic-resistant pathogens and failure of monotherapy, an alternative to ineffective monotherapy is combination therapy that uses two or more drugs to broaden the antibacterial spectrum and prevent the development of resistance (Hughes *et al.,* 1997). A combination of antibiotics provides a broader spectrum of coverage than any single antibiotic alone. A well-chosen combination should be synergistic, provide an antibacterial spectrum greater than the sum of their individual activities and allow the use of smaller doses of each of the combined drugs. Combination therapy may reduce the likelihood that resistance will emerge during therapy, since only bacteria with mutations providing resistance to both antibiotics will be able to survive and grow (Mouton *et al.,* 1999). The combination of aminoglycosides with beta-lactams has been documented to be

synergistic (Sanz *et al.*, 2002; Bliziotis *et al.*, 2005; Chaudhary and Payasi, 2015).

In view of the above background, Venus Medicine Research Centre, India has developed a new antibiotic adjuvant entity (AAE) which is named as Potentox, and is a combination of fourth-generation cephalosporins and aminoglycoside amikacin in a ratio of 4:1, respectively along with antibiotic resistance breakers (ARBS).

Therefore, present study is aimed to evaluate the antibiotic susceptibility patterns of Potentox (cefepime+amikacin), in comparison with other drugs against different clinical isolates of Gram-positive and Gram negative.

Materials and Methods

Sample collection

Various clinical specimens including urine, stool, pus/swab, sputum, vagina, throat, synovial fluid, ear swab, aural fluid, conjuctival fluid blood etc were collected from indoor and outdoor patients at Sharma Diagnostic, Darbhanga, Bihar (India).

Isolation and identification of microbes

All the samples were collected aseptically in a sterile robust leak proof containers in sufficient amount. The samples were transported immediately to microbiology lab for further processing. The samples were inoculated on blood agar and Mac Conkey's agar.

The collection and processing of the specimens were done as per Standard Operating Procedures. The growth obtained was identified by the colony characteristics, gram staining and by standard biochemical reactions.

Antibiotic susceptibility testing

The Kirby-Bauer disc diffusion method was performed to determine the susceptibilities of the different antibiotics and the results were interpreted as per the Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2019).

In brief, similar colony of the overnight grown cultures of bacterial isolates on Mueller-Hinton agar (MHA) plate was diluted in saline to adjust the turbidity of the bacterial suspension to 0.5 McFarland standard (approximately 10^8 cfu/ml). Soon after, a sterile cotton swab was dipped into the bacterial suspension and streaked it across the surface of the MHA plate. For even distribution of inoculum, the swab was streaked two more times at 60° over the agar surface. The plates were dried at room temperature for 15 min before applying the discs containing different antibiotics. The discs were applied in such a way to ensure a minimum distance of 24 mm from center to center. These plates were then incubated at 37°C in an incubator for 18–24 hours. All determinations were made in duplicate. Zone diameter end points were measured and recorded. Control strains of *Escherichia coli* ATCC 25922 and *Klebsiella pneumoniae* ATCC 700603 were used for quality control of susceptibility testing. Positive growth controls of each isolate (bacteria in medium) were incubated under the same conditions. Negative control for each plate was medium only.

Results and Discussion

This study reports on rates of antimicrobial resistance/susceptibility among Gram negative and Gram positive pathogens collected from Sharma Diagnostic, Darbhanga, Bihar, India between October 2018 to January 2019. This study

demonstrated change in the patterns of antibiotic resistance. The antimicrobial resistance against antibiotics varies according to geographical areas and depends upon various factors such as abuse, availability and consumption of antibiotics (Miriagou *et al.*, 2010). In recent years, increasing occurrence of aminoglycoside resistant strains have imposed a major threat not only because of their ability to cause serious infections but also because of their increasing resistance to antimicrobial agents. Combination antibiotic therapy is appropriate and desirable; however, it should be used wisely. Therefore, present study is conducted to evaluate the efficacy of combination of cefepime and amikacin in comparison with other drugs.

