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Antibiotic resistance spectrum of *E. coli* strains from different samples and age-grouped patients: a 10-year retrospective study

Sipei Wang [1], Sheng Zhao,[1] Yangxiao Zhou,[1] Shanshan Jin,[1] Tinghua Ye,[1] Xinling Pan [2]

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[1]Department of Clinical Laboratory, Wenzhou Medical University Affiliated Dongyang Hospital, Dongyang, Zhejiang, China
[2]Department of Biomedical Sciences Laboratory, Wenzhou Medical University Affiliated Dongyang Hospital, Dongyang, Zhejiang, China

Correspondence to
Dr Xinling Pan;
panfengyuwuzu@163.com

ABSTRACT

Objective *Escherichia coli* (*E. coli*) is the most common opportunistic clinical micro-organism with high drug resistance. This study aimed to analyse the resistance pattern of *E. coli* according to patient age and clinical sample type.

Design and setting This retrospective observational study was conducted in a tertiary hospital in southeastern China.

Participants *E. coli* strains were isolated from blood, urine and sputum of infected inpatients. The patients were divided into four age groups: children (0–14 years old, including neonatal and non-neonatal groups), youths (15–40 years old), middle-aged (41–60 years old) and old (>60 years old).

Results A total of 7165 *E. coli* strains were collected from all samples. Compared with urine and blood isolates, more sputum isolates were resistant against 12 tested antibiotics. Furthermore, urine isolates were more resistant to levofloxacin than sputum and blood isolates. Although the patients' age was not associated with resistance rates of *E. coli* strains isolated from blood, a larger proportion of urine-derived strains from youths were resistant to sulfamethoxazole-trimethoprim and piperacillin-tazobactam than those from old people. The sputum strains from the elderly were more resistant to most of the tested antibiotics compared with sputum strains isolated from children.

Conclusions The resistance profile of *E. coli* is different among age groups and specimen sources and should be considered during *E. coli* infection treatment.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study evaluates bacterial resistance patterns in a county from southeastern China.
⇒ This is an observational study with large sample size, different sample sources and patient groups involved.
⇒ This is a retrospective study from a single centre.
⇒ This study provides limited information on nosocomial or community-acquired infection.

INTRODUCTION

Escherichia coli (*E. coli*)is a normal intestinal flora and one of the most common clinical pathogens infecting the urinary tract, brain, lung, blood system, bone marrow and wound.[1] The overuse and misuse of antibiotics have caused the emergence of antibiotic resistance and life-threatening infections. WHO reported that antimicrobial resistance is one of the top 10 global public health threats facing humanity.[2] The emergence of carbapenem resistance and extended-spectrum beta-lactamase (ESBL) has significantly influenced antibiotic choices for controlling severe *E. coli* infections. Carbapenem-resistant and ESBL bacteria-related infections are mainly treated using tigecycline and polymyxins or combination with other antibiotics. Therefore, individualised therapy, which involves antibiotic susceptibility testing to determine the most effective antibiotics, is important in preventing acquired resistance.

Recent studies have shown that *E. coli* resistance rates vary among various regions. For example, a WHO report showed that the rate of ciprofloxacin-resistant *E. coli* ranges in over 30 countries and regions is about 8.4%–92.9%.[3] A multicentre study revealed that the prevalence of multiple drug-resistant *E. coli* in China varies among different hospitals.[4] Therefore, routine surveillance and retrospective analysis of the resistance spectrum of clinical isolates can improve the management of infections and antibiotic usage.

Induced microbial resistance is positively correlated with drug usage frequency.[5] The frequency of antibiotic usage increases with increasing infection events in the whole life cycle. Huang and colleagues reported that the microbial resistance spectrum significantly varies among patients of different ages.[6] Similarly, a related study revealed that most *E. coli* strains isolated from female patients older

than 65 years are resistant to two or more drugs.[7] However, whether the same trend occurs in bacteria isolated from other clinical centres is unknown.

