Antimicrobial Susceptibilities of Aerobic and Facultative Gram-Negative Bacilli from Intra-abdominal Infections in Patients from Seven Regions in China in 2012 and 2013

Hui Zhang,^a Qiwen Yang,^a Kang Liao,^b Yuxing Ni,^c Yunsong Yu,^d Bijie Hu,^e Ziyong Sun,^f Wenxiang Huang,^g Yong Wang,^h Anhua Wu,ⁱ Xianju Feng,^j Yanping Luo,^k Zhidong Hu,^l Yunzhuo Chu,^m Shulan Chen,ⁿ Bin Cao,^o Jianrong Su,^p Bingdong Gui,^q Qiong Duan,^r Shufang Zhang,^s Haifeng Shao,^t Haishen Kong,^u Robert E. Badal,^v Yingchun Xu^a

Peking Union Medical College Hospital, Peking Union Medical College, Chinese Academy of Medical Science, Beijing, China^a; First Affiliated Hospital, Sun Yat-Sen University, Guangzhou, China^b; Ruijin Hospital, School of Medicine, Shanghai Jiaotong University, Shanghai, China^c; Sir RunRun Shaw Hospital, School of Medicine, Zhejiang University, Hangzhou, China^d; Zhong Shan Hospital of Fu Dan University, Shanghai, China^e; Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China^f; First Affiliated Hospital of Chongqing Medical University, Chongqing, China^g; Shandong Provincial Hospital Affiliated to Shandong University, Jinan, China^h; Xiangya Hospital, Central Southern University, Changsha, Chinaⁱ; First Affiliated Hospital of Zhengzhou University, Zhengzhou, China^j; The General Hospital of People's Liberation Army, Beijing, China^k; General Hospital of Tianjin Medical University, Tianjin, China^l; First Affiliated Hospital of Chinese Medical University, Shenyang, China^m; First Affiliated Hospital of Harbin Medical College, Harbin, Chinaⁿ; Chaoyang Hospital of Capital Medical College, Beijing, China^o; Friendship Hospital of Capital Medical College, Beijing, China^p; Second Affiliated Hospital of Nanchang University, Nanchang, China^q; People's Hospital of Jilin Province, Jilin, China^r; People's Hospital of Haikou City, Haikou, China^s; General Hospital of Nanjing Military Command, Nanjing, China^t; First Affiliated Hospital of Zhejiang University, Hangzhou, China^u; International Health Management Associates, Schaumburg, Illinois, USA^v

To evaluate the antimicrobial susceptibility of Gram-negative bacilli that caused hospital-acquired and community-acquired intra-abdominal infections (IAIs) in China between 2012 and 2013, we determined the susceptibilities to 12 antimicrobials and the extended-spectrum β -lactamase (ESBL) statuses of 3,540 IAI isolates from seven geographic areas in China in a central laboratory using CLSI broth microdilution and interpretive standards. Most infections were caused by *Escherichia coli* (46.3%) and *Klebsiella pneumoniae* (19.7%). Rates of ESBL-producing *E. coli* ($P = 0.031$), *K. pneumoniae* ($P = 0.017$), and *Proteus mirabilis* ($P = 0.004$) were higher in hospital-acquired IAIs than in community-acquired IAIs. Susceptibilities of enterobacteriaceae to ertapenem, amikacin, piperacillin-tazobactam, and imipenem were 71.3% to 100%, 81.3% to 100%, 64.7% to 100%, and 83.1% to 100%, respectively, but imipenem was ineffective against *P. mirabilis* (<20%). Although most ESBL-positive hospital-acquired isolates were resistant to third- and fourth-generation cephalosporins, the majority were susceptible to cefoxitin (47.9% to 83.9%). Susceptibilities of ESBL-positive isolates to ampicillin-sulbactam (<10%) were low, whereas susceptibilities to ciprofloxacin (0% to 54.6%) and levofloxacin (0% to 63.6%) varied substantially. The prevalences of cephalosporin-susceptible *E. coli* and *K. pneumoniae* were higher in the northeastern and southern regions than in the central and eastern regions, reflecting the ESBL-positive rates in these areas, and were lowest in the Jiangsu-Zhejiang (Jiang-Zhe) area where the rates of carbapenem resistance were also highest. Ertapenem, amikacin, piperacillin-tazobactam, and imipenem are the most efficacious antibiotics for treating IAIs in China, especially those caused by *E. coli* or *K. pneumoniae*. Resistance to cephalosporins and carbapenems is more common in the Jiang-Zhe area than in other regions in China.

