Indian Journal of Experimental Biology
Vol. 62, February 2024, pp. 119-125
DOI: 10.56042/ijeb.v62i02.2549

A short-term study on statistical numeration of multidrug resistant *Escherichia coli* isolates among the patients with urinary tract infection

Neha Srivastava[1,2,3*], Sheetal Verma[2], Meenu Singh[3] & Abhinav Kumar[3]

[1] Department of Biotechnology, Dr. APJ Abdul Kalam Technical University, Jankipuram, Lucknow-226 031, Uttar Pradesh, India

[2] Department of Microbiology, King George's Medical University Shah Mina Rd, Chowk, Lucknow-226 003, Uttar Pradesh, India

[3] Department of Biotechnology, IILM Academy of Higher Learning, College of Engineering & Technology, Gautam Buddh Nagar-201 306, Uttar Pradesh, India

Received 12 March 2023; *revised 08 November 2023*

Along with malaria and plague, urinary tract infections (UTIs) are among the oldest types of illnesses till today. Antibiotics, however, have consistently been the initial treatment option chosen by medical specialists despite the fact that treating this complex condition has never been simple. Antibiotic abuse or overuse is linked to the development of resistance, the recurrence of illness, suffering, and financial hardship. In this study, we examed the pattern of *Escherichia coli* antibiotic susceptibility in urine samples from UTI patients in a local population in India as well as the formation of multiple drug resistances (MDR) among the isolates. The level of resistance to multiple antibiotics is accessed by multiple antibiotic resistance index (MARI), a quantitative measure, which is determined by simply dividing number of antibiotics to which the isolate is resistant to total number of antibiotics tested. We found that second and third generations of flouroquinone were shown the highest levels of resistance, followed by widely used antibiotics like ampicillin and cephalosporin. The drugs fosfomycin (FO) and nitrofurantoin (NIT) had the highest levels of sensitivity. In addition, we observed 80% of isolates with multiple antibiotic resistance indexes more than 0.2 and 97% of isolates that are multidrug resistant, which amply illustrates the severity of rising antibiotic resistance that must be properly controlled to treat UTI effectively.

Keywords: Antibiotic resistance, Multiple antibiotic resistance index (MARI)

Clinically, UTIs are rezognised for their frequency, recurrence, and subsequent emergence of multidrug resistence (MDR) and antimicrobial resistance (AMR). It was first identified in Egypt approximately 1550 BC, and today it ranks among the most common bacterial illnesses worldwide. According to recent studies, the number of UTI cases has climbed significantly over the past three decades, from 150 million cases in the past to more than 404.6 million cases today, with an estimated 236,786 fatalities in 2019[1]. According to the Urology Care Foundation of the American Urological Association, 8 million people with UTI symptoms seek medical assistance every year. Approximately, 10 in 25 women and 3 in 25 men will experience symptoms at some point in their lifetime[2].

Clinical signs and symptoms, associated risk, and source of infection are used to categorise UTIs[3-5]. *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, and other *Enterobacteriaceae* are the most often reported pathogens causing an acute, uncomplicated lower UTI (mostly cystitis). *E. coli* is the most prevalent pathogen among elderly individuals, followed by various *Enterobacteriaceae*[4]. Women are more prone than men to have UTIs at any age, particularly during pregnancy and after menopause. Additionally, researchers discovered that metropolitan areas had a somewhat higher incidence or infection rate than rural locations[6,7].

Chemotherapy was first employed to treat UTIs in the early 20th century, despite the fact that the condition was well-known and well-characterized in the early 19th century without knowledge of the microorganisms that caused it[8]. Despite having poor spectrum activity, nitrofurantoin (NIT) is considered as the first line of defense in UTI. Amoxicillin (AMX) and other beta lactam antibiotics were introduced after the 1970s, but their widespread use led to the development of antibiotic resistance. Trimethoprim/sulfamethoxazole (TMP/SMX) was

*Correspondence:
Phone: +91 9650990184 (Mob.)
E-Mail: Srivastava.85@gmail.com

then chosen as the first line treatment for UTI. According to American and European standards, fluoroquinolones (and to a lesser extent gatifloxacin) can be used as an alternative when TMP/SMX resistance is 10% or greater[3,9,10].