E. coli can cause infection in several anatomical sites, indicating that isolation of the bacteria from the corresponding clinical specimens is important for diagnosis and treatment. The selection pressures at different anatomic sites are influenced by the difference in the pharmacogenetics of antibiotics.[8] For instance, *Klebsiella pneumoniae* strains in urine are more resistant to a broader spectrum of antibiotics than respiratory tract bacteria.[9] Also, lower respiratory tract-derived bacteria have a higher drug resistance rate than those isolated from urine.[10] Different guidelines among regions could cause this inconsistency. Furthermore, a study showed that *K. pneumoniae* strains in the urinary tract are more likely to develop resistance against carbapenems than bacteria from sputum or blood.[11] However, only a few studies have reported the antibiotic resistance profile of *E. coli* strains from multiple specimen sources.

In the present study, the resistance profile of *E. coli* strains isolated from different anatomic sites in a tertiary hospital in China was retrospectively analysed. The resistance rates and patterns were analysed based on the age of patients and the type of clinical sample. This study may guide the clinical management of *E. coli* infections, minimise treatment failure and the emergence of resistance caused by drug misuse.

MATERIALS AND METHODS

Specimen collection, bacterial culture and species identification

Urine, sputum and blood samples were collected from inpatients in a tertiary hospital in China between January 2012 and December 2021. These patients were suspected of infection based on clinical symptoms, radiological examinations or laboratory tests. Collection and transfer of specimens followed the health industry standard of the People's Republic of China (WS/T640-2018 specimen collection and transport in clinical microbiology). Briefly, urine and sputum samples were collected in sterile containers, while 5–10 mL of blood samples were collected in a blood culture bottle. The samples were stored at room temperature and transferred to the laboratory (bioM é rieux, France) within 2 hours. The samples were cultured on blood agar and Mackand agar plates, then incubated under 5% CO_2 at 35°C for 24–48 hours. A viteck2 compact system and matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry were used for species identification (visible colony).

Table 1 The antimicrobial drug resistance of *Escherichia coli* from different sample sources

Antimicrobial type	Antimicrobial drug	Blood (n=911)	Urine (n=5132)	Sputum (n=1122)	P value
	ESBL	387 (42.72)	2111 (41.25)	624 (56.17)	<0.001
Penicillins	AMP	509 (76.08)	3938 (77.92)	779 (86.36)	<0.001
Aztreonam	ATM	150 (22.46)	1234 (24.44)	304 (33.70)	<0.001
Cephems	CZO	308 (46.74)	1779 (46.06)	578 (64.01)	<0.001
	CAZ	119 (13.12)	817 (15.96)	251 (22.37)	<0.001
	CRO	403 (44.48)	2124 (41.53)	652 (58.37)	<0.001
	CTT	3 (0.45)	51 (1.01)	16 (1.77)	0.033
	FEP	108 (11.92)	553 (10.80)	221 (19.75)	<0.001
Carbapenems	ETP	4 (0.44)	18 (0.35)	5 (0.45)	0.708
	IPM	2 (0.22)	33 (0.64)	7 (0.63)	0.303
β-lactam/β-lactamase inhibitor combinations	TZP	14 (1.55)	48 (0.94)	30 (2.69)	<0.001
	SAM	294 (44.08)	2156 (42.79)	494 (54.65)	<0.001
Aminoglycosides	GEN	237 (35.43)	1691 (33.54)	355 (39.53)	0.002
	TOB	58 (8.71)	416 (8.24)	106 (11.74)	0.003
	AMK	14 (1.55)	85 (1.67)	23 (2.06)	0.603
Nitrofurantoin	NIT	28 (4.19)	167 (3.31)	33 (3.67)	0.461
Folate pathway inhibitors	SXT	450 (49.56)	2186 (42.65)	591 (52.91)	<0.001
Quinolones	LVX	331 (36.45)	2490 (48.63)	479 (43.00)	<0.001

χ^2 test was used to compare between groups.
AMK, amikacin; AMP, ampicillin; ATM, aztreonam; CAZ, ceftazidime; CRO, ceftriaxone; CTT, cefotetan; CZO, cefazolin; ESBL, Extended spectrum beta-lactamase; ETP, ertapenem; FEP, cefepime; GEN, gentamicin; IPM, imipenem; LVX, levofloxacin; NIT, nitrofurantoin; SAM, sulbactam/ampicillin; SXT, sulfamethoxazole-trimethoprim; TOB, tobramycin; TZP, piperacillin-tazobactam.