Out of 741 clinical isolates, 575 (77.59%) were of Gram negative and 166 (22.40%) were of Gram positive. Many studies have also revealed that Gram negative bacteria is major opportunistic and frequent pathogens and are extremely prevalent in hospital-associated infections which favours recent study (Neil, 2014; Ejaz *et al.*, 2006). Among Gram negative pathogens, (n=575), the highest occurrence of pathogens was found in urine samples (81.57%) followed by stool (17.04%), pus (0.35%) and others (1.04%) whereas Gram positive (n=166) isolates were more prevalent in sputum (24.70%) followed by pus/swab (23.49%), throat (18.07%), vagina (9.04%), synovial fluid (1.2%), each of ear swab, aural fluid, conjuctival fluid contributed to 0.6% and others making 21.69% (Table 3).

Morphological and biochemical characterization of the pathogens (n=741) showing bacterial growth revealed presence of each of 4 different Gram negative organisms and Gram positive organisms. The detailed profile of various organisms used in the study is shown in Figure 1. Among the identified Gram negative bacteria, *Escherichia coli* (63.43%) was found to be the most dominant pathogen followed by *Enterobacter species* (8.64%), *Proteus* species (3.78%), *Klebsiella* species (1.48%) and *Pseudomonas* species (0.27%). The findings is comparable with other studies indicating 49.2% to 68.8% prevalence of *E. coli* (Sikka *et al.*, 2012; Dash *et al.*, 2013; Patil *et al.*, 2013; Sachdeva, 2016). In another study performed by Hamdan *et al.*, (2011) reported *E. coli* as the most common pathogen about 77.7% among Gram negative isolates. *Proteus* spp. (3.78 %) contribute nonsignificantly in the present study, same as reported by Ejaz *et al.*, (2006) and Sachdeva (2016) where they reported low prevalence of *P. mirabilis* (1.0 %) and 1.5%. Contrary to previous studies (Bagga, 2015; Sachdeva, 2016), we have noticed least prevalence of *Pseudomonas* species and *Klebsiell*a species. Among, Gram positive bacteria, *Staphylococcus* spp. and *Streptococcus* spp. being most commonly isolated pathogens. In out study, *Streptococcus pyogenes* (9.18%) was the most commonly isolated followed by *Streptococcus species* (8.77%), *Streptococcus haemolyticus* (3.10%) and *Staphylococcus* species (1.35%) (Figure 1).The incidence of *Staphylococcus* species and *S. haemolyticus* in this study was quite lower compared to earlier study (Gupta *et al.*, 2015; Amutha and Viswanathan, 2015; Sarkar *et al.*, 2015). Prevalence of *Streptococci* in India ranges from 4.2% to 23.7%, which are comparable to the current study (Rao Sadanand and Shanker Venkatesh, 2018; Sarkar *et al.*, 2015).

The overall susceptibility pattern of antibiotics against tested pathogens is presented in Figure 2. The susceptibility pattern in this study revealed that Potentox was the most active antibacterial agent with the majority of isolates displaying 88.66% susceptibility, which was 20.10-54.25% high compared to other tested drugs. This may be due to synergism of aminoglycosides with β-

lactams which enhanced the intracellular uptake of aminoglycosides by enhancing bacterial cell permeability. Furthermore, Potentox synergistically is assumed of having protein kinase inhibitor activity to inhibit the aminoglycoside modification through ATP-dependent O-phosphorylation, catalysed by aminoglycoside kinases particularly aminoglycoside phosphotransferases (Aphs). The enhanced susceptibility of Potentox is consistent with our previous studies where it has been demonstrated to have noticeable antibacterial activity (Chaudhary *et al.*, 2013; Chaudhary and Payasi, 2014). Its antibacterial activity has also been proved in animal model (Chaudhary *et al.*, 2011; Dwivedi *et al.*, 2009). Although, Potentox showed very low resistance (2.34%) compared to other drugs.

Although fluoroquinolones are the potent antibiotics and have been useful in the treatment of a range infections, reports in a number of countries indicates an increase in microbial resistance (Dalhoff, 2012; Redgrave *et al.*, 2014). Resistance to these agents is multifactorial and can be via one or a combination of target-site gene mutations, increased production of multidrug-resis-tance (MDR) efflux pumps, modifying enzymes, and/or target-protection proteins (Redgrave *et al.*, 2014). Besides these, another possible reason for this could be indiscriminate use of fluoroquinolones in the treatment of human and animal infections (Poppe *et al.*, 2001). The current study revealed that, overall susceptibility of microbial organisms to levofloxacin was 68.56% which was in line with previous studies (Afriyie *et al.*, 2018). On the contrary, other studies from India reported up to 46 % susceptibility for levofloxacin (Gupta *et al.*, 2016; Chaudhary and Payasi, 2015). In this study higher prevalence of antimicrobial resistance was noted, in gram negative organisms. This might be due to indiscriminate use of antibiotics in hospital.

