ORIGINAL ARTICLE

Frequency of carbapenem resistant uro-pathogenic *Escherichia Coli* in ICU patients of a tertiary Care Hospital of Southern Punjab

Muhammad Javed Akhtar, Blossom Neelam, Sumera Malik, Syed Muhammad Abbas Naqvi, Rashda Shabbir, Muhammad Shahid Javed

Nishtar Medical University, Multan Pakistan

ABSTRACT

Background: Urinary tract infections in ICU patients is widespread and carbapenem resistant uropathogenic *Escherichia Coli* in ICU admitted catheterized patients is alarming. To determine the frequency of carbapenem resistant UPEC in ICU patients of a tertiary care hospital in southern Punjab.

Material and Methods: This cross-sectional study was done at Microbiology laboratory of Nishtar Medical University Multan, Pakistan from 01 March 2021 to 31 December 2021. A total of 367 urine samples were taken from patients admitted in ICU department. Urine samples were inoculated on CLED agar according to standard protocols and 160 *E. coli* were recognized with traditional biochemical tests. According to CLSI 2020 standards, the antimicrobial profile of isolates against carbapenems were determined using the Kirby-Bauer disc diffusion method, and carbapenemase production was determined by using the Modified Hodge test. All data was entered and analyzed in SPSS 26 version.

Results: 271 samples (73.84%) were found positive for urinary tract infections while other 96 (26.15%) samples were found negative for UTIs. Among all the causative agents, *E. coli* (*n*=160) was the most commonly isolated organism. Its prevalence was pointedly higher in male, as 84 (52.5%) and 76 (47.5%) were isolated from males and females respectively. A total of 19 (11.88%) isolates of *E. coli* were carbapenem resistant. Further, 89.47% carbapenem resistant isolates were positive for MHT while rests were negative.

Conclusion: Carbapenem resistance is alarming in *UPEC* among the patients admitted in ICU department, mainly due to carbapenemase enzyme.

Keywords: CLED, Carbapenem resistant, ICU, UTI, Uropathogenic *E. coli*.

BACKGROUND

The infection of any component of the urinary system, including the kidneys, urethra, ureters, and bladder, is known as a urinary tract infection (UTI).[1] UTIs are considered among the severe public health issues and many gram negative and gram positive bacteria are involved.[2] Among all the pathogens *E. coli* is found to be the most predominant in urinary tract infections.[3] Occurrence of urinary tract infections (UTIs) in the patients admitted in intensive care units (ICUs) is more common than in general population. It is thought that it is because of many sources of infection and their exposure to the ICU patients.[4] Different studies showed that many drugs are not useful anymore against uro-pathogens because they have developed resistance against available drugs.[5] This situation of increasing prevalence and antibiotics resistance is becoming a threat to the economy of the country and society.[2]

Carbapenems are active against a wide variety of organisms.[6] However; resistance has been developed against carbapenems. β-lactamase production by bacteria is the most important mechanism associated with carbapenem resistance.[7]

Resistance in gram-negative bacteria is increasing day by day against carbapenems. Many alternate treatment regimens have been proposed to replace carbapenems in the face of increasing gram-negative pathogen resistance. To examine each of the numerous combined techniques, randomized clinical studies are required.[8] Antibiotic resistance is a rising concern in the UTI's treatment, particularly when infections are induced by gram-negative bacteria. Different combinations of carbapenems, cefepime, nitrofurantoin, piperacillin-

Correspondence: Dr. Muhammad Javed Akhtar, Senior Demonstrator, Department of Pathology, Nishtar Medical University, Multan Pakistan

Email: javedakhtar169.ja@gmail.com

This article can be cited as: Akhtar MJ, Neelam B, Malik S, Naqvi SMA, Shabbir R, Javed MS. Frequency of carbapenem resistant uro-pathogenic *Escherichia Coli* in ICU patients of a tertiary Care Hospital of Southern Punjab. Infect Dis J Pak. 2025; 34(2): 111-116.

DOI: https://doi.org/10.61529/idjp.v34i2.397

Receiving date: **06 Jan 2025** Acceptance Date: **29 May 2025**
Revision date: **06 May 2025** Publication Date: **30 Jun 2025**

tazobactam, fosfomycin, and fluoroquinolones were suggested for UTI's treatment.[9] Bacterial isolates including uro-pathogens harbouring such lethal enzymes have been disseminated into community and hospital environment. This is the need of hour to do larger scale researches to elucidate the mechanism and burden of carbapenem resistance to contain its spread. The aim of this study was to evaluate the prevalence of urinary tract infections due to *E. coli*, and resistance of *E. coli* against carbapenems in patients admitted in ICU of Nishtar hospital, Multan.