Drug sensitivity testing

Strain resistance against 17 antibiotics (ampicillin, aztreonam, cefazolin, ceftazidime, ceftriaxone, cefotetan, cefepime, ertapenem, imipenem, piperacillin-tazobactam (TZP), sulbactam/ampicillin, gentamicin, tobramycin, amikacin, nitrofurantoin, sulfamethoxazole-trimethoprim (SXT) and levofloxacin) was assessed using AST-GN13 and AST-GN334 cards in vitek2 compact systems. The minimum inhibitory concentration was automatically generated by the system, and the phenotypes were determined according to the Clinical and Laboratory Standards Institute guidelines (Performance Standards for Antimicrobial Susceptibility Testing, 31st edition). *E. coli* ATCC25922 was used as the reference strain. The resistance rates were displayed as resistant strains among the tested strains for antibiotic agents.

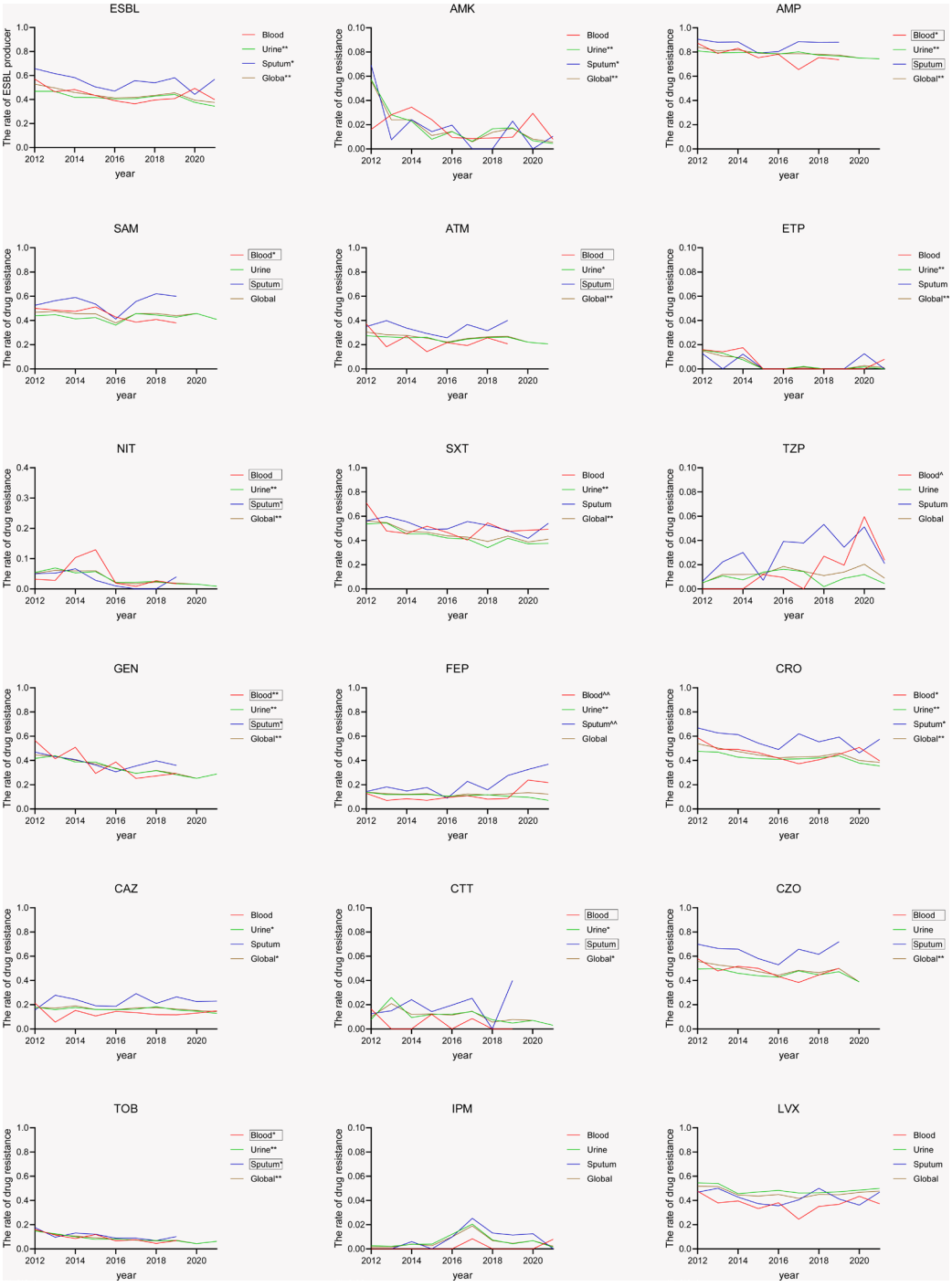

Figure 1 The trend of *E. coli* resistance to various antibiotics from 2012 to 2021. *Downward trend with statistical significance p<0.05; **p<0.001; ^Upward trend with statistical significance p<0.05; ^^p<0.001. □Missing data for 2020 and 2021. AMK, amikacin; AMP, ampicillin; ATM, aztreonam; CAZ, ceftazidime; CRO, ceftriaxone; CTT, cefotetan; CZO, cefazolin; ETP, ertapenem; FEP, cefepime; GEN, gentamicin; IPM, imipenem; LVX, levofloxacin; NIT, nitrofurantoin; SAM, sulbactam/ampicillin; SXT, sulfamethoxazole-trimethoprim; TOB, tobramycin; TZP, piperacillin-tazobactam.

Patient age and sample type subgroup analyses

Only the first strain isolated from hospitalised patients was included, and repeated isolation and patient records were excluded using WHONET V.5.6 software. *E. coli* resistance analyses were performed based on the patients' age and the sample type. The patients were divided into four groups based on their age: children (0–14 years old), youths (15–40 years old), middle-aged (41–60 years old) and old (>60 years old). In addition, the children group for sputum samples was divided into neonatal (≤28 days) and non-neonatal (29 days–14 years) groups.

