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Original Research Article

Antimicrobial susceptibility patterns of urinary pathogens in Indian clinical isolates

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Abstract

Background: Urinary tract infections (UTIs) are a major health concern in India. The emergence of multidrug-resistant pathogens has become a global concern. Thus, this study aimed to assess the prevalence of bacterial pathogens in clinical urine samples and there in vitro susceptibility to various antibiotics.
Materials and Methods: Clinical urinary samples collected from outpatients and inpatients during a period of 3 years (2018 to 2021) were identified. Antibiotic susceptibility to various drugs was done as per the Clinical Laboratory Standards Institute (CLSI) guidelines.
Results: Among 1508 patients, age data were recorded for 1485, with 37.5% aged >50 to ≤70 years. Of the 1505 patients with recorded gender, 57.7% were male. The UTIs were diagnosed in 90.9% of cases. The predominant isolates were *Escherichia coli* (iib to Ceftriaxone/Sulbactam/EDTA (CSE) nwas highest (83.4%), while Meropenem, Imipenem, and Piperacillin/Tazobactam (TZP) showed lower susceptibility rates (65.8%, 63.6% and 48.3%, respectively). Among isolates non-susceptible to Meropenem and Imipenem, CSE showed susceptibility rates of 75.1 and 76.5 %, respectively.
Conclusion: The UTIs were the most common diagnosis, with *E. coli* being the predominant pathogen. The findings underscore the higher susceptibility to CSE and rising non-susceptibility to Meropenem, Imipenem, and TZP, underscoring the concerning resistance level among bacterial isolates.

Keywords: In-vitro, urinary tract infection, Escherichia coli, Ceftriaxone/Sulbactam/EDTA, Meropenem non-susceptible.

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1. Introduction

Healthcare-associated infections are infections acquired during hospitalization or medical interventions, and urinary tract infections (UTIs) are among the most common hospital-acquired infections.[1] UTIs are especially prevalent in diabetic patients and can lead to serious complications such as renal papillary necrosis, renal or perirenal abscess, emphysematous pyelitis or cystitis, emphysematous pyelonephritis, urosepsis, and bacteraemia.[2]

UTIs are a significant public health concern and can be caused by a variety of pathogens, including both gram-negative, gram-positive bacteria as well as certain fungi. However, Gram-negative bacteria are the most prevalent pathogens associated with UTIs.[3,4] Among the gram-negative, the most common causative agents include *Escherichia coli, Klebsiella pneumoniae, and Proteus mirabilis.*[5] Over time, the spectrum of causative organisms and their resistance to commonly prescribed antibiotics has evolved, making effective management increasingly difficult.[6]

The emergence of multidrug-resistant (MDR) pathogens has become a global concern. Risk factors associated with antibiotic resistance in UTIs include prior use of broad-spectrum antimicrobials, previous hospitalization, urinary tract anomalies, catheterization, advanced age, and recurrent infections.[7] Hence, analysing the antimicrobial susceptibility patterns of urinary isolates is critical, particularly for antibiotics such as Ceftriaxone/Sulbactam/ ethylenediaminetetraacetic acid [EDTA] (CSE), Meropenem, Imipenem, and Piperacillin/Tazobactam (TZP).

CSE is a novel combination antibiotic consisting of ceftriaxone, sulbactam, and disodium edetate. It exhibits synergistic effects: ceftriaxone inhibits bacterial cell wall synthesis, sulbactam acts as a beta-lactamase inhibitor, and

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ethylenediaminetetraacetic acid enhances the activity through its chelating properties.[8] Meropenem, a broad-spectrum carbapenem, is effective against *Pseudomonas species* and extended-spectrum β-lactamase-producing bacteria,[9] though the rise of carbapenem-resistant *Enterobacteriaceae* poses a major threat.[10] Imipenem, another carbapenem, offers extensive antibacterial coverage against most clinically significant aerobic and anaerobic pathogens.[11]

TZP is a combination of β-lactam/β-lactamase inhibitor, offering broad-spectrum antibacterial activity against both gram-positive and gram-negative bacteria, including both aerobic and anaerobic species.[12]

This retrospective study aims to assess the antimicrobial susceptibility patterns of urinary pathogens to these four antibiotics, such as CSE, Meropenem, Imipenem, and TZP. Considering increasing antibiotic resistance, the study aimed to find trends in pathogen susceptibility to support more informed clinical decisions and improve treatment outcomes.