MATERIAL AND METHODS

The cross-Sectional study was done in microbiology laboratory of Nishtar Medical University Multan from 01 March to 31 December 2021. Sample size was calculated as;

$$n = \frac{Z^2{}_{1-\alpha/2}\ \mathrm{P}\ (1-\mathrm{P})}{d^2}$$

for 95% confidence level = $1.96Z^2{}_{1-\alpha/2}0$

P = Proportion of carbapenem resistance of uro-pathogenic *E. coli,* 7%,[10]

q = 1-P

d = Margin of error ≈ 4%

n = 160 = (E. coli.)

The non-probability convenient sampling technique was used. For confirmed 160 E.coli, a total of 367 urine samples were collected with aseptic measures from the patients admitted in the intensive care unit of Nishtar Hospital Multan. Informed written consent was taken from patients/ attendants before collection of samples.

Urine samples were collected by following method:

1. Bag tubing of catheterized ICU patients was clamped 15 –20 minutes before sample collection.
2. Distal part of Foley's catheter where tubing is attached, was disinfected with 70% alcohol solution and stayed few minutes to dry.
3. Bag tubing was removed from the Foley to collect urine sample.
4. Separate sterile container was used for each urine sample.
5. At least 10 ml urine was collected from each patient.

Then all the collected samples were immediately transported to the microbiology laboratory for further processing. These specimens were streaked on the (CLED) agar using 0.001 ml wire loop and incubated for 24 hours at a temperature of 37° C. Criteria for defining significant growth of bacteria in urine was presence of 10^4-10^5cfu/ml or more for each pathogenic bacterium isolated. The isolates obtained after the over-night incubation of CLED agar plates, were further processed for bacterial identification. Identification was carried out on the basis of colonial characteristics, morphology, motility, gram staining and conventional biochemical tests. If any *E. coli* was in doubt, it was confirmed biochemically with the help of Analytical Profile Index -20E (BioMerieux, France). Kirby-Bauer disk diffusion method was used to evaluate *E. coli* resistance against carbapenems. Mueller Hinton agar was used to apply Kirby-Bauer disk diffusion method. 3 – 5 well separated and grown colonies with similar characters were transferred to a sterile tube having 5 ml normal saline. Then, colonies were suspended to make 0.5 McFarland bacterial suspensions. Each Mueller Hinton plate was inoculated with sterile cotton swab dipped in bacterial suspension. Antibiotic disks of different groups were then applied to check the resistance status. These plates were then incubated for 24 hours at a temperature of 37° C. After the completion of incubation period, antibiotic zones of inhibition were measured according to Clinical and Laboratory Standard Institute (CLSI, 2020) guidelines in millimeters. Samples were then categorized in three categories i.e resistant, susceptible and intermediate susceptible on the basis of size of antibiotic zone of inhibition.

Furthermore, four drugs of carabapenem group were used to evaluate the carbapenem resistance. These were: Imipenems (10 µg), Meropenems (10 µg), Ertapenems (10 µg) and Doripenems (10 µg). After evaluation of resistance status of *E. coli*, all resistant isolates were further processed for Modified Hodge test (phenotypic method) to detect and evaluate carbapenemases. The test was performed according to guidelines of CLSI 2020. In Modified Hodge Test (MHT), carbapenemase causes the inactivation of the carbapenem drug of test isolates that enable carbapenem sensitive strain (*E. coli* ATCC 25922), that extended towards carbapenem disk along with lawn of

inoculums from test organism. Positive results of the test appear as indentation like clover leaf.

Statistical Package for Social Sciences, version 26 was used for all statistical analysis. The frequency and percentages were used for carbapenem resistant *E. coli* and graphical presentation by bar charts.

RESULTS

For confirmed 160 UPEC, a total of 367 ICU patients were initially included in the study to collect and examine urine samples for the prevalence of UTI and other mentioned parameters according to our research topic. Among these, 191 (52%) were males while the remaining 176 (48%) were females.