Statistical analysis

Differences in the resistance rates between different age groups and sample types were analysed using the χ^2 or Fisher's exact tests. Data were analysed using the SPSS software (V.16.0, USA). The significance of tendency by years was tested by Cochran-Armitage function in the DescTools package in R software. P<0.05 was considered significant.

Patient and public involvement

Neither patients nor the public was involved in the study design, development of the research question or implementation of this study.

RESULTS

E. coli strains in different samples

A total of 7165 *E. coli* strains, including 5132 from urine (71.63%), 1122 from sputum (15.66%) and 911 from blood (12.71%), were isolated. The percentage of sputum isolates decreased from 26.3% in 2012 to 10.7% in 2021 (online supplemental figure 1). ESBL was detected in 56.17% of *E. coli* isolates from sputum samples, significantly higher than the percentage from blood and urine samples (table 1).

Sputum isolates had higher resistance rates against ampicillin, aztreonam, cefazolin, ceftazidime, ceftriaxone, cefotetan, cefepime, sulbactam/ampicillin, TZP, gentamicin, tobramycin, and SXT than blood and urine isolates. However, urine isolates had a higher resistance rate against levofloxacin than blood and sputum isolates.

E. coli antibiotic resistance over the years

The percentage of ESBL-positive *E. coli* strains from all samples significantly decreased from 52.81% in 2012 to 37.56% in 2021. A similar trend was observed for amikacin, ampicillin, aztreonam, ertapenem, nitrofurantoin, SXT, gentamicin, ceftriaxone, ceftazidime, cefotetan, cefazolin and tobramycin (figure 1). However, the proportion of ESBL-positive strains in the blood was not significantly different across the study period, while

Table 2 Antimicrobial drug resistance of *Escherichia coli* from blood in various age groups