Antimicrobial resistance is a global public health problem. Surgical patients have a particularly high risk of infection. Intra-abdominal infections (IAIs) are associated with high morbidity and mortality and are a major cause of severe sepsis in intensive care units (1). In a recent worldwide observational study of complicated IAIs, the overall mortality rate was 10.5%, and extended-spectrum β -lactamase (ESBL) producers were the most prevalent drug-resistant microorganisms involved (2).

For sepsis patients who require immediate empirical therapy, selecting the optimal antimicrobial medication based on the local antibiogram and current resistance patterns is critical to successful treatment outcomes (3–5). The molecular structures of carbapenems differ from those of other β -lactam antibiotics, such as penicillins and cephalosporins. Carbapenems are the only β -lactam antibiotics that are effective for treating severe infections caused by ESBL-producing bacteria (6). Thus, the development of carbapenem resistance, especially in ESBL-producing bacteria, is of particular clinical relevance (7, 8).

The Study for Monitoring Antimicrobial Resistance Trends (SMART) is a global surveillance program that monitors the *in*

vitro antimicrobial susceptibility of aerobic and facultative Gram-negative bacilli (GNB) isolated from patients with IAIs. The findings of SMART will provide clinicians with important insight into current trends in the emergence of antibiotic-resistant bacterial strains involved in IAIs.

In our present study, we analyzed IAI isolates collected from

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Address correspondence to Yingchun Xu, xycpumch@139.com.

H.Z. and Q.Y. contributed equally to this paper.

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FIG 1 Map of Chinese regions in which IAI strains were collected during 2012 and 2013.

patients in 21 hospitals in 16 cities in China during 2012 and 2013 and determined their susceptibilities to a wide range of antimicrobials to evaluate the trends in emerging antimicrobial resistance in different regions of China.

MATERIALS AND METHODS

Clinical isolates. As shown in Fig. 1, a total of 3,540 aerobic and facultative aerobic GNB isolates were collected from consecutive IAI cases during the 2-year study period (2012 and 2013) at 21 centers (17 university hospitals, 2 military hospitals, 1 provincial hospital, and 1 municipal hospital) located in 16 cities in the following regions of China: northeastern (496 isolates), northern (647 isolates), central (578 isolates), southern (403 isolates), southwestern (192 isolates), and eastern (655 isolates plus 540 isolates from Jiangsu-Zhejiang [Jiang-Zhe]) (the geographic origins of 29 isolates are unknown). The eastern region included the Jiang-Zhe area, which consisted of Zhejiang and Jiangsu Provinces. The isolates were obtained from the following sources: 1,192 from the gallbladder, 881 from peritoneal fluid, 668 from abscesses, 210 from the liver, 92 from the pancreas, 181 from the appendix, 4 from diverticula, 68 from the colon, 57 from the rectum, 44 from the small intestine, 32 from the stomach, and 111 from other types of tissues or fluids. Duplicate isolates (the same organism from the same patient) and isolates obtained from abdominal drains or drainage bottles, stools, superficial wounds, blood, urine, or perirectal abscesses were excluded. Isolates collected within 48 h of hos-

TABLE 1 Bacterial identification and epidemiological status of isolates from intra-abdominal infections in China during 2012 and 2013