All 19 carbapenem-resistant isolates exhibited resistance to all four carbapenems tested (imipenem, meropenem, ertapenem, and doripenem) and we compiled the data about the resistance of *E. coli* against these drugs on the basis of different age groups and genders as shown below in Figure-I and Table-I. Antibiotic sensitivity of isolated *E. coli* strains were tested for all the mentioned carbapenems and results of each carbapenem are shown separately on the basis of age and gender of ICU patients (figure 1). Out of 19 carbapenem resistant *E. coli*, majority of isolates (n=10, 52.63%) were isolated from male patients while rest were isolated from female patients (n=09, 47.37%). We found that all the carbapenem isolates were resistant to all tested antibiotics, i.e. imipenem, meropenem, doripenem and ertapenem. If isolate is either sensitive to one carbapenem drug then it is sensitive to rest of carbapenem drugs. All the remaining isolates (n=141, 88.13%) were sensitive to all the tested antibiotics, i.e. imipenem, meropenem, doripenem and ertapenem.

In this section, the resistance levels of *E. coli* causing urinary tract infections against all selected carbapenems on the basis of different age groups were evaluated. Table-I showed age wise distribution of resistance pattern of uro-pathogenic *E. coli* for carbapenems. Resistance to carbapenem drugs were more in age group of 36-45- and 46-55-years age groups and Older ICU patients may have increased resistance due to prolonged hospital stays, greater prior antibiotic exposure, or more frequent invasive procedures. We found that all the isolated *E. coli* were 0% resistant for carbapenems for first age group (≥ 35 years) while *E. coli* isolated from 36-45 years, 46-55 years, and ≤ 56 years age group were resistant to carbapenems by 5%, 4.4% and 2.5% respectively.

Modified Hodge test was used to identify the carbapenemase enzyme in *E. coli* isolates (Figure-II). This carbapenemase enzyme causes resistance against carbapenems. Out of 19 carbapenem resistant *E.coli*, 17 (89.47%) carbapenem resistant isolates were positive for MHT while only two were negative. Majority of the isolates (47%) with MHT positive, were isolated from age group of 36-45 years.

Table-I: Age wise overall resistance pattern of *E. coli* against carbapenems

Age	Imipenem	Meropenem	Ertapenem	Doripenem
≤ 35 years, (n=17)	0.00%	0.00%	0.00%	0.00%
36- 45 years, (n=83)	5%, (n=08)	5%, (n=08)	5%, (n=08)	5%, (n=08)
46- 55 years, (n=43)	4.4%, (n=07)	4.4%, (n=07)	4.4%, (n=07)	4.4%, (n=07)
≥ 56 years, (n=17)	2.5%, (n=04)	2.5%, (n=04)	2.5%, (n=04)	2.5%, (n=04)
Total **(n=160)**			19 (11.88%)	

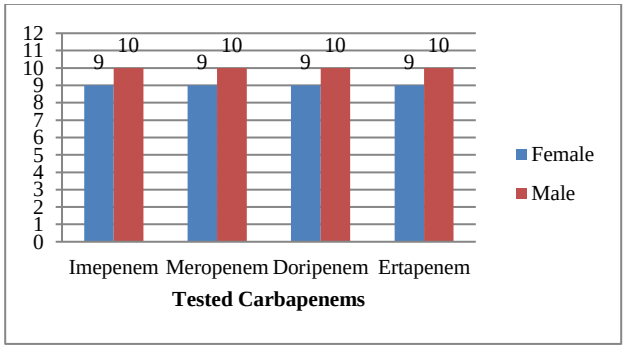

Figure-I Gender wise resistance of *E. coli* against carbapenems.

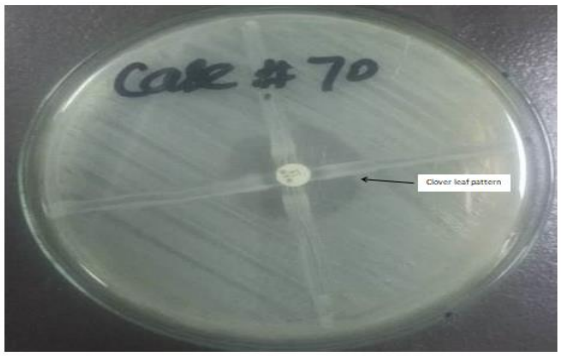

Figure-II: Modified Hodge Test: Positive Modified Hodge test showing a clover leaf-type indentation at the intersection of test organism.