Antibiotic misuse, overuse and unwarranted recommendations raise disease burden, financial burden, AMR, and MDR significantly. AMR was recently named one of the top 10 global public health hazards by WHO, with 0.7 million deaths reported in 2019 and an estimated significant increase to 20 million by 2050. The resistance to the routinely given antibiotics for the treatment of UTIs has dramatically increased, according to the Global MAR and Use Surveillance System (GLASS) of the WHO. Many nations have reported high rates of resistance to commonly prescribed antibiotics as AMP, amoxicillin/clavulanic acid (AMC), oral cephalosporins, co-trimoxazole (CM) and ciprofloxacin (CIP). Even fluoroquinolones, which were a better alternative option for treating UTIs, have a significant rate of resistance, and are therefore not permitted for oral use. On the other side, as MDR causative agents develop, the situation becomes worse in terms of disease recurrence and treatment failure.

In these situations, it is essential to follow accepted procedures, employ precise terminology, and interpret data in a manner that takes into account the seriousness of drug-resistant diseases and the underlying causative agents. The European Centre for Disease Control (ECDC) and the Centre for Disease Control and Prevention (CDC), Atlanta, have developed a formal definition of the word "MDR" to convey the scope and severity of microbial resistance, and it appears to be frequently used in the medical sciences these days. According to the definition, extensively drug resistant (XDR) (i.e., bacterial isolates) is defined as nonsusceptibility to at least one agent in all but two or fewer antimicrobial groups and MDR, or resistance to at least one agent in three or more antimicrobial categories. Further, nonsusceptibility to all agents in all antimicrobial categories is characterized as pandrug resistance (PDR)[11].

On the other hand, the multiple antibiotic resistance index (MARI), a reliable and cost-effective measurement, is being used to assess a bacterial isolate's level of resistance to a variety of different antibiotics. The number of antibiotics to which the isolate is resistant divided by the total number of antibiotics to which the isolate was tested is used to determine the index. A higher MARI (greater than 0.2) indicates a higher level of MDR[12,13].

Correct diagnostic procedures, focused treatment, and adequate drug resistance monitoring are essential given the problem of MDR's growth in UTI cases[14-16]. Antibiotic susceptibility profiles should be periodically investigated for adequate surveillance, along with accurate reporting of the occurrence of AMR and MAR. In this context, in order to understand the severity of the establishment of MDR, here, we tried to identify the susceptibility pattern of *E. coli* isolates that cause UTI as well as their frequency as MDR, XDR, PDR and MARI calculations.

Materials and Methods

Collection of *E. coli strains* and antibiotic susceptibility testing (AST)

For this study, the *E. coli* strains from urine sample of UTI patients were collected from Microbiology lab, King George's Medical University, Lucknow, Uttar Pradesh during Feb-July. 2022. The collected strained were stored in 1% nutrient agar for further usage. AST was performed on *E. coli* isolates using the Kirby-Bauer agar disc diffusion method as per the guidelines suggested by Clinical & Laboratory Standards Institute (CLSI)[17]. The *E. coli* isolates were tested against a panel of 21 antibiotics agents of 14 different categories (Table 1). Briefly, a good light turbidity suspension was prepared using 3-5 well isolated colonies of the *E. coli* in 3-5 mL sterile physiological saline and incubated until turbidity reached to a standard uniform concentration of 0.5 McFarland solutions. The suspension was immediately swabbed on Mueller–Hinton agar (Himedia) plate using sterile dry cotton swab (Himedia). Antibiotic disks were placed on swabbed plate, followed by incubation at 37°C for 24 h. Antibiotic susceptibility pattern was determined for each *E. coli* isolate followed by comparison against zone diameter breakpoints and susceptibility interpretation as per CLSI guidelines. For quality control, *E. coli* ATCC 25922 strain was used as a control strain.