Carbapenems are broad-spectrum antibiotics which possess stability against hydrolysis by ESBL and AmpC chromosomal β-lactamase enzymes and are often reserved to treat the most serious infections (Zhanel *et al.*, 2007). However, carbapenem-resistance among Gram negative bacteria has been reported increasingly throughout the world including India (Gupta *et al.*, 2006; Shah and Narang, 2005; Hu *et al.*, 2012).

In the current study, susceptibility to meropenem was 45.75% which is similar to previous study (Chaudhary *et al.*, 2015, Turner, 2008). The reduced to meropenem in these isolates probably results from reduced accumulation of drug or over activation of efflux pump (Sinha and Srinivasa, 2007). Several authors have highlighted the reduced susceptibility od penems (Chaudhary and Payasi, 2012; Chaudhary *et al.*, 2013).

Table.1 Selective culture medium used for isolation of different pathogens

Sr. No.	Pathogen	Selected media
1	*E. coli*	EMB agar medium
2	*Proteus spp.*	EMB agar and Mcconkey's agar
3	*Staphylococcus spp.*	Mannitol Salt Agar
4	*Pseudomonas spp.*	Citrimide agar
5	*Klebsiella spp.*	Hicrome Klebsiella selective agar base medium
6	*Streptococcus spp.*	Streptococci Selective Agar

Table.2 Comparative zone diameters used for interpreting as susceptible, intermediate or resistant

Drugs	Microorganisms	Zone of diameter (mm)		
		Susceptible	Intermediate	Resistance
Potentox (Cefepime/Amikacin)	*Enterobacteriaceae*	≥ 19	16-18	≤15
Cefepime/Tazobactam		≥ 25	19–24 (SDD)	≤ 18
Amikacin		≥ 17	15–16	≤ 14
Levofloxacin		≥ 17	14–16	≤ 13
Meropenem		≥23	20-22	≤19
Potentox	*Pseudomonas spp.*	≥ 18	15–17	≤14
Cefepime/Tazobactam		≥ 18	15–17	≤14
Amikacin		≥ 17	15–16	≤ 14
Levofloxacin		≥ 17	14–16	≤ 13
Meropenem		≥19	16-18	≤15
Potentox	*Staphylococcus spp.*	≥ 18	15–17	≤14
Cefepime/Tazobactam		-	-	-
Amikacin		-	-	-
Levofloxacin		≥ 19	16–18	≤ 15
Meropenem		-	-	-
Potentox	*Streptococcus spp.*	≥ 18	15–17	≤14
Cefepime/Tazobactam		≥ 24	-	-
Amikacin		-	-	-
Levofloxacin		≥ 17	14–16	≤ 13
Meropenem		-	-	-

Table.3 A profile of clinical samples used as a source of the pathogenic isolates

Sr. No.	Specimen	Gram Negative	Gram Positive
1	Urine	469 (81.57)	0
2	Stool	98 (17.04)	0
3	Pus/Swab	2 (0.35)	39 (23.49)
4	Sputum	0	41 (24.70)
5	Vagina	0	15 (9.04)
6	Throat	0	30 (18.07)
7	Synovial fluid	0	2 (1.20)
8	Ear swab	0	1 (0.60)
9	Aural fluid	0	1 (0.60)
10	Conjuctival fluid	0	1 (0.60)
11	Other	6 (1.04)	36 (21.69)
Total (n)	**741**	**575**	**166**

Figure.1 Prevalence percentage of clinical pathogens among different clinical samples