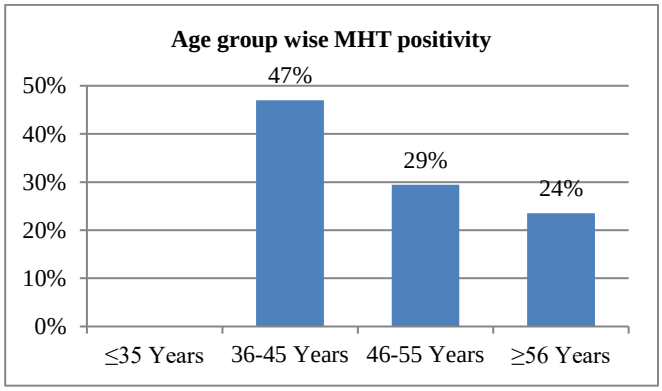

Figure-III: Modified Hodge test results on the basis of different age group.

DISCUSSION

The prevalence of urinary tract infections is much higher among ICU patients when compared with incidence of UTIs in general populations. UTI in patients with urinary catheters could be a serious complication in ICU admitted patients.[11] A study from India reported that frequency of UTI in ICU was 40%.[12] In *E. coli*, carbapenem resistance has only been observed on a few occasions. In *E. coli* , carbapenem resistance was linked to the presence of an outer-membrane porin deficiency and the production of a plasmid-mediated class C β-lactamase.[13] A total of 19 (11.88%) isolates of *E. coli* were carbapenem resistant in our study.

In India, a study done in patients admitted in ICU with UTI, age more than 18 years showed gram negative bacteria of *Enterobacteriaceae* family 89.7% and 16.4% isolates were carbapenem resistant, while *E. coli* was most prevalent followed by *Klebsiella*. This is in accordance to our study.[14]

Multiple international studies reported similar carbapenem resistance pattern in *E. coli*. According to one study from Iran, 10% of clinical *E. coli* isolates were carbapenem resistant, which is similar to the current study's findings.[15] A study from India found that 8.7% of clinical *E. coli* isolates were carbapenem resistant, which is similar to the current study's findings.[16] The results of current study are different from the studies conducted in Iran,[17] China,[18] Nepal,[19] Bahrain[20] and Bangladesh[21]as these studies reported that 38.5%, 19.8%, 6.2%, 0.5% and 0% clinical isolates of *E. coli* were carbapenem resistant, respectively. These findings differ from those of the current study. This discrepancy in results could be explained by geographical differences. Furthermore, discrepancies in results could be related to differences in sample sizes and the time the bacterial isolates were collected.[22]

As shown in figure-I resistance of uro-pathogenic *E. coli* against all the tested carbapenems is higher in male patients as compared to female patients. This study also indicates that all the tested drugs of carbapenem group have almost similar resistance and susceptibility levels of uro-pathogenic *E. coli*. These results were in line with the results of previously available literature.[23]

The table 1 in results section consists of age wise resistance of *E. coli* for carbapenems. It was less for both age groups i.e. the youngest age group (≤ 35 years) and the oldest age group (≥56 years). These findings are consistent with those of a previous study.[24] But some recent studies showed that resistance is increasing with time.[25,26] These findings also suggest that resistance of uro-pathogenic *E. coli* against carbapenems increases with age. Similar pattern of resistance of uro-pathogenic *E. coli* against carbapenems was also observed during our study i.e. resistance increases and susceptibility decreases with growing age.

Similarly, a study done in Bangladesh on E. coli obtained from UTI cases. Isolates from male and elder patients had more drug resistance.[27]

Our last parameter was to detect carbapenemase enzyme by MHT method. MHT is simple, reliable and easy to perform in laboratory to screen organisms for carbapenemase production.[28] In India, a study conducted and reported that 94.4% bacterial isolates were MHT positive which is in accordance with results (89.47%) of our study.[29] In a study done in India out of 132 resistant gram-negative rods, 75% (99/132) were MHT positive.[30] In another study out of 107 CRE, 46 (43%) were confirmed by Modified Hodge Test.[31]

In Pakistan, one study reported 69% MHT positivity among gram negative rods.[28] Difference in carbapenemase detection rate might be due to inclusion of carbapenem sensitive isolates in studies, while our study population was only carbapenem resistant isolates. In a study conducted by only 67% *E. coli* were MHT positive.[31] Moreover, in their study, MHT positivity was detected higher ratio in females as compared to males and this difference was due to

difference in population because there were 18.2% males and 81.8% females in their study.[32]

This study discovered a growing tendency of microbes developing resistance to widely prescribed antibiotics, which is concerning because broader spectrum medications are more expensive and rarely available in hospital pharmacies.