Determination of MARI

Multiple antibiotic resistance index (MARI) was calculated for each isolate using the formula, MARI = A/B, where A represents the number of antibiotics to which the isolate is resistant and B represents the total

Table 1 — Group of antibiotics used to test antibiotic susceptibility pattern of *E. coli* isolates obtained from UTI patients in the study

Antimicrobial category	Antimicrobial agent	Conc. (µg)
Aminoglycosides	Gentamicin (GEN)	10
	Tobramycin (TOB)	30
	Amikacin (AK)	10
Antipseudomonal penicillins + b-lactamase inhibitors	Piperacillin-tazobactam (PIT)	100/10
Carbapenems	Ertapenem (ETP)	10
	Imipenem (IMP)	10
	Meropenem (MRP)	10
Non-extended spectrum cephalosporins; 2nd generation cephalosporins	Cefazolin (CZ)	30
Extended-spectrum cephalosporins; 3rd and 4th generation cephalosporins	Cefotaxime or ceftriaxone (CTR)	30
	Cefepime (CPM)	30
Cephamycins	Cefoxitin (CX)	30
Fluoroquinolones	Ciprofloxacin (CIP)	5
	Norfloxacin (NX)	10
	Levoflaxacin (LE)	5
Inhibitor of folate synthesis pathway	Co-Trimoxazole (Sulpha/Trimethoprim) or Trimethoprim-sulphamethoxazole (COT)	25 (23.75/ 1.25)
Monobactams	Aztreonam (AT)	50
Penicillin	Ampicillin (AMP)	10
Penicillins + b-lactamase inhibitors	Amoxicillin/clavulanic acid (AMC)	30 (20/10)
Phosphonic acids	Fosfomycin (FO)	200
Tetracyclines	Tetracycline (TE)	30
Synthetic derivative of imidazolidinedione	Nitrofurantoin (NIT)	300

number of antibiotics tested to evaluate susceptibility of that isolate[12,13,18].

Characterization of *E. coli* isolates as MDR, XDR and PDR

As per the definition recommended by European Centre for Disease Control (ECDC) and Centre for Disease Control & Prevention (CDC), Atlanta, *E. coli* isolates were further characterized as MDR, XDR and PDR as follows: MDR: non-susceptible/resistant to ≤1 agent in ≥3 antimicrobial categories; XDR: non-susceptible/resistant to ≤1 agent in all but ≤2 anti-microbial categories; and PDR: non-susceptible/ resistant to all antimicrobial agents in all categories[11,19].

Statistical analysis

Statistical Package for Social Sciences (SPSS) was used to analysis data. Data was analyzed using frequency distribution in number and percentage, also represented in graphical formats.

Ethical clearance

The ethical approval for the presented work was sought and granted from Institution Ethical committee of King George's Medical University, Lucknow, Uttar Pradesh, India (*Ref. code: 112th ECM IIA/P7*).

Table 2 — Antibiotic susceptibility response (%) of *E. coli* isolates from UTI patients, tested using a panel of 21 antibiotics

AST/Antibiotics	Sensitive (%)	Resistance (%)	Intermediate (%)
FO	99	1	0
NIT	92	8	0
AK	69	30	1
ETP	65	34	1
MRP	65	31	4
AMC	64	31	5
IMP	63	28	9
PIT	63	35	2
GEN	58	42	0
TOB	56	40	4
CX	46	53	1
AT	38	53	9
COT	36	63	1
TE	32	67	1
CPM	22	72	6
NX	21	79	0
LE	20	76	4
CIP	19	77	4
CTR	17	83	0
CZ	15	85	0
AMP	10	90	0