Organism	No. of isolates ^a (% of indicated strains)				
	Total	%	HA	CA	NC
<i>Enterobacteriaceae</i>	2,893	81.7	2,165	720	8
<i>Escherichia coli</i>	1,638	46.3	1,207	426	5
ESBL-producing strains	1,063 (64.8)	30.0	824 (68.3)	237 (55.6)	2
Non-ESBL strains	549 (33.5)	15.5	363 (30.1)	183 (43.0)	3
Not identified	26 (1.9)	0.7	20 (1.7)	6 (1.4)	
<i>Klebsiella pneumoniae</i>	699	19.7	528	170	1
ESBL-producing strains	279 (39.9)	7.9	231 (43.8)	48 (28.2)	
Non-ESBL strains	406 (58.1)	11.5	287 (54.4)	118 (69.4)	1
Not identified	14 (2.0)	0.4	10 (1.9)	4 (2.3)	
<i>Proteus mirabilis</i>	80	2.3	59	21	
ESBL-producing strains	32 (40.0)	0.9	31 (52.5)	1 (4.8)	
Non-ESBL strains	48 (60.0)	1.4	28 (47.5)	20 (95.2)	
<i>Klebsiella oxytoca</i>	39	1.1	30	8	1
ESBL-producing strains	12 (30.8)	0.3	11 (36.7)	1 (12.5)	
Non-ESBL strains	27 (69.2)	0.8	19 (63.3)	7 (87.5)	1
<i>Enterobacter cloacae</i>	186	5.3	150	35	1
<i>Citrobacter freundii</i>	63	1.8	49	14	
<i>Enterobacter aerogenes</i>	60	1.7	45	15	
<i>Morganella morganii</i>	39	1.1	31	8	
<i>Serratia marcescens</i>	24	0.7	16	8	
<i>Proteus vulgaris</i>	11	0.3	11		
<i>Citrobacter koseri</i>	8	0.2	7	1	
<i>Citrobacter braakii</i>	6	0.2	3	3	
<i>Citrobacter diversus</i>	5	0.1	4	1	
Other	35	1.0	25	10	
<i>Non-Enterobacteriaceae</i>	647	18.3	525	117	5
<i>Pseudomonas aeruginosa</i>	347	9.8	284	60	3
<i>Acinetobacter baumannii</i>	233	6.6	193	38	2
<i>Stenotrophomonas maltophilia</i>	31	0.9	23	8	
<i>Aeromonas hydrophila</i>	19	0.5	12	7	
Other	17	0.5	13	4	
Total	3,540		2,690	837	13

^a HA, hospital-acquired isolates; CA, community-acquired isolates; NC, not classifiable.

TABLE 2 Sources of IAI isolates

Organism	No. (%) of ESBL-producing strains from ^a :											
	Gallbladder		Peritoneal fluid		Abscess		Liver and pancreas		Appendix and colon		Other	
	HA	CA	HA	CA	HA	CA	HA	CA	HA	CA	HA	CA
<i>E. coli</i>	407 (59.5)	110 (56.4)	280 (76.8)	109 (64.2)	231 (67.5)	37 (61.7)	101 (79.2)	15 (60.0)	81 (75.3)	100 (46.0)	107 (80.7)	55 (54.2)
<i>K. oxytoca</i>	20 (20.0)	6 (0)	5 (80.0)	2 (50.0)	1 (0)	0 (NA)	2 (50.0)	0 (NA)	0 (NA)	0 (NA)	2 (50.0)	0 (NA)
<i>K. pneumoniae</i>	177 (45.8)	50 (28.0)	102 (49.0)	44 (29.6)	131 (42.8)	20 (50.0)	82 (37.8)	31 (12.9)	8 (50.0)	8 (12.5)	28 (55.0)	17 (42.9)
<i>P. mirabilis</i>	18 (61.1)	11 (0)	21 (52.4)	4 (0)	10 (40.0)	2 (0)	1 (100.0)	1 (0)	3 (33.3)	1 (0)	6 (50.00)	2 (50.0)
Total	622	177	408	159	373	82	186	47	154	47	143	74

^a CA, community acquired; HA, hospital acquired; NA, not applicable.

pitalization were categorized as community-acquired IAIs, and those collected after 48 h were categorized as hospital-acquired IAIs.

Bacterial identification and antimicrobial susceptibility testing. All of the samples were analyzed in the clinical laboratory of Peking Union Medical College Hospital (Beijing, China). For bacterial identification, the isolates were analyzed for the presence of *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Klebsiella oxytoca*, *Enterobacter cloacae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii*. To assess antimicrobial susceptibility, the MICs of ceftriaxone (CRO), ceftazidime (CAZ), cefotaxime (CTX), cefepime (FEP), cefoxitin (FOX), ertapenem (ETP), imipenem (IPM), ampicillin-sulbactam (SAM), piperacillin-tazobactam (TZP), ciprofloxacin (CIP), levofloxacin (LVX), and amikacin (AMK) were determined using dehydrated MicroScan broth microdilution panels (Siemens Medical Solutions Diagnostics, West Sacramento, CA, USA) according to the 2012 guidelines of the Clinical and Laboratory Standards

Institute (CLSI) (9). Susceptibility interpretations were based on the CLSI M100-S23 clinical breakpoints (10). We used the ATCC 25922 strain of *E. coli*, the ATCC 27853 strain of *P. aeruginosa*, and the ATCC 700603 strain of *K. pneumoniae* as reference strains in each set of MIC tests for quality control.