Antimicrobial drug	0–14 (n=21)	15–40 (n=91)	41–60 (n=237)	>60 (n=562)	P value
ESBL	5 (25.00)	42 (46.15)	101 (42.80)	239 (42.75)	0.391
AMP	8 (53.33)	59 (79.73)	134 (72.43)	308 (77.97)	0.083*
ATM	2 (13.33)	19 (25.68)	44 (23.66)	85 (21.63)	0.719*
CZO	3 (21.43)	35 (48.61)	81 (44.26)	189 (48.46)	0.200
CAZ	2 (10.00)	15 (16.48)	27 (11.44)	75 (13.39)	0.643*
CRO	6 (28.57)	45 (50.00)	102 (43.40)	250 (44.64)	0.336
CTT	0 (0.00)	2 (2.74)	0 (0.00)	1 (0.26)	0.072
FEP	1 (4.76)	13 (14.29)	27 (11.39)	67 (12.03)	0.735
ETP	0 (0.00)	0 (0.00)	2 (0.84)	2 (0.36)	0.755*
IPM	0 (0.00)	0 (0.00)	1 (0.42)	1 (0.18)	0.620*
TZP	0 (0.00)	1 (1.10)	2 (0.84)	11 (1.97)	0.708*
SAM	2 (13.33)	36 (48.65)	77 (41.40)	179 (45.66)	0.061*
GEN	6 (40.00)	30 (40.54)	63 (33.87)	138 (35.03)	0.752
TOB	0 (0.00)	6 (8.22)	16 (8.60)	36 (9.16)	0.883*
AMK	0 (0.00)	0 (0.00)	4 (1.69)	10 (1.79)	0.745*
NIT	0 (0.00)	3 (4.11)	8 (4.30)	17 (4.31)	1.000*
SXT	11 (52.38)	49 (55.68)	119 (50.21)	271 (48.22)	0.607
LVX	4 (20.00)	30 (33.33)	84 (35.44)	213 (37.97)	0.335

χ^2 test was used for comparison between groups.
*Fisher's exact test.
AMK, amikacin; AMP, ampicillin; ATM, aztreonam; CAZ, ceftazidime; CRO, ceftriaxone; CTT, cefotetan; CZO, cefazolin; ESBL, Extended spectrum beta-lactamase; ETP, ertapenem; FEP, cefepime; GEN, gentamicin; IPM, imipenem; LVX, levofloxacin; NIT, nitrofurantoin; SAM, sulbactam/ampicillin; SXT, sulfamethoxazole-Trimethoprim; TOB, tobramycin; TZP, piperacillin-tazobactam.

the resistance rates against TZP and cefepime increased with time. In contrast, resistance rates against ampicillin, gentamicin, ceftriaxone and tobramycin decreased with time. The proportion of ESBL isolates in urine decreased for all antibiotics with time, especially for amikacin, ampicillin, aztreonam, ertapenem, nitrofurantoin, SXT, gentamicin, cefepime, ceftriaxone, ceftazidime, cefotetan, tobramycin. The resistance rates for the sputum isolates against amikacin, nitrofurantoin, gentamicin, ceftriaxone and tobramycin decreased with time, while resistance rates against cefepime increased ($p<0.05$).

E. coli resistance across age groups

The resistance rates for blood isolates were not significantly different among different age groups (table 2).

The urine-derived isolates had a higher resistance rate against SXT in children than in the elderly (table 3). Similarly, the percentage of TZP resistant strains was higher among the youth than among the elderly. Also, levofloxacin resistance rate was significantly higher in the middle-aged and the elderly than in the youth and children.

The resistance rates of sputum isolates against all the tested antibiotics were higher in the middle-aged and the elderly than in children (except against cefotetan, ertapenem, imipenem, amikacin and SXT). A similar trend was observed for ESBL strains (table 4).

Notably, aztreonam resistance was significantly higher among the elderly (42.66%) than in any other group. In addition, resistance rates of sputum strains against cefoperazone-sulbactam and nitrofurantoin were considerably lower in children than in other age groups. Moreover, the positive rate of ESBL was lower in the neonatal group than in the non-neonatal group (table 5). The drug resistance rates for ampicillin, ceftriaxone, cefperazone-sulbacta were also lower in neonatal group than in the non-neonatal group.

DISCUSSION

The Global Antimicrobial Resistance and Use Surveillance System report has indicated that *E. coli* is the most common clinical micro-organism globally.[3] In the present study, *E. coli* strains were isolated from the blood, urine and blood of patients admitted at a tertiary hospital in China. This study aimed to characterise the resistance profile of the bacteria based on the sample type and the patients' ages.