Results

Antibiotic susceptibility response of *E. coli* isolates

Total 110 confirmed *E. coli* isolates, were obtained from urine samples of patients with UTI and included in this study. Antibiotic susceptibility pattern was recorded for all collected *E. coli* isolates using a panel of 21 antibiotics agents as shown in Table 2. Overall, AST result showed highest resistance for AMP (90%), Cefazolin (Cz; 85%) and ceftriaxone (Ctr; 83%). However, high resistance was also observed for norfloxacin (NX; 79%), ciprofloxacin (Cip; 77%), Levoflaxacin (LE; 76%) and cefepime (CPM; 72%). On other hand, FO (99%) and NIT (92%) have shown highest sensitivity. However, significant high sensitivity has also reported for amikacin (AK; 69%), AMC (64%), ertapenem (ETP; 65%), meropenem (MRP; 65%), imipenem (IMP; 63%) and Piperacillin-tazobactam (PIT; 63%).

Antibiotic susceptibility response of *E. coli* isolates for different categories of antibiotics

Antibiotic susceptibility response of *E. coli* isolates has been recorded for all 14 different categories of antibiotics, a-n (a=Aminoglycosides, b=Antipseudomonal penicillins + b-lactamase inhibitors, c=Carbapenems, d=Non-extended spectrum cephalosporins 1st and 2nd generation cephalosporins, e=Extended-spectrum cephalosporins 3rd and 4th

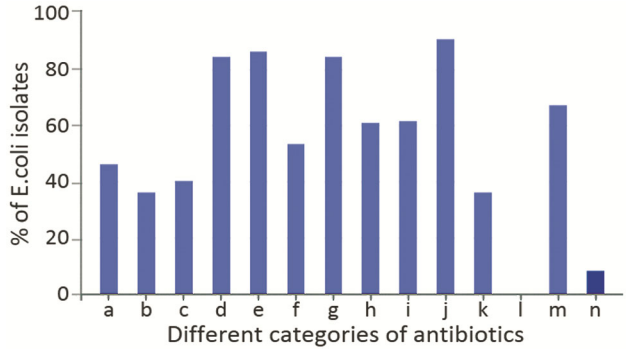

Fig. 1 — Antibiotic resistance response of *E. coli* isolates against different category of antibiotics: Antibiotic resistance response of *E. coli* isolates obtained from UTI patients, against 14 different categories of antibiotics. [a, Aminoglycosides; b, Antipseudomonal penicillins + b-lactamase inhibitors; c, Carbapenems; d, Non-extended spectrum cephalosporins 1st and 2nd generation cephalosporins; e, Extended-spectrum cephalosporins 3rd and 4th generation cephalosporins; f, Cephamycins; g, Fluoroquinolones; h, Folate pathway inhibitors; i, Monobactams; j, Penicillins; k, Penicillins + b-lactamase inhibitors; l, Phosphonic acids; m, Tetracyclines; and n, Synthetic derivative of imidazolidinedione]

generation cephalosporins, f=Cephamycins, g=Fluoroquinolones, h=Folate pathway inhibitors, i=Monobactams, j= Penicillins, k=Penicillins + b-lactamase inhibitors, l=Phosphonic acids, m=Tetracyclines and n=Synthetic derivative of imidazolidinedione). It revealed that isolates have shown maximum resistant to Penicillin (91%), cephalosporin (2nd generation, 85%; 3rd & 4th generation, 86%) and Fluoroquinolones (85%). However, significant resistance has also been found to other class of antibiotics such as tetracyclines (67%), monobactams (62%), and inhibitor of folate synthesis pathway (61%). Low resistance has been recorded for phosphonic acids (1%), antipseudomonal penicillins + b-lactamase inhibitors (36%) and penicillins + b-lactamase inhibitors (36%) (Fig. 1).

Characterization of *E. coli* isolates as MDR, XDR and PDR

The obtained AST result were further analyzed to numerate MDR, XDR, PDR (Fig. 2). Analyses revealed that 97% of isolates were non-susceptible to >=1 agent in >=3 antimicrobial categories, characterized as MDR isolates. The isolates (3%) have shown non-susceptible to >=1 agent in all but <=2 categories, named as XDR. None of the isolate has shown non-susceptible to all antimicrobial agents listed, thus 0% have been reported under PDR group.