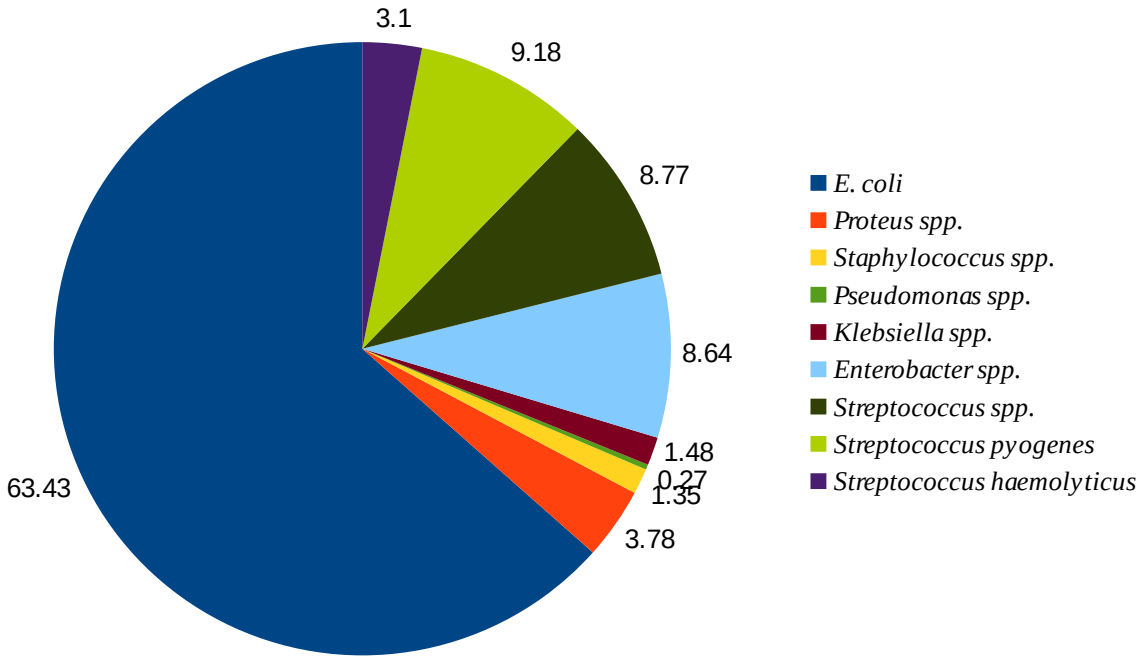
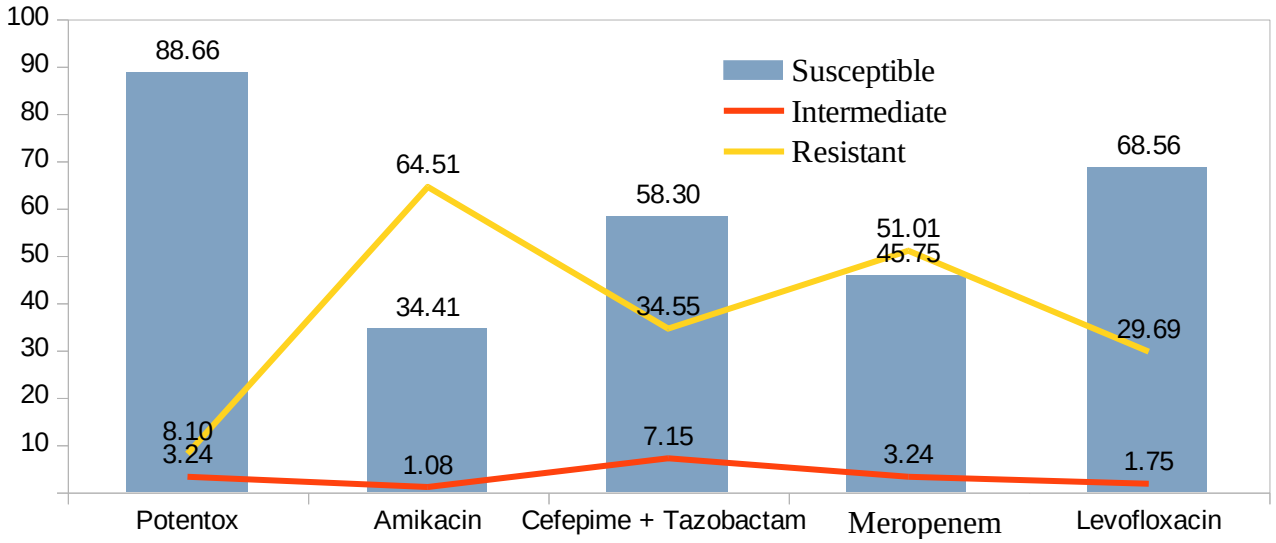


Figure.2 Susceptibility pattern of clinical isolates towards different antibacterial agents



Cefepime/tazobactam is a new promising combination and it can be used as an alternative to therapeutic option to carbapenems against fermenters and nonfermenters for the treatment of moderate-to-severe infections (Agarwal *et al.*, 2019; Sharma *et al.*, 2012; Ghafur *et al.*, 2012). Combination of a fourth-generation cephalosporin with a β lactamase inhibitor has the theoretical advantage of additional activity

against Amp C and possibly OXA enzymes over a third-generation cephalosporin-BLI combination (Ghafur *et al.,* 2012). Our study revealed 58.14% susceptibility of this combination which is little lower to the study of Agarwal *et al.,* (2019) who reported 68 % susceptibility of cefepime plus tazobactam.