Table 3 Antimicrobial drug resistance of *Escherichia coli* from urine in various age groups

	Ages				
Antimicrobial drug	0–14 (n=60)	15–40 (n=247)	41–60 (n=1152)	>60 (n=3673)	P value
ESBL	32 (55.17)	108 (44.08)	491 (42.73)	1480 (40.38)	0.054
AMP	52 (88.14)	184 (76.67)	907 (79.70)	2795 (77.27)	0.079
ATM	14 (24.14)	60 (25.10)	274 (24.10)	886 (24.50)	0.988
CZO	25 (55.56)	101 (52.88)	399 (46.45)	1254 (45.32)	0.118
CRO	33 (55.00)	114 (46.72)	477 (41.62)	1500 (40.94)	0.052
CAZ	11 (18.33)	49 (19.92)	172 (14.98)	585 (15.96)	0.268
CTT	1 (1.75)	4 (1.67)	11 (0.97)	35 (0.97)	0.436*
FEP	8 (13.33)	33 (13.36)	115 (10.02)	397 (10.83)	0.419
ETP	0 (0.00)	0 (0.00)	2 (0.18)	16 (0.44)	0.532*
IPM	1 (1.67)	5 (2.02)	5 (0.43)	22 (0.60)	0.032*
SAM	29 (49.15)	103 (43.28)	492 (43.39)	1532 (42.46)	0.724
TZP	1 (1.69)$_{ab}$	7 (2.87)$_{b}$	7 (0.61)$_{a}$	33 (0.90)$_{a}$	0.017*
GEN	24 (40.68)	89 (37.08)	400 (35.27)	1178 (32.64)	0.136
TOB	4 (6.78)	24 (10.00)	96 (8.44)	292 (8.09)	0.722*
AMK	2 (3.33)	2 (0.81)	26 (2.27)	55 (1.51)	0.126*
NIT	2 (3.39)	9 (3.75)	29 (2.55)	127 (3.51)	0.390*
SXT	34 (56.67)$_{a}$	113 (45.93)$_{ab}$	506 (44.15)$_{ab}$	1533 (41.74)$_{b}$	0.041
LVX	20 (33.33)$_{a}$	102 (41.63)$_{a}$	562 (49.04)$_{b}$	1806 (49.22)$_{b}$	0.011

χ^2 test was used to compare groups.
The groups with the same subscript letter indicate no significant difference between the compared groups.
*Fisher's exact test.
AMK, amikacin; AMP, ampicillin; ATM, aztreonam; CAZ, ceftazidime; CRO, ceftriaxone; CTT, cefotetan; CZO, cefazolin; ESBL, extended spectrum beta-lactamase; ETP, ertapenem; FEP, cefepime; GEN, gentamicin; IPM, imipenem; LVX, levofloxacin; NIT, nitrofurantoin; SAM, sulbactam/ampicillin; SXT, sulfamethoxazole-trimethoprim; TOB, tobramycin; TZP, piperacillin-tazobactam.

Table 4 Antimicrobial drug resistance of *Escherichia coli* from sputum in various age groups

Antimicrobial drug	Ages				P value
	0–14 (n=336)	15–40 (n=43)	41–60 (n=99)	>60 (n=644)	
ESBL	153 (45.95)$_a$	22 (51.16)$_{ab}$	61 (62.24)$_b$	388 (60.91)$_b$	<0.001
AMP	211 (75.90)$_a$	28 (80.00)$_{ab}$	69 (92.00)$_b$c	471 (91.63)c	<0.001
ATM	60 (21.43)$_a$	6 (17.14)$_a$	20 (26.32)$_a$	218 (42.66)$_b$	<0.001
CZO	147 (52.69)$_a$	18 (51.43)$_{ab}$	51 (67.11)$_b$c	362 (70.57)c	<0.001
CRO	165 (49.25)$_a$	22 (51.16)$_{ab}$	60 (61.22)$_b$	405 (63.18)$_b$	<0.001
CAZ	53 (15.77)$_a$	6 (13.95)$_{ab}$	18 (18.18)$_{ab}$	174 (27.02)$_b$	<0.001
CTT	4 (1.43)	0 (0.00)	0 (0.00)	12 (2.33)	0.562
FEP	42 (12.50)$_a$	8 (18.60)$_{ab}$	23 (23.23)$_b$	148 (23.09)$_b$	0.001
ETP	1 (0.30)	0 (0.00)	0 (0.00)	4 (0.64)	0.831*
IPM	1 (0.30)	1 (2.33)	0 (0.00)	5 (0.78)	0.39
SAM	102 (36.43)$_a$	19 (54.29)$_b$	45 (59.21)$_b$	328 (63.94)$_b$	<0.001
TZP	2 (0.60)$_a$	1 (2.33)$_{ab}$	2 (2.02)$_{ab}$	25 (3.92)$_b$	0.011*
GEN	78 (28.36)$_a$	12 (34.29)$_{ab}$	39 (52.00)$_b$	226 (44.05)$_b$	<0.001
TOB	11 (3.96)$_a$	1 (2.86)$_a$	14 (18.92)$_b$	80 (15.50)$_b$	<0.001
AMK	2 (0.60)	0 (0.00)	3 (3.06)	18 (2.80)	0.064
NIT	3 (1.08)$_a$	2 (5.71)$_b$	5 (6.76)$_b$	23 (4.48)$_b$	0.011
SXT	158 (47.16)	22 (51.16)	56 (57.73)	355 (55.30)	0.076
LVX	76 (22.75)$_a$	12 (27.91)$_a$	48 (49.48)$_b$	343 (53.59)$_b$	<0.001