Detection of extended-spectrum β -lactamase. Phenotypic identification of ESBL-producing strains of *E. coli*, *K. pneumoniae*, *P. mirabilis*, and *K. oxytoca* was performed according to the CLSI recommendations (9). We defined ESBL production as a decrease in the MICs for CTX and CAZ of >8-fold when tested in combination with clavulanic acid relative to the MICs for CTX and CAZ in the absence of clavulanic acid.

Statistical analysis. Data were included in the statistical analysis only when the results for the corresponding quality control isolates were within the accepted range in the CLSI guidelines (9). We used a chi-square analysis to compare the ESBL status of the community-acquired IAI isolates

TABLE 3 Antimicrobial susceptibilities of the indicated IAI isolates to 12 commonly prescribed antibiotics

		Susceptibility rate (%) ^b											
Organism	Source (HA/CA) ^a	CAZ	CRO	CTX	FEP	FOX	ETP	IPM	SAM	TZP	CIP	LVX	AMK
<i>Enterobacteriaceae</i>													
<i>E. coli</i>													
ESBL	HA (<i>n</i> = 824)	34.5	0.9	0.5	14.4	64.8	91.9	97.9	4.6	86.7	17.0	19.1	91.0
	CA (<i>n</i> = 237)	35.0	1.3	0.0	18.1	67.9	93.7	97.5	7.2	89.0	18.6	23.2	90.3
Non-ESBL	HA (<i>n</i> = 363)	95.6	91.7	94.5	98.9	84.9	98.6	98.6	43.8	96.1	55.9	60.3	98.1
	CA (<i>n</i> = 183)	93.4	90.7	92.4	98.4	85.3	97.8	97.8	41.5	98.4	57.4	58.5	98.4
<i>K. pneumoniae</i>													
ESBL	HA (<i>n</i> = 231)	36.8	1.7	0.9	21.7	58.9	77.9	83.1	2.6	68.4	35.9	50.2	84.4
	CA (<i>n</i> = 48)	25.0	0.0	2.1	25.0	47.9	77.1	87.5	2.1	66.7	33.3	54.2	81.3
Non-ESBL	HA (<i>n</i> = 287)	96.2	91.3	93.0	100.0	82.9	96.5	97.6	71.1	97.6	85.0	89.6	99.3
	CA (<i>n</i> = 118)	94.9	90.7	92.4	98.3	78.8	94.1	96.6	71.2	95.8	88.1	90.7	97.5
<i>P. mirabilis</i>													
ESBL	HA (<i>n</i> = 31)	100.0	3.2	3.2	25.8	83.9	96.8	12.9	6.5	87.1	12.9	16.1	87.1
	CA (<i>n</i> = 1)	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0
Non-ESBL	HA (<i>n</i> = 28)	100.0	96.4	100.0	100.0	92.9	100.0	10.7	60.7	100.0	53.6	85.7	100.0
	CA (<i>n</i> = 20)	100.0	100.0	100.0	100.0	95.0	100.0	15.0	95.0	100.0	70.0	80.0	100.0
<i>K. oxytoca</i>													
ESBL	HA (<i>n</i> = 11)	45.5	0.0	0.0	9.1	81.8	100.0	90.9	0.0	90.9	54.6	63.6	90.9
	CA (<i>n</i> = 1)	100.0	0.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0	0.0	0.0	100.0
Non-ESBL	HA (<i>n</i> = 19)	89.5	89.5	89.5	100.0	68.4	100.0	100.0	47.4	89.5	79.0	79.0	100.0
	CA (<i>n</i> = 7)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
<i>E. cloacae</i>													
	HA (<i>n</i> = 150)	42.7	28.7	27.3	64.7	4.7	71.3	85.3	8.0	64.7	68.0	73.3	91.3
	CA (<i>n</i> = 35)	54.3	40.0	48.6	77.1	5.7	82.9	85.7	17.1	77.1	74.3	85.7	97.1
<i>Non-Enterobacteriaceae</i>													
<i>P. aeruginosa</i>													
	HA (<i>n</i> = 284)	62.3	NA	NA	59.5	NA	NA	61.6	NA	61.6	72.9	70.4	87.7
	CA (<i>n</i> = 60)	75.0	NA	NA	65.0	NA	NA	68.3	NA	76.7	70.0	73.3	96.7
<i>A. baumannii</i>	HA (<i>n</i> = 193)	20.7	17.1	10.9	15.5	NA	NA	26.4	19.7	20.2	21.8	24.4	32.6
	CA (<i>n</i> = 38)	34.2	23.7	21.1	23.7	NA	NA	39.5	31.6	31.6	31.6	36.8	47.4

^a HA, hospital-acquired isolates; CA, community-acquired isolates.