Though aminoglycoside drugs are being widely prescribed to patients in India, in the current study, amikacin appeared to be least susceptible (34.41%). Less susceptibility of amikacin could be due to a decreased uptake and/or accumulation of the drug in bacteria and the expression of aminoglycoside modifying enzymes (AMEs) that eventually inactivate the drugs (Gad *et al.,* 2011). Studies from different parts of India show increasing resistance to aminoglycoside drugs among the bacterial isolates and more and more AMEs genes are being identified and found responsible for molecular mechanism of the drug resistance (Mir *et al.,* 2016). This study displayed 64.51 % resistance to amikacin against tested pathogens which is comparable to other studies conducted in Turkey and India which have detected 49.7% and 55.1% resistance of Gram negative organisms to amikacin in India and Turkey, respectively (Shahid and Malik, 2005; Over *et al.,* 2001). A study done by Estahbanati *et al.,* (2001) reported 53.3% of clinical isolates from Iranian burn patients were resistant to amikacin.

Wattal *et al.,* (2010) observed increasing prevalence of carbapenems resistance, varying from 13 to 51% in E. coli and Klebsiella spp. in New Delhi, India hospitals. Similarly, Gupta *et al.,* (2006) also demonstrated high prevalence of resistance, varying from 17 to 22% to various carbapenems among Enterobacteriaceae strains.

The strength of this study was that it had included a large number of pathogens recovered from patients clinical specimens including both community and hospital acquired infections, thereby being able to present the susceptibility behaviour of pathogens in a broader way.

Conclusion of the study is as follows:

From the above results, it is evident that Potentox has enhanced *in-vitro* antibacterial activity and exhibited 20 to 54 % superiority over other drugs. Therefore, it can be a better choice to treat the infections caused by drug-resistant Gram negative and Gram positive pathogens in the clinical settings, and can be an important empiric consideration as a drug of choice to carbapenem.

Acknowledgment

I would like to thank Venus Remedies Limited, Baddi, Himachal Pradesh, India for providing sensitivity discs of cefepime+amikacin with brand name of Potentox.

References

Amutha B, Viswanathan T. Incidence of Staphylococcus species in surgical site infections prospective study from tertiary care centre, Coimbtore, Tamilnadu. Int J Pharm Pharm Sci, 2015;l 7: 225-228.

Agarwal R, Agarwal V, Tewari A, Upadhyay P. Cefepime/tazobactam as a new treatment option for multidrug resistant gram negative bacilli. Int J Res Med Sci, 2019; 7:72278-2281.

Afriyie DK, Adu LB, Dzradosi M, Amponsah SK. Ohene-Manu P, Manu-Ofei F. Comparative *in vitro* activity of ciprofloxacin and levofloxacin against isolated uropathogens in Ghana: a pilot study. The Pan Afr Med J, 2018;30:194

Bliziotis IA, Samonis G, Vardakas KZ, Chrysanthopoulou S, Falagas ME. Effect of aminoglycoside and beta-lactam combination therapy versus beta-lactam monotherapy on the emergence of antimicrobial resistance: a

meta-analysis of randomized, controlled trials. Clin Infect Dis 2005; 41:149–58.

Bagga R. Retrospective analysis of antibiotic susceptibility and resistance patterns against nosocomial Gram negative pathogens in Fortis Memorial Research Institute, Gurgaon. Int J Curr Adv Res, 2015; 4: 347-351.

Chaudhary M, Payasi A, Dwivedi VK. Comparative safety evaluation of potentox® vs coadministration of cefepime and amikacin in healthy albino rat. Int J Drug Dev Res, 2011; 3: 348-355.

Chaudhary M, Kumar S, Payasi A. Prevalence and antimicrobial sensitivity of extended-spectrum β-lactamase producing gram negative bacteria from clinical settings in India from 2010-2012. Int J Med Med Sci, 2013; 46: 1212-1217.