χ^2 test was used to compare groups.
The groups with the same subscript letter indicate no significant difference between compared groups.
*Fisher's exact test.
AMK, amikacin; AMP, ampicillin; ATM, aztreonam; CAZ, ceftazidime; CRO, ceftriaxone; CTT, cefotetan; CZO, cefazolin; ESBL, extended spectrum beta-lactamase; ETP, ertapenem; FEP, cefepime; GEN, gentamicin; IPM, imipenem; LVX, levofloxacin; NIT, nitrofurantoin; SAM, sulbactam/ampicillin; SXT, sulfamethoxazole-trimethoprim; TOB, tobramycin; TZP, piperacillin-tazobactam.

ESBLs can hydrolyze and inactivate most β-lactam antibiotics, including penicillin, broad-spectrum cephalosporins and monobactams.[12] In this study, 56.17% of the sputum isolates were ESBL-positive strains, considerably higher than the blood and urine isolates. The proportion of ESBL bacteria was higher than the previously reported proportion in South Asia (33.2%), Europe (3.3%–23.6%) and America (1.8%–8%)[13] but comparable to the proportion reported in a hospital in Henan, China.[14] A previous study revealed that the proportion of ESBL strains is higher in urine samples than in sputum and blood samples.[15] This inconsistency could be because the data simultaneously contained *K. pneumoniae* and *E. coli* since *K. pneumoniae* is a common strain in urine with a higher prevalence of ESBL.[9]

In this study, the isolates had different antibiotic resistance patterns. *E. coli* strains isolated from sputum were mostly resistant to 12 antibiotics, including sulfonamides, aminoglycosides, cephalosporins and β-lactamase inhibitors, partly because of the higher prevalence of ESBL strains, which carry many antibiotic resistance genes.[16] More urine isolates were resistant to levofloxacin than sputum and blood isolates, possibly due to the overuse of the drug for prophylaxis among patients with urinary tract diseases. Also, the resistance rate against carbapenems was very low (0.22%–0.64%) among different clinical samples, which was lower than the national resistance rate in 2021 (2.0%).[17] Although carbapenems are highly effective for treating *E. coli* infections, they should be cautiously used since they are associated with sporadic emergence of related resistance.[18 19]

In this study, the resistance rates against most antibiotics decreased with time, possibly due to the strict antibiotic use policies in hospitals in China. Also, the resistance rates were different among the samples. Notably, the decrease in antibiotic resistance was lower for sputum and blood isolates than for urine isolates, implying that the management of antibiotic usage in urine infections is very strict. Nonetheless, urinary tract infections are not fatal compared with blood and respiratory tract infections and thus do not require urgent treatment. Specifically, TZP can effectively treat severe infection caused by susceptible and ESBL-positive strains.[20] In this study, the resistance rate of blood strains against TZP increased compared with sputum and urine strains. However, a randomised clinical trial showed that TZP could not effectively treat blood infection caused by ESBL positive strain, and thus further research is needed.[21]

In the present study, the resistance rates varied among patients of different ages. Besides infection type and site,

Table 5 Antimicrobial drug resistance of *Escherichia coli* from sputum in neonatal (≤28 days) and non-neonatal groups (29 days–14 years)