LIMITATIONS

This study was conducted in a single tertiary care center, which may limit generalizability of findings. Molecular characterization of carbapenem resistance genes (e.g., bla_KPC, bla_NDM) was not performed, which could have provided deeper insight into the resistance mechanisms. Additionally, the Modified Hodge Test, though easy to perform, may lack specificity compared to more recent diagnostic assays. The relatively small number of resistant isolates also restricts subgroup analysis.

Future it is suggested to implement molecular diagnostics for early detection of resistance genes, active surveillance of ICU-acquired infections, and antimicrobial stewardship programs to mitigate the rise of carbapenem resistance.

CONCLUSION

To conclude, frequency of urinary tract infections is high in ICU admitted patients and may occur in both genders (males and females). The most common gram-negative bacteria that cause urinary tract infections is *E. coli*. Resistance of *E. coli* against carbapenem drugs may vary depending upon age and gender. Carbapenemase enzyme is main cause of resistance for UPEC in our ICU patients.

CONFLICT OF INTEREST

None

GRANT SUPPORT & FINANCIAL DISCLOSURE

Declared none

AUTHOR CONTRIBUTION

Muhammad Javed Akhtar: Idealized and conceptualized the study, manuscript writing, final approval, agreement to be accountable for all aspects of the work

Blossom Neelam: Reviewing it critical for important intellectual content, final approval, agreement to be accountable for all aspects of the work

Sumera Malik: Data interpretation, data analysis, manuscript writing, final approval, agreement to be accountable for all aspects of the work

SM Abbas Naqvi: Manuscript writing, final approval, agreement to be accountable for all aspects of the work

Rashda Shabbir: Critical revisions, final approval, agreement to be accountable for all aspects of the work

Muhammad Shahid Javed: Data analysis, manuscript writing, final approval, agreement to be accountable for all aspects of the work

REFERENCES

1. Khavandi S, Arzanlou M, Teimourpour R, Peeridogaheh H. Phenotypic and Molecular Characterization of Carbapenems Resistant Escherichia coli Isolated from Patients with Urinary Tract Infections in Ardabil Province, Iran. Iran J Pathol. 2022; 17(3): 261-7. DOI: https://doi.org/10.30699/IJP.2022.538613.2716
2. Flores-Mireles AL, Walker JN, Caparon M, Hultgren SJ. Urinary tract infections: Epidemiology, mechanisms of infection and treatment options. Nat Rev Microbiol. 2015; 13(5): 269-84. DOI: https://doi.org/10.1038/nrmicro3432
3. Alanazi MQ, Alqahtani FY, Aleanizy FS. An evaluation of E. coli in urinary tract infection in emergency department at KAMC in Riyadh, Saudi Arabia: retrospective study. Ann Clin Microbiol Antimicrob. 2018; 17: 3. DOI: https://doi.org/10.1186/s12941-018-0255-z
4. Liu Y, Xiao D, Shi XH. Urinary tract infection control in intensive care patients. Medicine (Baltimore). 2018; 97(38): e12195. DOI: https://doi.org/10.1097/MD.0000000000012195
5. Caron F, Galperine T, Flateau C, Azria R, Bonacorsi S, Bruyère F, *et al*. Practice guidelines for the management of adult community-acquired urinary tract infections. Med Mal Infect. 2018; 48(5): 327-58. DOI: https://doi.org/10.1016/j.medmal.2018.03.005
6. Bonomo RA, Burd EM, Conly J, Limbago BM, Poirel L, Segre JA, Westblade LF. Carbapenemase-producing organisms: a global scourge. Clin Infect Dis. 2018; 66(8): 1290-7. DOI: https://doi.org/10.1093/cid/cix893
7. Ahmed KA, Hussein S, Qurbani K, Ibrahim RH, Fareeq A, Mahmood KA, *et al*. Antibacterial resistance: Impact, challenges and future prospects. J Med, Surgery, Public Health. 2024; 2: 10081. DOI: https://doi.org/10.1016/j.glmedi.2024.100081
8. Fritzenwanker M, Imirzalioglu C, Herold S, Wagenlehner FM, Zimmer KP, Chakraborty T. Treatment options for carbapenem-resistant gram-negative infections. Dtsch Ärztebl Int. 2018; 115(20-21): 345-52. DOI: https://doi.org/10.3238/arztebl.2018.0345
9. Bader MS, Loeb M, Leto D, Brooks AA. Treatment of urinary tract infections in the era of antimicrobial resistance and new antimicrobial agents. Postgrad Med. 2020; 132(3): 234-50. DOI: https://doi.org/10.1080/00325481.2019.1680052