Chong Y, Yakushiji H, Ito Y, Kamimura T. Cefepime-resistant Gram-negative bacteremia in febrile neutropenic patients with hematological malignancies. Int J Infect Dis, 2010; 14: e171-e175.

Chaudhary M, Payasi A. A solution to combat aminoglycoside and quinolone resistant gram negative organisms. Int J Curr Res, 2015; 7:17006-17011.

Chaudhary M, Payasi A. Molecular characterization and antimicrobial susceptibility study of *Acinetobacter baumannii c*linical isolates from Middle East, African and Indian Patients. J Proteomics Bioinform, 2012; 5(11): 265-269.

CLSI. Performance Standards for Antimicrobial Susceptibility Testing. 29th ed. CLSI supplement M100. Wayne, PA: Clinical and Laboratory Standards Institute 2019.,

Chaudhary M, Kumar S, Payasi A, Characterization of quinolone resistant genes and control of qnrB transfer by Potentox in clinical isolates. J Phar Res, 2013; 7: 62-69.

Chaudhary M, Kumar S, Payasi A, Resistance Patterns and Prevalence of the Aminoglycoside Modifying Enzymes in Clinical Isolates of Gram Negative Pathogens. Global Journal of Pharmacology 2014; 8: 73-79, 2014.

Chaudhary S, Kumar M, Gupta R, Walia E, Gangal A. Alarmingly rising beta-lactamase-mediated meropenem resistance in nosocomial infections in Indian Hospitals. Int J Curr Res, 2015; 7:17868-17873.

Dalhoff A. Global fluoroquinolone resistance epidemiology and implictions for clinical use. Interdisc Persp Infect Dis, 2012; ID 976273.

Dwivedi VK, Chaudhary M, Soni A, Shrivastava SM. Nephrotoxicity reduction by fixed dose combination of cephalosporins and aminoglycosides in Mus musculus mice. Asian J Biochem, 2009; 4: 13-21.

Dua RS. Shrivastava SK, Sonwane, Srivastava SK.Pharmacological significance of synthetic heterocycles scaffold: a review. Adv Biol Res, 2011; 5: 120-144.

Dash M, Padhi S, Mohanty I, Panda P, Parida B. Antimicrobial resistance in pathogens causing urinary

tract infections in a rural community of Odisha, India. J Family Comm Med, 2013; 20: 20-26.

Estahbanati H, Kashani P, Ghanaatpisheh F, Frequency of Pseudomonas aeruginosa serotypes in burn wound infections and their resistance to antibiotics. Burns, 2002; 28: 340-8

Ejaz H, Zafar A, Anwar N, Cheema TA, Shah H. 2006. Prevalence of bacteria in urinary tract infections among children. Biomedica. 2006; 22.

Ghafur A, Pushparaju R, Nalini S, Rajkumar K, Sureshkumar D. Sensitivity pattern of Gramnegative bacteria to the new β-lactam/β-lactamase inhibitor combination: cefepime/tazobactam. J Microbiol Inf Dis 2012; 2(1): 5-8

Garneau-Tsodikova S, Labby KJ. Mechanisms of resistance to aminoglycoside antibiotics: overview and perspectives. Medchemcomm, 2016; 7: 11-27.

Galimand M, Courvalin P, Lambert T. RmtF, a new member of the aminoglycoside resistance 16S rRNA N7 G1405 methyltransferase family. Antimicrob.Agents Chemother, 2012; 56: 3960–3962.

Gupta R, Malik A, Rizvi M, Ahmed M, Hashmi A. Multidrug Resistant Gram Positive Pathogens with Special Reference to MRSA and Biofilm Production in ICU Patients: Recurrent Challenge for Clinicians. Int J Curr Microbiol App Sci, 2015;1: 207-212.

Gupta E, Mohanty S, Sood S, Dhawan B, Das BK, Kapil A. Emerging resistance to carbapenems in a tertiary care hospital in north India. Indian J Med Res. 2006; 124:95-98.

Gad GF, Mohamed HA, Ashour HM, Aminoglycoside resistance rates, phenotypes, and mechanisms of Gram-negative bacteria from infected patients in upper Egypt. PLoS ONE, 2011; 6: e17224.