2. Materials and Methods

This retrospective in-vitro observational study was conducted between January 2018 and December 2021, utilizing existing data from medical records and microbiology laboratory reports to assess and compare the susceptibility of various pathogens isolated from urine samples to different antibiotic drugs. Data were retrieved from urine culture results and corresponding drug susceptibility profiles, focusing on identifying pathogens and their susceptibility to a range of antibiotics. Demographic data, including age and gender, were recorded for all patients. Clinical diagnoses were also documented. Urine samples were collected and subjected to the standard culture method. Pathogen identification was performed using standard microbiological techniques. Antibiotic susceptibility testing was conducted using Kirby-Bauer's disk diffusion method, recommended as per the Clinical Laboratory Standards Institute (CLSI) guidelines. The susceptibility and non-susceptibility (intermediate + resistant) patterns of the following antibiotics: CSE, Meropenem, Imipenem, and TZP were noted. The zone of inhibition of each drug was interpreted as per the breakpoints provided by CLSI and as per the manufacturer for CSE.

All urine samples (one sample per patient) that came to the laboratory in the specified period were included in the study. The study included a sample size of 1,508 non-duplicate urine samples, ensuring a comprehensive representation of pathogen-drug interactions. This sample size allowed for robust analysis and generalizability of the findings. The study aimed to determine the prevalence of bacterial pathogens in urine samples from patients with UTIs and evaluate their in vitro susceptibility to CSE, Meropenem, Imipenem, and TZP. Data were analyzed using descriptive statistics, which were employed to describe categorical variables (frequency and percentages).

3. Results

In a cohort of 1508 patients, the age distribution data were recorded for 1485 patients with 37.5% aged between >50 and ≤70 years, 23.7% aged between >30 and ≤50 years, 18.3% were aged >70 years, and 17.9% were aged between >10 and ≤30 years (**Figure 1**). Of the 1505 patients with recorded gender data, 57.7% (n=868) were male and 42.3% (n=637) were female.

Table 1: Isolate-wise antimicrobial susceptibility profile

Isolates (N=1508)	Ceftriaxone/Sulbactam/EDTA	Meropenem	Piperacillin/Tazobactam	Imipenem
Escherichia coli (n=921)	870 (94.5)	689 (74.8)	458 (49.7)	656 (71.2)
Klebsiella pneumoniae (n=221)	192 (86.9)	100 (45.2)	70 (31.7)	111 (50.2)
Pseudomonas aeruginosa (n=195)	49 (25.1)	108 (55.4)	113 (57.9)	110 (56.4)
Enterobacter species (n=86)	73 (84.9)	37 (43.0)	30 (34.9)	33 (38.4)
Proteus mirabilis (n=23)	17 (73.9)	15 (65.2)	20 (87.0)	8 (34.8)
Acinetobacter baumannii (n=18)	15 (83.3)	10 (55.6)	8 (44.4)	11 (61.1)
Citrobacter koseri (n=17)	15 (88.2)	13 (76.5)	11 (64.7)	13 (76.5)
Proteus vulgaris (n=11)	10 (90.9)	8 (72.7)	8 (72.7)	5 (45.5)
Providencia species (n=9)	8 (88.9)	8 (88.9)	6 (66.7)	8 (88.9)
Morganella morganii (n=4)	3 (75)	3 (75)	3 (75)	2 (50)
Serratia species (n=1)	-	-	-	-
Achromobacter xylsoxidans (n=1)	-	1 (100)	1 (100)	1 (100)
Citrobacter freundii (n=1)	1 (100)	1 (100)	-	1 (100)
Data presented as n (%) EDTA, ethylenediaminetetraacetic acid				

Table 2: Ceftriaxone/Sulbactam/EDTA susceptibility in non-susceptible isolates

Antibiotics	Piperacillin/Tazobactam non-susceptible (n=780)	Imipenem non-susceptible (n=549)	Meropenem non-susceptible (n=515)
Ceftriaxone/Sulbactam/EDTA susceptibility	627 (80.4)	420 (76.5)	387 (75.1)
Data presented as n (%) EDTA, ethylenediaminetetraacetic acid Non-susceptible, (Intermediate + Resistant)			