Calculation of MARI of *E. coli* isolates

Multiple antibiotic resistance index (MARI) was calculated for each isolate and it revealed that 80% of isolates have shown MARI greater than 0.2. Precisely,

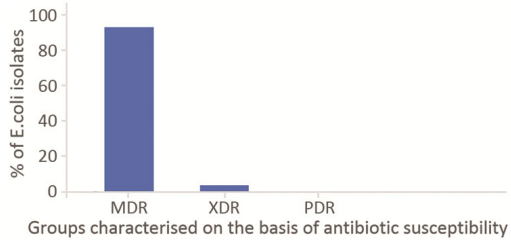

Fig. 2 — Characterization of *E. coli* isolates on the basis of their antibiotic susceptibility response to different antimicrobial agents of different categories. *E. coli* isolates obtained from UTI patients were characterized as MDR, XDR, PDR and overall sensitive.

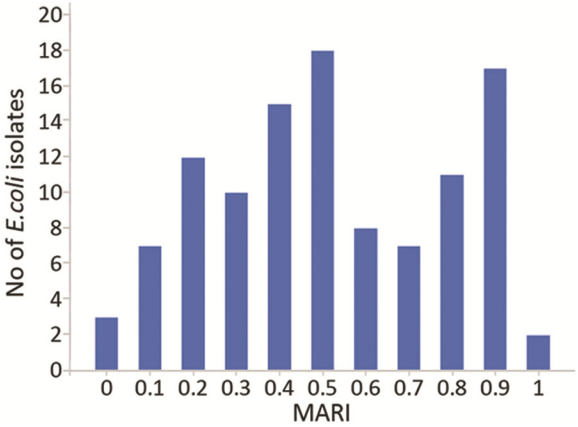

Fig. 3 — Multiple antibiotic resistance index (MARI) of *E. coli* isolates obtained from urine sample of UTI patients. *E. coli*

MARI was found 0 in 3 isolates, 0.1 in 7 isolates, 0.2 in 12 isolates, 0.3 in 10 isolates, 0.4 in 15 isolates, 0.5 in 18 isolates, 0.6 in 8 isolates, 0.7 isolates in 7 isolates, 0.8 in 11 isolates, 0.9 in 17 isolates and 1 in 2 isolates (Fig. 3).

Discussion

Worldwide research is being done quite consistently on AMR and antibiotic susceptibility trends[20-27]. The examined pattern of antibiotic susceptibility in this study is comparable to and reflects other recent studies that have been published in various Indian states. Our results show that for *E. coli* isolates that cause urinary tract infections, there is a high level of resistance to penicillin (AMP) and cephalosporin, followed by the second and third generations of flouroquinone. This is consistent with earlier research' examinations in the northern region of India[28-32]. There have also been reports of resistance to all cephalosporin generations, aminoglycosides (with the exception of GEN), and macrolides[32]. High levels of resistance to cephalosporin, fluoroquinolones, and AMP have also been documented in studies from the southern region of India in the past[33-35]. Similar findings, including

reduced susceptibility to cotrimoxazole, were identified in a cross-sectional study undertaken in western India in 2016[36]. However, a study done in the west Bengal region of India between 2008 and 2013 found that fourth generation cephalosporins were most susceptible[37]. Cephalosporin, however, was identified in our study to be among the resistant antibiotics for UTI caused by *E. coli*[28-30,32,34].

The highest level of resistance for AMP and strikingly high resistance for tested 2nd and 3rd generation fluoroquinolones coincide with the 12-year (2008-2012) history of resistance pattern in India, according to a team of researchers[32]. Centralized resistance to popular antibiotic classes including penicillin, cephalosporin, and fluoroquinolones may have developed as a result of inappropriate or improper usage of these drugs without knowledge of the underlying causes and the medicines they are susceptible to. The predominance of genes for antibiotic resistance, which increases resistance to beta-lactams and/or cephalosporins as a result of extended-spectrum beta-lactamase (ESBL), is another explanation that has been put out. However, this would necessitate cross-rectification via additional molecular research.