Gupta A, Chauhan Bimal, Pethani J, Shah P. Fluoroquinolones resistance among uropathogens at the tertiary-care hospital, Ahmedabad. Int J Med Sci Public Health, 2016; 5(8): 1583-1587

Hamdan HZ, Ziad AHM, Ali SK, Adam I, Epidemiology of urinary tract infections and antibiotics sensitivity among pregnant women at Khartoum North Hospital, Ann Clin Microbiol Antimicrobials, 2011; 10: 2.

Hu F, Chen S, Xu X, Guo Y, Liu Y, Zhu D, Zhang Y. Emergence of carbapenemresistant clinical Enterobacteriaceae isolates from a teaching hospital in Shanghai. China J Med Microbiol. 2012; 61:132-136

Hughes WT, Armstrong D, Bodey GP, Brown AE, Edwards JE, Feld R. *et al.*, Guidelines for the use of antimicrobial agents in neutropenic patients with unexplained fever. Infectious Diseases Society of America. Clin Infect Dis, 1997; 25:551–73

Hermann T. Aminoglycoside antibiotics: old drugs and new therapeutic approaches. Cell Mol Life Sci, 2007; 64: 1841–1852.

Kallen AJ, Hidron AI, Patel J, Srinivasan A. Multidrug resistance among Gramnegative pathogens that caused healthcare-associated infections reported to the National Healthcare Safety Network, 2006–2008. Infect Cont Hosp Epidemiol. 2010; 31:528-531.

Levy SB, Chadwick DJ, Goode J. Chichester, Antibiotic Resistance: An Ecological Imbalance, in Ciba Foundation Symposium 207 - Antibiotic Resistance: Origins, Evolution, Selection and Spread; 2007; 1: 1–14.

Mouton JW, van Ogtrop ML, Andes D, Craig WA. Use of pharmacodynamic indices to predict efficacy of combination therapy in vivo. Antimicrobial Agents Chemotherapy. 1999; 43(10): 2473-8.

Miriagou V, Cornaglia G, Edelstein M, Galani I, Giske CG, Gniadkowski M, Malamou-Lada E, Martinez-Martinez L, Navarro F, Nordmann P, Peixe L. Acquired carbapenemases in Gram-negative bacterial pathogens: detection and surveillance issues. Clinical Microbiology Infection. 2010;16(2):112-22.

Miró E, Grünbaum F, Gómez L, Rivera A, Mirelis B, Coll P, Navarro F. Characterization of aminoglycoside-modifying enzymes in Enterobacteriaceae clinical strains and characterization of the plasmids implicated in their diffusion. Micro Drug Res. 2013 ; 19(2): 94-9.

Mir AR, Bashir Y, Dar FA, Sekhar M. Identification of Genes Coding Aminoglycoside Modifying Enzymes in E. coli of UTI Patients in India. The Sci World, 2016; ID 1875865.

O'Neill J. Antimicrobial resistance: tackling a crisis for the health and wealth of nations. review on antimicrobial resistance—tackling drug-resistant infections globally. UK: HM Government and Wellcome Trust. 2014.

Över U, Gür D, Ünal S, Miller GH, Aminoglycoside Resistance Study Group. The changing nature of aminoglycoside resistance mechanisms and prevalence of newly recognized resistance mechanisms in Turkey. Clin Microbiol Infect, 2001; 7(9): 470-8.

Poole K. Efflux-mediated multi resistance in Gramnegative bacteria. Clin Microbiol Infect, 2004; 10:12-26.

Poppe C, Ayroud M, Ollis G, Chirino-Trejo M, Smart N, Quessy S, Michel P. Trends in antimicrobial resistance of Salmonella isolated from animals, foods of animal origin and the environment of animal production in Canada, 1994-1997. Microb Drug Resist. 2001; 7(2): 197-212.

Patil A, Patil K, Pawar P, Maheshwari V. Isolation and survey of antibiotic sensitivity in nosocomial
infections in North Maharashtra region. J Assoc Phy, 2013;61.

Peleg AY, Hooper DC. Hospital-acquired infections due to Gram-negative bacteria. N Engl J Med. 2010; 362: 1804-1813.

Randhawa VS, Kapoor L, Singh V, Mehta G. Aminoglycoside resistance in enterococci isolated from paediatric septicaemia in a tertiary care hospital in north India. Indian J Med Res. 2004; 119: 77-9.