10. Awan M, Rasheed F, Saeed M, Irum S, Ashraf F, Imran AA. Dissemination and detection of carbapenemases producing gram-negative rods. Pak Armed Forces Med J. 2019; 69(1): 9-14. Available from: https://www.pafmj.org/PAFMJ/article/view/2486/2043
11. Duszyńska W, Rosenthal V, Szczęsny A, Woźnica E, Ulfik K, Ostrowska E, *et al*. Urinary tract infections in intensive care unit patients—a single-centre, 3-year observational study according to the INICC project. Anaesthesiol Intensive Ther. 2016; 48(1): 1-6. DOI: https://doi.org/10.5603/ait.2016.0001
12. Kumar A, Chaudhry D, Goel N, Tanwar S. Epidemiology of intensive care unit-acquired infections in a tertiary care hospital of North India. Indian J Crit Care Med. 2021; 25(12): 1427. DOI: https://doi.org/10.5005/jp-journals-10071-24058
13. den Heijer CD, Penders J, Donker GA, Bruggeman CA, Stobberingh EE. The importance of gender-stratified antibiotic resistance surveillance of unselected uropathogens: A Dutch Nationwide Extramural Surveillance study. PLoS One. 2013; 8(3): e60497. DOI: https://doi.org/10.1371/journal.pone.0060497
14. Kishore N, Modi S, Khanduri S, Kakati B. Urinary tract infection in critically ill patients with diabetes mellitus: Spectrum of uropathogens and antimicrobial susceptibility pattern. Bali J Anesthesiol. 2020; 4(Suppl 2): S55-60.
DOI: http://dx.doi.org/10.4103/BJOA.BJOA_97_20
15. Ghadiri H, Vaez H, Razavi-Azarkhiavi K, Rezaee R, Haji-Noormohammadi M, Rahimi AA, *et al*. Prevalence and antibiotic susceptibility patterns of Extended-Spectrum ß-Lactamase and Metallo-ß-Lactamase–producing uropathogenic *Escherichia Coli* isolates. Lab Med. 2014; 45(4): 291-6.
DOI: https://doi.org/10.1309/lmhep4vqhey2pook
16. Khan R, Saif Q, Fatima K, Meher R, Shahzad HF, Anwar KS. Clinical and bacteriological profile of UTI patients attending a North Indian tertiary care center. Integrative Med Nephrol Androl. 2015; 2(1): 29-34.
DOI: https://doi.org/10.4103/2225-1243.150009
17. Lesani SS, Soleimani M, Shakib P, Zolfaghari MR. Prevalence of blaCTX-M, blaSHV, and blaTEM genes in *Escherichia Coli* strains isolated from urinary tract infection samples of patients in the Intensive Care Unit in Qom, Iran. Gene Cell Tissue. 2020; 7(2): e102700.
DOI: https://doi.org/10.5812/gct.102700
18. Wang Q, Zhang X, Xia P, Chen Y, Wang Q, Feng W, Sun F. Spectrum and antimicrobial resistance of uropathogens from patients with urinary tract infection in urology and non-urology departments. Saudi Med J. 2014; 35(2): 198-200. Available from: https://smj.org.sa/content/smj/35/2/198.full.pdf
19. Baral P, Neupane S, Marasini BP, Ghimire KR, Lekhak B, Shrestha B. High prevalence of multidrug resistance in bacterial uropathogens from Kathmandu, Nepal. BMC Res Notes. 2012; 5: 38.
DOI: https://doi.org/10.1186/1756-0500-5-38
20. AlKhawaja S, Alkhawaja S, Saeed NK, Fawzy NA, EL-Moez AA, Hussian SM. Catheter-Associated urinary tract infections at intensive care unit in Bahrain. EC Microbiol. 2017; 8: 71-9.
Available from:
https://ecronicon.net/assets/ecmi/pdf/ECMI-08-00238.pdf