Table 3: Susceptibility of Ceftriaxone/Sulbactam/EDTA towards meropenem non-susceptible gram-negative bacteria

Meropenem non-susceptible bacteria	Escherichia coli (n=231)	Klebsiella pneumoniae (n=121)	Acinetobacter baumannii (n=8)	Pseudomonas aeruginosa (n=87)
Ceftriaxone/Sulbactam/EDTA susceptible	209 (90.5)	101 (83.5)	5 (62.5)	16 (18.4)
Data presented as n (%) EDTA, ethylenediaminetetraacetic acid Non-susceptible, (Intermediate + Resistant)				

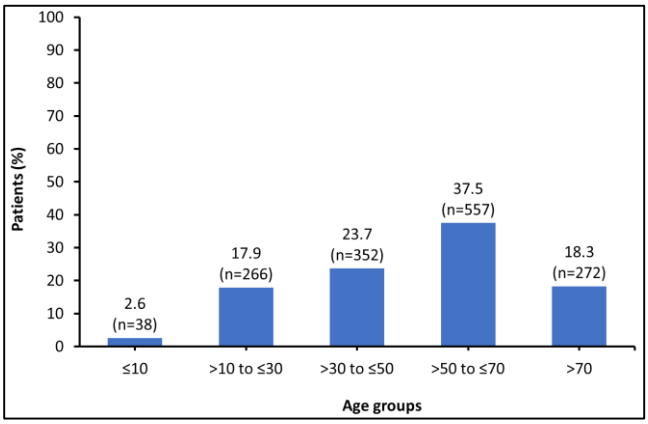

Figure 1: Distribution of patients according to age groups (N=1485)

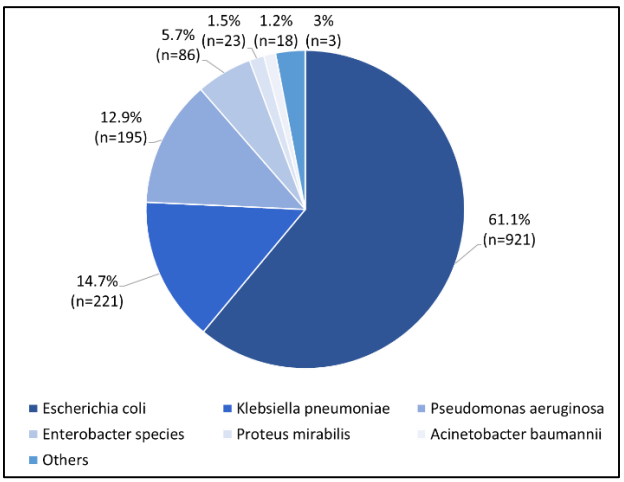

Figure 2: Distribution of bacterial isolates

UTIs were the most frequently observed diagnosis, present in 90.9% of patients. The predominant bacterial isolates from the urine samples were *E. coli* (61.1%), followed by *K. pneumoniae* (14.7%) and *P. aeruginosa* (12.9%) (**Figure 2**). CSE showed the highest overall susceptibility (83.4%; n=1257) towards these bacterial isolates. Species-wise, *E. coli* exhibited the highest susceptibility to CSE (94.5%), followed by *P. vulgaris* (90.9%), *Citrobacter koseri* (88.2%), *K. pneumoniae* (86.9%), and *Acinetobacter baumannii* (83.3%). In contrast, *P. aeruginosa* showed a relatively low susceptibility to CSE (25.1%) (**Table 1**). In contrast, the susceptibility rates for Meropenem, Imipenem, and TZP were 65.8%, 63.6% and 48.3 %, respectively (**Figure 3**). Among the Meropenem and Imipenem non-susceptible isolates, CSE showed 75.1 and 76.5 % susceptibility, respectively (**Table 2**). In a sub-group analysis, CSE showed 84.3% (n=296/351) susceptibility among TZP-resistant but Meropenem-susceptible isolates (Suggestive of extended-spectrum beta-lactamases/AmpC producers). Ceftriaxone/Sulbactam/EDTA also showed high susceptibility in meropenem non-susceptible *E. coli* (90.5%) and *K. pneumoniae* (83.5%), followed by *A. baumannii* (62.5%) and *P. aeruginosa* (18.4%)(**Table 3**).