^b Shading and boldface indicate susceptibilities of >90%. NA, not analyzed.

FIG 2 Comparison of the percentages of ESBL-producing *E. coli* and *K. pneumoniae* in hospital-acquired (HA) IAI isolates from the various regions of China with those in community-acquired (CA) isolates from the same regions. The numbers above the bars indicate the total numbers of isolates from the regions. No data were available for community-acquired isolates from the southwestern region.

with that of the hospital-acquired isolates. The level of statistical significance was set at a *P* value of <0.05.

RESULTS

The majority of the infections were caused by *E. coli* (46.3%), *K. pneumoniae* (19.7%), *P. aeruginosa* (9.8%), and *A. baumannii* (6.6%). The prevalences of hospital-acquired ESBL-producing strains were 68.3% for *E. coli*, 43.8% for *K. pneumoniae*, 52.5% for *Proteus mirabilis* (Table 1), and 36.7% for *K. oxytoca*, which were significantly higher than those for community-acquired *E. coli* (*P* = 0.031), *K. pneumoniae* (*P* = 0.017), and *P. mirabilis* (*P* = 0.004), with the exception of community-acquired *K. oxytoca* (*P* = 0.425).

The sources of the ESBL-producing bacterial strains that were analyzed are listed in Table 2. The majority of the IAI specimens were collected from gallbladders (33.7%). Most patients with IAIs caused by *K. oxytoca* had gallbladder infections. The percentage of IAIs caused by *P. mirabilis* was high compared with most of the other types of IAIs. The percentages of ESBL-producing *E. coli* and *K. oxytoca* strains isolated from the gallbladders of patients with hospital-acquired infections were the lowest (Table 2).

The antimicrobial susceptibilities of *E. coli*, *K. pneumoniae*, *P. mirabilis*, and *K. oxytoca* and those of *E. cloacae*, *P. aeruginosa*, and *A. baumannii* are shown in Table 3. The ESBL-producing *E. coli*, *K. pneumoniae*, *P. mirabilis*, and *K. oxytoca* strains were most susceptible to AMK, ETP, IPM, and TZP. For the ESBL-producing strains, susceptibilities to the third- and fourth-generation cephalosporins, FEP, CTX, CAZ, and CRO, were relatively low. Susceptibility rates ranged from 0% to 45.5%, with the exception of the FEP (100%) and CAX (100%) susceptibility rates for community-acquired *K. oxytoca* and the FEP, CTX, CAZ, and CRO susceptibility rates (100%) for the community-acquired and CAZ (100%) for the hospital-acquired *P. mirabilis* strains. The FOX susceptibility rates were higher than those for third- and fourth-generation cephalosporins but lower than those for AMK, ETP, IPM, and TZP. The CIP and LVX susceptibility rates for ESBL-producing *E. coli*, *K. pneumoniae*, *P. mirabilis*, and *K. oxytoca* ranged from 0% to 63.6%. The *E. cloacae* isolates were the most

susceptible to AMK, IMP, and ETP (71.3% to 97.1%). The *P. aeruginosa* isolates were highly susceptible to AMK (>85%) only, whereas the susceptibility rates for all 12 antimicrobials were generally low (<50%) for *A. baumannii* (Table 3). These data collectively indicate that antimicrobial susceptibilities were generally higher in the community-acquired IAIs than in the hospital-acquired IAIs.

To identify geographical differences in ESBL-positive rates and antimicrobial susceptibilities, we compared hospital-acquired and community-acquired isolates from various regions of China. As shown in Fig. 2, the ESBL-positive rates for hospital-acquired IAIs were generally higher than those for community-acquired IAIs in almost every region, with the exception of *K. pneumoniae* in the northeastern region. In addition, ESBL rates varied between the regions, especially those for *K. pneumoniae*. The highest ESBL-positive rate for *E. coli* occurred in the southwestern region, whereas the highest ESBL-positive rates for *K. pneumoniae* occurred in the Jiang-Zhe area and the central region.