21. Pouladfar G, Basiratnia M, Anvarinejad M, Abbasi P, Amirmoezi F, Zare S. The antibiotic susceptibility patterns of uropathogens among children with urinary tract infection in Shiraz. Medicine. 2017; 96(37): e7834.
DOI: https://doi.org/10.1097/md.0000000000007834
22. Waheed A, Saleem S, Shahzad N, Akhtar J, Saeed M, Jameel I, *et al*. Prevalence of extended spectrum [beta]-lactamase SHV and OXA producing gram negative bacteria at tertiary care hospital of Lahore, Pakistan. Pak J Zoology. 2019 Dec 31;51(6):2345. Available from: https://researcherslinks.com/current-issues/Prevalence-of-Extended-Spectrum-lactamase/20/1/2469/html
23. Ali I, Kumar N, Ahmed S, Dasti JI. Antibiotic resistance in uropathogenic E. coli strains isolated from non-hospitalized patients in Pakistan. J Clin Diagn Res. 2014; 8(9): DC01-DC04.
DOI: https://doi.org/10.7860/JCDR/2014/7881.4813
24. Malik S, Rana JS, Nehra K. Prevalence and antibiotic susceptibility pattern of uropathogenic *Escherichia Coli* strains in Sonipat region of Haryana in India. Biomed Biotech Res J. 2021; 5(1): 80-7.
DOI: http://dx.doi.org/10.4103/bbrj.bbrj_212_20
25. Meletis G. Carbapenem resistance: Overview of the problem and future perspectives. Ther Adv Infect Dis. 2016; 3(1): 15-21.
DOI: https://doi.org/10.1177/2049936115621709
26. Amladi AU, Abirami B, Devi SM, Sudarsanam TD, Kandasamy S, Kekre N, *et al*. Susceptibility profile, resistance mechanisms & efficacy ratios of fosfomycin, nitrofurantoin & colistin for carbapenem-resistant Enterobacteriaceae causing urinary tract infections. Indian J Med Res. 2019; 149(2): 185-91.
DOI: https://doi.org/10.4103/ijmr.ijmr_2086_17
27. Hossain A, Hossain SA, Fatema AN, Wahab A, Alam MM, Islam MN, *et al*. Age and gender-specific antibiotic resistance patterns among Bangladeshi patients with urinary tract infection caused by Escherichia coli. Heliyon. 2020; 6(6): e04161.
DOI: https://doi.org/10.1016/j.heliyon.2020.e04161
28. Amjad A, Mirza IA, Abbasi SA, Farwa U, Malik N, Zia FJ. Modified Hodge test: A simple and effective test for detection of carbapenemase production. Iranian J Microbiol. 2011; 3(4): 189. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC3330182/pdf/IJM-3-189.pdf
29. Amudhan MS, Sekar U, Kamalanathan A, Balaraman S. blaIMP and blaVIM mediated carbapenem resistance in Pseudomonas and Acinetobacter species in India. J Infect Dev Ctries. 2012; 6(11): 757-62.
DOI: https://doi.org/10.3855/jidc.2268
30. Datta S, Dey R, Dey JB, Ghosh S. A comparative study of modified Hodge test and Carba NP test for detecting carbapenemase production in Gram-negative bacteria. Medical Journal of Dr. DY Patil University. 2017; 10(4): 365-9. DOI: http://dx.doi.org/10.4103/0975-2870.213930
31. Patidar N, Vyas N, Sharma S, Sharma B. Phenotypic detection of carbapenemase production in carbapenem-resistant Enterobacteriaceae by modified hodge test and modified strip carba NP test. J Lab Physicians. 2021; 13(01): 014-21. DOI: https://doi.org/10.1055/s-0041-1723859
32. Gurung S, Kafle S, Dhungel B, Adhikari N, Thapa Shrestha U, Adhikari B, *et al*. Detection of OXA-48 gene in carbapenem-resistant *Escherichia Coli* and Klebsiella pneumoniae from urine samples. Infect Drug Resist. 2020: 2311-21.
DOI: https://doi.org/10.2147/IDR.S259967