The most effective antibiotics reported in different state of India were NIT, aminoglycosides (AK and GEN) and carbapenems the time frame of 2013-2019 [33,30,34,36]. Our findings are also coinciding with the past recorded data. We also included FO in our antibiotic panel and found highest level of effectiveness for *E. coli* isolates as also reported by a research team[31]. The present study used MARI tool to assess antibiotic resistance among *E. coli* isolates causing UTI and found MARI greater than 0.2 for 80% isolates. This finding itself reflects the alarming condition of MAR, as higher MARI values indicate a greater level of resistance to multiple antibiotics. However, many studies conducted to state the emerging resistance among *E. coli* isolates in India but very less has implemented a significant measuring tool like MARI[18].

Similarly, emerging MDR are being much studied in India, as discussed above, but none of them characterized isolates on basis of their non-susceptibility against different categories of antibiotics, in recent past years. Also, in the present study, *E. coli* isolates were characterized and reported the occurrence of 97% MDR isolates, very less XRD (3%) and no PDR. Scarifying condition can be visualize as only 3% of the isolates were found to be sensitive for all antibiotic agents used in the study.

Conclusion

The results revealed reduced susceptibility of commonly prescribed antibiotics is alarming in case of urinary track infection (UTI) for area under the study. The effectiveness of fosfomycin (FO) and nitrofurantoin (NIT) will be considerable for the treatment of UTIs when other common antibiotics meet resistance barricades. Maximum number of *E. coli* isolates have shown high degree of resistance to different class of antibiotics which gives warning message in the context of empirical usage of antibiotics and emergence of MDR. We suggest that empirical use of antibiotics should be based on the knowledge of local prevalence of bacterial organisms and their antibiotic susceptibility rather than referring universal guidelines. Easy availability of antibiotics without prescription and recommendation of antibiotics without knowing the causative organism and their susceptibility pattern should be prohibited and compliance of monitoring and surveillance are much demanded to handle the present situation of continuously emerging antibiotic resistance in case of UTI as cautioned by researchers time to time.

Acknowledgement

Authors express their gratitude to the Ms. Priyam Srivastava, Lab technician, Microbiology Lab, King George's Medical University, for collection of samples.

Conflict of Interest

Authors declare no competing interests.

References

1 Zeng Z, Zhan J, Zhang K, Chen H & Cheng S, Global, regional, and national burden of urinary tract infections from 1990 to 2019: an analysis of the global burden of disease study 2019. *World J. Urol*, 40 (2022) 755.

2 Urology Care Foundation, Understanding UTIs Across the Lifespan. Available at <https://www.urologyhealth.org/healthy-living/urologyhealth-extra/magazine-archives/summer-2016/understanding-utis-across-the-lifespan> Accessed Jan 10, 2023.

3 Kot B, Antibiotic resistance among uropathogenic *Escherichia coli*. *Pol J Microbiol*, 68 (2019) 403.

4 Öztürk R & Murt A, Epidemiology of urological infections: a global burden. *World J Urol*, 38 (2020) 2669.

5 Urinary tract infection (catheter-associated urinary tract infection [CAUTI] and non-catheter-associated urinary tract infection [UTI]) and other urinary system infection [USI])

events. In: *National Healthcare Safety Network (NHSN), Patient Safety Component Manual. Device-associated Module CAUTI*. (Centers for Disease Control and Prevention (CDC), Atlanta, Georgia, USA), 2024, 107. Available at <http://www.cdc.gov/nhsn/PDFs/pscManual/7pscCAUTIcurrent.pdf.> Accessed 10 Feb 2015.

6 Czajkowski K, Broś-Konopielko M & Teliga-Czajkowska J, Urinary tract infection in women. *Menopause Rev*, 2021 (20) 40.