Redgrave LS, Sutton SB, Webber MA, Piddock LJ. Fluoroquinolone resistance: mechanisms, impact on bacteria, and role in evolutionary

success. Trends Microbiol, 2014; 22(8): 438-45.

Rao Sadanand LN, Shanker Venkatesh BM. A Study of Group A Streptococcal Pharyngitis among School Children (3–15 Year) of Urban Community. Sch J App Med Sci. 2018; 6(11): 4269-4274.

Sinha M, Srinivasa H. Mechanisms of resistance to carbapenems in meropenem-resistant Acinetobacter isolates from clinical samples. Indian J Med Microbiol, 2007; 25: 121-125.

Sharma S, Gupta A, Arora A. Cefepime Tazobactam: A new β lactam/β lactamase inhibitor combination against ESBL producing gram negative bacilli. Int J Pharm Biomed Sci. 2012; 2: 35-8.

Shah D, Narang M. Meropenem. Indian pediatrics. 2005; 42(5): 443-50.

Sarkar S, Chakraborty A, Sengupta M, Ghosh S, Mukhopadhyay S, SenGupta M. In vitro activity of levofloxacin against lower respiratory tract pathogens. J Basic Clin Pharmacy. 2015; 6(3): 89.

Sachdeva N, Antibiotic sensitivity pattern of bacterial pathogens in Rajeev gandhi Cancer Hospital, Delhi. Int J Rec Sci Res, 2016; 7: 8480-8485.

Shahid M, Malik A. Resistance due to aminoglycoside modifying enzymes in Pseudomonas aeruginosa isolates from burns patients. Indian J Med Res. 2005; 122(4): 324.

Sikka R, Mann JK, Vashist DMG, Chaudhary U, Deep A. Prevalence and antibiotic sensitivity pattern of bacteria isolated from nosocomial infections in a surgical ward. Indian J Clin Pract. 2012; 22: 519-525.

Sanz MA, López J, Lahuerta JJ, Rovira M, Batlle M, Pérez C, Vázquez L, Julià A, Palau J, Gutiérrez M, Capote FJ. Cefepime plus amikacin versus piperacillin–tazobactam plus amikacin for initial antibiotic therapy in haematology patients with febrile neutropenia: results of an open, randomized, multicentre trial. J Antimicrob Chemother. 2002; 50(1):79-88.

Shrivastava SM, Saurabh S, Rai D, Dwivedi VK, Chaudhary M. In vitro microbial efficacy of sulbactomax: a novel fixed dose combination of ceftriaxone sulbactam and ceftriaxone alone. Curr Drug Ther, 2009; 4(1): 73-7.

Shakil S, Khan R, Zarrilli R, Khan AU. Aminoglycosides versus bacteria–a description of the action, resistance mechanism, and nosocomial battleground. J Biomed Sci. 2008; 15(1): 5-14.

Turner PJ. Meropenem activity against European isolates: report on the MYSTIC (meropenem yearly susceptibility test information collection) 2006 results. Diag. Microbiol Infect Dis, 2008; 60: 185-92.

Vasoo S, Barreto JN, Tosh PK. Emerging issues in gram-negative bacterial resistance: an update for the practicing clinician. In Mayo Clinic Proceedings 2015 Mar 1 (Vol. 90, No. 3, pp. 395-403). Elsevier.

Wattal C, Goel N, Oberoi JK, Raveendran R, Datta S, Prasad KJ. Surveillance of Multidrug Resistant Organisms in a Tertiary Care Hospital in Delhi, India. J Assoc Phys India, 2010; 58: 32-36.

Wright GD. Antibiotic resistance in the environment: a link to the clinic?. Current opinion in microbiology. 2010; 13(5): 589-94.

WHO. Global Action Plan on Antimicrobial Resistance, 2015.

Zhanel GG, Wiebe R, Dilay L, Thomson K, Rubinstein E, Hoban DJ, Noreddin AM, Karlowsky JA. Comparative review of the carbapenems. Drugs. 2007; 67(7): 1027-52.

How to cite this article:

Sharma, B. K. and Roy Sujata. 2020. Antibiotic Susceptibility Profiling among Gram Positive and Gram Negative Pathogens in North Bihar, India. *Int.J.Curr.Microbiol.App.Sci.* 9(01): 2577-2587. doi: https://doi.org/10.20546/ijcmas.2020.901.292