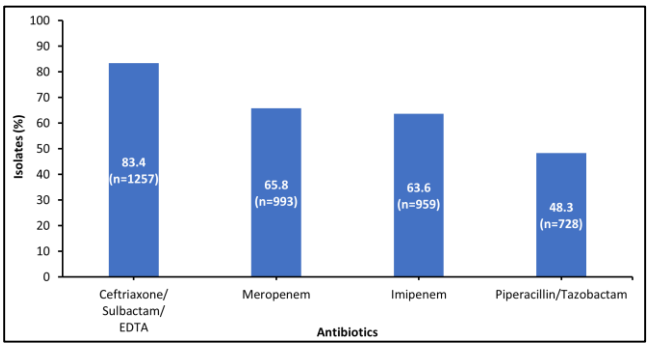

Figure 3: Overall susceptibility rate of antibiotics (N=1508)

4. Discussion

The findings of this study provide significant insights into the biology and antibiotic susceptibility patterns of various urinary pathogens in a cohort of 1508 patients. The patient population was predominantly male (57.7%), with most affected individuals aged between >50 and ≤70 years (add its %). UTIs were the leading diagnosis, accounting for 90.9%

of the cases. This was consistent with a one-year cross-sectional study of 500 patients with UTI symptoms, where the majority (76.8%) were male, and the male-to-female ratio was 1.43:1. The most affected age group was 51-60 years, which comprised 25.4% of the patients.[13]

The bacterial isolates identified in this study predominantly included *E. coli* (61.1%), followed by *K. pneumoniae* (14.7%), and *P. aeruginosa* (12.9%). These findings are consistent with previous research, including a study of 492 patients with urine samples, in which *E. coli* occurred at a frequency of 67.21%, followed by *Proteus species*, *Enterococcus faecalis*, and *Enterobacter.*[14] Similarly, a retrospective study conducted in the intensive care unit (ICU) of Hi-Tech Medical College and Hospital, Odisha, Eastern India, found UTIs to be the most common infection (54.9%), with *E. coli* as the predominant isolate (52.7%), followed by *P. mirabilis* (15.4%) and *P. aeruginosa* (13.2%).[15] Collectively, these results highlight the prevalence of *E. coli* and *Proteus species* as major pathogens across various clinical settings.

The current study also evaluated the antibiotic susceptibility of the bacterial isolates, where CSE showed the highest overall susceptibility (83.4%) towards isolates. Species-wise, *E. coli* exhibited the highest susceptibility to CSE (94.5%), followed by *P. vulgaris* (90.9%), *Citrobacter koseri* (88.2%), *K. pneumoniae* (86.9%), and *A. baumannii* (83.3%). In contrast, *P. aeruginosa* showed a relatively low susceptibility to CSE (25.1%). In contrast, the susceptibility rates for Meropenem, Imipenem, and TZP were 65.8%, 63.6% and 48.3%, respectively. According to a comparative in-vitro susceptibility study conducted by Singh et al in in-ICU settings, CSE was the most effective antibiotic, showing 94% sensitivity for *Enterobacteriaceae* and 97% for *Acinetobacter* and *Pseudomonas species.* Thus, strongly recommend inclusion of CSE in routine sensitivity panel and may be used as a carbapenem- and colistin-sparing drug and a promising option against ESBL and metallo-beta-lactamases producers, especially in ICU.[16]

Additionally, a study on the prevalence and susceptibility of gram-negative pathogens in super specialty tertiary care centers in Pune, India, from January 2018 to January 2019, reported that CSE was the most susceptible drug (95.10%) towards *Enterobacteriaceae* isolates, which was approximately 31-50% more susceptible than other tested drugs. A similar pattern was observed for non-*Enterobacteriaceae* isolates (62.90%), where CSE exhibited approximately 1-5% higher activity. The susceptibility profile indicated that CSE (an antibiotic-adjuvant entity) was equivalent to Carbapenem drugs (Meropenem and Imipenem) and superior to TZP against clinical pathogens. CSE was also found to be active against Meropenem, Imipenem, and TZP non-susceptible pathogens.[17] In a similar study of carbapenem non-susceptible gram-negative pathogens in a tertiary care hospital in Mumbai, the antibiogram profile revealed that CSE was extremely effective (100% susceptible) against clinical pathogens, outperforming other antibiotics such as TZP (0-6.7%), Cefoperazone+Sulbactam (0-20%), Cefepime+Tazobactam (0-33.3%), and Tigecycline (34.7-100%). The susceptibility profile revealed that CSE was significantly superior to other antibiotics, including β-lactam/β-lactamase inhibitor combinations and protein synthesis inhibitors. Hence, CSE can be considered one of the most efficient treatment options for infections caused by carbapenem-non-susceptible pathogens.[18]