7 Bhonsle K, Vyas H, Hemwani K & Vyas A, Study of prevalence of urinary tract infections in patients of Ujjain, Madhya Pradesh (India). *Int J Sci Res*, 9 (2020) 69.

8 Nickel JC, Management of urinary tract infections: historical perspective and current strategies: part 1—before antibiotics. *J Urol*, 173 (2005) 21.

9 Zhou Y, Zhou Z, Zheng L, Gong Z, Li Y, Jin Y, Huang Y & Chi M, Urinary Tract Infections Caused by Uropathogenic Escherichia coli: Mechanisms of Infection and Treatment Options. *Int J Mol Sci*, 24 (2023) 10537.

10 Schaeffer AJ, The expanding role of fluoroquinolones. *Am J Med*, 113 (2002) 45.

11 Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, Harbarth S, Hindler JF, Kahlmeter G, Olsson-Liljequist B & Paterson DL, Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin Microbiol Infect*, 18 (2012) 268.

12 Woh PY, Yeung MP & Goggins III WB, Multiple antibiotic resistance index (MARI) of human-isolated Salmonella species: a practical bacterial antibiotic surveillance tool. *J Antimicrob Chemother*, 78 (2023) 1295.

13 Sandhu R, Dahiya S & Sayal P, Evaluation of multiple antibiotic resistance (MAR) index and Doxycycline susceptibility of Acinetobacter species among inpatients. *Indian J Microbiol Res*, 3 (2016) 299.

14 Sabih A & Leslie SW, Complicated urinary tract infections. *InStatPearls [internet]* (StatPearls Publishing, Treasure Island (FL)), 2022.

15 Gombash A & Pergola M, Guidelines for Acute Urinary Tract Infections. *Curr Emerg Hosp Med Rep*, 10 (2022).

16 Jesudason T, A new research agenda to combat antimicrobial resistance. *Lancet Infect Dis*, 23 (2023) 281.

17 Performance Standards for Antimicrobial Susceptibility Testing. 32nd edn. *CLSI supplement M100*. (Clinical and Laboratory Standards Institute, Malvern, PA, USA), 2022.

18 Devi AS & Rajkumar J, A study on antibiotic susceptibility and resistance profiles of bacterial strains isolated from patients with urinary tract infection (UTI) at Kanchipuram District, Tamilnadu, India. *Int J Pharm Pharm Sci*, 5 (2013) 817.

19 Halah MH, AL-Hasani Dalal S, AL-Rubaye Dalal S, AL-Rubaye & Alyaa Abdelhameed, The Emergence of Multidrug-Resistant (MDR), Extensively Drug-Resistant (XDR), and Pandrug-Resistant (PDR) In Iraqi Clinical Isolates of *Escherichia coli*. *J Popul Ther Clin Pharmacol*, 30 (2023) 469.

20 Klingeberg A, Noll I, Willrich N, Feig M, Emrich D, Zill E, Krenz-Weinreich A, Kalka-Moll W, Oberdorfer K, Schmiemann G & Eckmanns T, Antibiotic-Resistant *E. coli* in Uncomplicated Community-Acquired Urinary Tract Infection: A Prospective Cohort Study from 2015/16 (the SARHA Study) Compared with Data From the Antimicrobial Resistance Surveillance System (ARS). *Dtsch Arztebl Int*, 115 (2018) 494.

21 Sherchan JB, Dongol A, Humagain S, Joshi A, Magar SR & Bhandari S, Antibiotic Susceptibility Pattern of Bacteria Causing Urinary Tract Infection. *J Nepal Health Res Counc*, 20 (2022) 218.

22 Kim YJ, Lee JM, Cho J & Lee J, Change in the annual antibiotic susceptibility of Escherichia coli in community-onset urinary tract infection between 2008 and 2017 in a tertiary care hospital in Korea. *J Korean Med Sci*, 34 (2019) 34.