Antimicrobial drug	Neonatal (n=88)	Non-neonatal (n=248)	P value
ESBL	30 (34.48)	123 (50.00)	0.017
AMP	32 (60.38)	179 (79.56)	0.003
ATM	9 (16.67)	51 (22.57)	0.343
CZO	23 (43.40)	124 (54.87)	0.132
CAZ	12 (13.64)	41 (16.53)	0.522
CRO	32 (36.36)	133 (53.85)	0.005
CTT	0 (0.00)	4 (1.77)	1.000*
FEP	12 (13.64)	30 (12.10)	0.708
ETP	1 (1.14)	0 (0.00)	0.263*
IPM	0 (0.00)	1 (0.40)	1.000*
TZP	0 (0.00)	2 (0.81)	1.000*
SAM	11 (20.37)	91 (40.27)	0.006
GEN	11 (20.37)	65 (29.68)	0.172
TOB	0 (0.00)	11 (4.91)	0.130*
AMK	1 (1.15)	1 (0.40)	0.454*
NIT	0 (0.00)	3 (1.34)	1.000
SXT	41 (46.59)	117 (47.37)	0.900
LVX	21 (23.86)	55 (22.36)	0.772

χ^2 test was used for comparison between groups.
*Fisher's exact test.
AMK, amikacin; AMP, ampicillin; ATM, aztreonam; CAZ, ceftazidime; CRO, ceftriaxone; CTT, cefotetan; CZO, cefazolin; ESBL, extended spectrum beta-lactamase; ETP, ertapenem; FEP, cefepime; GEN, gentamicin; IPM, imipenem; LVX, levofloxacin; NIT, nitrofurantoin; SAM, sulbactam/ampicillin; SXT, sulfamethoxazole-trimethoprim; TOB, tobramycin; TZP, piperacillin-tazobactam.

patient age should also be considered during antibiotic selection.[22] Herein, SXT resistance was higher in the urine isolates from children than in other age groups, indicating that SXT may not effectively treat such infections in children. Furthermore, more than half of urine isolates from children were resistant o SXT, consistent with a study conducted in another child hospital.[23] This alarming trend suggests that SXT should be cautiously used in children. Nonetheless, new agents for treating urinary tract infections in children are needed. Further results showed that levofloxacin resistance was higher in old patients than in children, possibly due to growth impairment induced by this drug in adolescents.[24] Antibiotic resistance rates of sputum isolates were higher in older patients than in younger patients, partly due to the higher prevalence of ESBL-positive strains in the older patients. Also, this might be caused by the lengthy usage of antibiotics in the elderly patients who are vulnerable to respiratory tract infections.[25] The drug resistance rates against ceftriaxone and sulbactam/ampicillin were lower in neonatal group than in non-neonatal group, compared with infants and children, possibly because of less chance of exposure to broad-spectrum antibiotics.[26] In contrast, a previous multicentre study revealed a higher ESBL-positive percentage in children than in the old patients.[4] This inconsistency may be due to regional populations. In addition, the antibiotics resistance patterns varied among sample types, and thus sample types should be considered in routine drug resistance surveillance.

However, this study has some limitations. Although several strains were reviewed, only a limited number of strains were included in the subgroup analysis (a small number of blood and urine samples from neonatal group). Information may be lost for certain aged patients when the resistance rates are analysed for different aged groups.

CONCLUSIONS

Although there has been a global decrease in the incidence of drug-resistant *E. coli* strains over the past 10 years, the trend is considerably different for patient age groups and specimen types. Furthermore, drug resistance rates of *E. coli* strains are higher in respiratory tract infections than in urinary tract and blood infections. Accordingly, age group and infection site should be strongly considered when selecting a treatment regimen for various infections.

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Ethics approval This study involves human participants and was approved by Dongyang People's Hospital Ethics Committee (No. 2022-YX-131). The analysis used routinely collected anonymised programmatic data. The research was operationally necessary with the aim of reviewing services and informing resource allocation. The need for informed consent was waived due to the retrospective nature of the study and all methods were carried out in accordance with relevant guidelines and regulations.

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ORCID iDs
Sipei Wang http://orcid.org/0000-0002-4904-3584
Xinling Pan http://orcid.org/0000-0003-0395-0426

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