Earlier studies have shown that the use of carbapenems and β-lactam/β-lactamase inhibitor combinations can contribute to antibiotic resistance in pathogens through mechanisms such as overexpression of efflux pumps, reduced cell wall permeability, and the production of enzymes like ESBLs, MBLs, and the formation of biofilms. In contrast, the higher susceptibility observed with CSE may be due to its ability to overcome resistance through multiple mechanisms.

The marketed formulation of CSE demonstrates superior permeability, improved drug penetration, enhanced stability, and higher periplasmic concentration, all of which contribute to its greater efficacy. A key component of CSE is EDTA, a non-antibiotic adjuvant that helps mitigate resistance by downregulating efflux pump expression, disrupting biofilms, and chelating metal ions necessary for the function of MBL-producing bacteria.

The presence of EDTA in CSE-1034 enhances its effectiveness against MDR gram-negative bacteria by destabilizing the bacterial outer membrane through cation chelation, thereby increasing antibiotic permeability. EDTA also boosts the activity of ceftriaxone and sulbactam against ESBL-producing strains through synergistic effects. Additionally, by binding to the divalent metal ions essential for MBL activity, EDTA inactivates these enzymes, further increasing CSE's effectiveness against MBL-producing pathogens. Overall, CSE has proven to be effective in treating infections caused by MDR gram-negative bacteria.[19]

The current study has several strengths, including a large sample size (1508 isolates), demographic data like age groups, which ensures a broad perspective, and relevant clinical findings, such as high susceptibility to CSE (83.4%). The focus on UTIs and bacterial isolates like *E. coli*, *K. pneumoniae*, and *P. aeruginosa* is valuable for guiding clinical decisions. However, the study also has limitations, such as potential bias due to non-random sampling, and the absence of genotypic testing to confirm whether the isolates were NDM or ESBL producers, which could have added more value to the findings.

5. Conclusion

This retrospective in-vitro study highlights the growing challenge of multidrug-resistant urinary tract infections, with

E. coli emerging as the predominant pathogen. Among the antibiotics evaluated, CSE demonstrated the highest susceptibility rates, including in isolates non-susceptible to meropenem, imipenem, and TZP. Notably, CSE showed promising activity against ESBL-suspected isolates (TZP Resistant Meropenem susceptible), suggesting its potential utility in overcoming β-lactam resistance.

These findings highlight the higher in-vitro susceptibility of CSE compared with other tested agents, suggesting its potential as a useful option in settings with rising carbapenem resistance. Nevertheless, further studies are required to validate these results across different patient demographics and clinical outcomes. While this study provides robust phenotypic data, genotypic confirmation of resistance mechanisms would have further strengthened the findings. Future studies incorporating molecular diagnostics and broader clinical validation are essential to confirm these observations and guide empirical therapy.