23 Tharwat N, El-Sherif R, Elnagdy S, Marzaban R & Amer S, Virulent Escherichia coli strains among Egyptian patients with acute diarrhoea versus urinary tract infection, and their antibiotic susceptibility. *Arab J Gastroenterol*, 20 (2019) 74.

24 Bao W, Koro M, Loh GW & Ortiz A, Urinary Tract Infections in Long-term Care: Evaluation of Uropathogens, Antibiotic Susceptibility, and Empiric Treatment. *Sr Care Pharm*, 37 (2022) 232.

25 Kettani Halabi M, Lahlou FA, Diawara I, El Adouzi Y, Marnaoui R, Benmessaoud R & Smyej I, Antibiotic resistance pattern of extended spectrum beta lactamase producing Escherichia coli isolated from patients with urinary tract infection in Morocco. *Front Cell Infect Microbiol*, 11 (2021) 720701.

26 Trevino M, Losada I, Fernandez-Perez B, Coira A, Peña-Rodríguez MF & Hervada X, Surveillance of antimicrobial susceptibility of Escherichia coli producing urinary tract infections in Galicia (Spain). *Rev Esp Quimioter*, 29 (2016) 86.

27 Mohamed MA, Abdifetah O & Hussein FA, Antibiotic resistance pattern of *Escherichia coli* isolates from outpatients with urinary tract infections in Somalia. *J Infect Dev Ctries*, 14 (2020) 284.

28 Bhargava K, Nath G, Bhargava A, Kumari R, Aseri GK & Jain N, Bacterial profile and antibiotic susceptibility pattern of uropathogens causing urinary tract infection in the eastern part of Northern India. *Front Microbiol*, 13 (2022) 965053.

29 Mehrishi P, Faujdar SS, Kumar S, Solanki S & Sharma A, Antibiotic susceptibility profile of uropathogens in rural population of Himachal Pradesh, India: Where We are heading?. *Biomed Biotechnol Res J*, 3 (2019) 171.

30 Chooramani G, Jain B & Chauhan PS, Prevalence and antimicrobial sensitivity pattern of bacteria causing urinary tract infection; study of a tertiary care hospital in North India. *CEGH*, 8 (2020) 890.

31 Batra P, Abrol AK, Gupta S, Pushpan P & Kumar R, Susceptibility pattern of oral antimicrobials in uncomplicated UTI: Does fosfomycin still stand effective? *J Family Med Prim Care*, 9 (2020) 850.

32 Shaifali I, Gupta U, Mahmood SE & Ahmed J, Antibiotic susceptibility patterns of urinary pathogens in female outpatients. *N Am J Med Sci*, 4 (2012) 163.

33 Eshwarappa M, Dosegowda R, Aprameya IV, Khan MW, Kumar PS & Kempegowda P, Clinico-microbiological profile of urinary tract infection in south India. *Indian J Nephrol*, 21 (2011) 30.

34 Madhu GN, Anjum Aara CA & Mahamud S, Prevalence and antibiotic susceptibility pattern of pathogens in children with

urinary tract infection in a tertiary care hospital. *Int J Contemp Pediatr*, 7 (2020) 1513.

35 Pardeshi P, Prevalence of urinary tract infections and current scenario of antibiotic susceptibility pattern of bacteria causing UTI. *Indian J Microbiol Res*, 5 (2018) 334.

36 Patel HB, Soni ST, Bhagyalaxmi A & Patel NM, Causative agents of urinary tract infections and their antimicrobial susceptibility patterns at a referral center in Western India: An audit to help clinicians prevent antibiotic misuse. *J Family Med Prim Care*, 8 (2019) 154.

37 Saha S, Nayak S, Bhattacharyya I, Saha S, Mandal AK, Chakraborty S, Bhattacharyya R, Chakraborty R, Franco OL, Mandal SM & Basak A, Understanding the patterns of antibiotic susceptibility of bacteria causing urinary tract infection in West Bengal, India. *Front Microbiol*, 5 (2014) 463.