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Fefar DR, Shingala HK, Mehta KD, Shah RV. Comparison of bacterial pathogens causing urinary tract infection among catheterized and non-catheterized patients at a tertiary care hospital in Jamnagar. *J Pure Appl Microbiol.* 2023;17(2):1238–45. https://doi.org/10.22207/JPAM.17.2.57.
2. Ahmed AE, Abdelkarim S, Zenida M, Baiti MAH, Alhazmi AAY, Alfaifi BAH, et al. Prevalence and associated risk factors of urinary tract infection among diabetic patients: A cross-sectional study. *Healthcare (Basel).* 2023;11(6):861. https://doi.org/10.3390/healthcare11060861.
3. Mazzariol A, Bazaj A, Cornaglia G. Multi-drug-resistant Gram-negative bacteria causing urinary tract infections: A review. *J Chemother.* 2017;29(sup1):2–9. https://doi.org/10.1080/1120009X.2017.1380395.
4. Bajaj JK, Karyakarte RP, Kulkarni JD, Deshmukh AB. Changing the aetiology of urinary tract infections and the emergence of drug resistance as a major problem. *J Commun Dis.* 1999;31(3):181–4.
5. 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. https://doi.org/10.1038/nrmicro3432.
6. Majumder MMI, Mahadi AR, Ahmed T, Ahmed M, Uddin MN, Alam MZ. Antibiotic resistance pattern of microorganisms causing urinary tract infection: A 10-year comparative analysis in a tertiary care hospital of Bangladesh. *Antimicrob Resist Infect Control.* 2022;11(1):156. https://doi.org/10.1186/s13756-022-01197-6.
7. Kot B, Grużewska A, Szweda P, Wicha J, Parulska U. Antibiotic Resistance of uropathogens isolated from patients hospitalized in district hospital in central Poland in 2020. *Antibiotics (Basel).* 2021;10(4):447. https://doi.org/10.3390/antibiotics10040447
8. Chaudhary M, Mir MA, Ayub SG. Protocol 06 Group. Safety and efficacy of a novel drug elores (ceftriaxone+sulbactam+disodium edetate) in the management of multi-drug resistant bacterial infections in tertiary care centers: A post-marketing surveillance study. *Braz J Infect Dis.* 2017;21(4):408–17. https://doi.org/10.1016/j.bjid.2017.02.007
9. Mukhopadhyay S, Wade KC, Puopolo KM. Drugs for the Prevention and Treatment of Sepsis in the Newborn. *Clin Perinatol.* 2019;46(2):327–47. https://doi.org/10.1016/j.clp.2019.02.012.
10. Iovleva A, Doi Y. Carbapenem-Resistant Enterobacteriaceae. *Clin Lab Med.* 2017;37(2):303–15. https://doi.org/10.1016/j.cll.2017.01.005.
11. Maddison JE, Watson ADJ, Elliott J. Antibacterial drugs. Small Animal Clinical Pharmacology (Second Edition). 2007;148-85.
12. Gin A, Dilay L, Karlowsky JA, Walkty A, Rubinstein E, Zhanel GG. Piperacillin-tazobactam: A beta-lactam/beta-lactamase inhibitor combination. *Expert Rev Anti Infect Ther.* 2007;5(3):365–83. https://doi.org/10.1586/14787210.5.3.365.
13. Karishetti MS, Shaik HB. Clinicomicrobial assessment of urinary tract infections in a tertiary care hospital. *Indian J Health Sci Biomed Res.* 2019;12(1):69–74. https://doi.org/10.4103/kleuhsj.kleuhsj_296_17.
14. Vranic SM, Zatric N, Rebic V, Aljicevic M, Abdulzaimovic A. The Most Frequent Isolates from Outpatients with Urinary Tract Infection. *Materia Socio-Medica.* 2017;29(1):17. https://doi.org/10.5455/msm.2017.29.17-20.
15. Pattanayak C, Patanaik SK, Datta PP, Panda P. A study on antibiotic sensitivity pattern of bacterial isolates in the intensive care unit of a tertiary care hospital in Eastern India. *Int J Basic Clin Pharmacol.* 2017;2(2):153–9. https://doi.org/10.5455/2319-2003.ijbcp20130307.
16. Singh S, Sahu C, Patel SS, Singh A, Yaduvanshi N. A comparative in vitro sensitivity study of "Ceftriaxone-Sulbactam-EDTA" and various antibiotics against gram-negative bacterial isolates from intensive care unit. *Indian J Crit Care Med.* 2020;24(12):1213–7. https://doi.org/10.5005/jp-journals-10071-23573.
17. Satras KB. 2019. Prevalence and susceptibility analysis of gram negative pathogens in super specialty tertiary care centers, Pune in India from January 2018- January 2019. *Microbiol Res J Int.* 2019;28(6):1–9. https://doi.org/10.9734/mrji/2019/v28i630150.
18. Sriram A, Tulara NK. Prevalence and susceptibility analysis of carbapenem resistant gram negative pathogens in tertiary care hospital, Mumbai. *J Basic Clin Pharma*. 2018;9(1).
19. Chaudhary M, Ayub SG, Mir MA; Members of Study Group. CSE-1034 versus Ceftriaxone: Efficacy and Safety Analysis from a Randomized, Open-labeled Phase III Study in Complicated Urinary Tract Infections. *J Glob Infect Dis.* 2018;10(4):188–95. https://doi.org/10.4103/jgid.jgid_98_17.

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