As shown in Fig. 3, antimicrobial susceptibilities for *E. coli* and *K. pneumoniae* also varied between the geographic regions, with the greatest differences in the susceptibilities to CAZ, CRO, CTX, and FEP occurring between the northeastern region and the central and southwestern regions. This trend was also observed for the other antimicrobials tested. Our analysis of the interregional differences in antimicrobial susceptibility revealed that the prevalences of antimicrobial-resistant *E. coli* and *K. pneumoniae* were highest in the Jiang-Zhe area for all of the drugs tested. Furthermore, the ETP and IPM susceptibilities for *K. pneumoniae* were significantly lower in the Jiang-Zhe area than in the other regions, indicating that the emergence of carbapenem-resistant *K. pneumoniae* has occurred more rapidly in that area than in the other regions of China (Fig. 4).

DISCUSSION

Our analysis of IAI isolates collected in China during 2012 and 2013 revealed that more than half of the infections were caused by *E. coli* (46.3%) and *K. pneumoniae* (19.7%), which is consistent with the findings of a worldwide observational study of compli-

FIG 3 Susceptibilities of *E. coli* and *K. pneumoniae* IAI isolates from the northeastern, northern, central, eastern, southern, and southwestern regions of China to the indicated antimicrobials.

cated IAIs conducted in 2012, which reported that *E. coli* (42%) and *K. pneumoniae* (12%) were the major causes of IAIs (2). The prevalences of hospital-acquired ESBL-producing strains of *E. coli*, *K. pneumoniae*, and *P. mirabilis* were higher than those of the community-acquired isolates, which reflected the higher susceptibilities of community-acquired *E. coli*, *K. pneumoniae*, and *P. mirabilis* to CAZ, CRO, CTX, FEP, FOX, SAM, and TZP (Fig. 5).

The overall prevalence of ESBL-producing strains of *E. coli* IAI isolates in China was 64.8%, which is similar to previous reports of ESBL-producing *E. coli* in 2009 (64.9%) (11) but somewhat less than that reported for 2010 to 2011 and 2011 (68.1% and 68.8%,

respectively) (12, 13). The overall prevalence of ESBL-producing strains of *K. pneumoniae* IAI isolates in China was 39.9%, which is consistent with the ESBL-positive rates reported for *K. pneumoniae* in 2010 to 2011 and 2011 (39.3% and 38.1%, respectively) (12, 13).

Comparing gallbladder ESBL-producing IAI strains with those isolated from other organs, the percentage of gallbladder infections caused by *K. oxytoca* was notably higher (3.3% versus 0.7%).

With the exception of isolates from peritoneal fluid, the percentage of gallbladder infections caused by *P. mirabilis* was higher than that for the other sites (3.6% versus 2.4%). This trend in *P. mirabilis* infections might be attributed to the presence of bile acids, which have antimicrobial properties, leading to the selection of bacteria that are less common among infections at other sites. Of the 12 antimicrobials tested, susceptibilities of *Enterobacteriaceae* to ETP (71.3 to 100%), AMK (81.3 to 100%), TZP (64.7 to 100%), and IMP (83.1 to 100%) were highest, with the exception of the IMP susceptibility of *P. mirabilis* (<20%). The CAZ, CRO, CTX, FEP, CIP, LVX, and SAM susceptibilities were lowest for ESBL-producing IAI isolates, whereas susceptibilities to ETP, AMK, TZP, IMP, and FOX were higher, with the susceptibility rate for FOX being lowest among them. These results are in agreement with recommendations that TZP or IMP-cilastatin be used as an empirical monotherapy and that FEP, CAZ, CIP, and LVX be used for combination therapies, with metronidazole for high-risk IAIs. The use of ETP is recommended only for mild and moderate IAIs, due to the reduced susceptibility of *P. aeruginosa* strains (14–16), and FOX might serve as an alternative to ETP (14, 17). These findings are also consistent with recently published guidelines (18). For *P. aeruginosa*, AMK was most effective, whereas susceptibilities to the other antibiotics were <80%. *A. baumannii* demonstrated low susceptibilities to all tested antibiotics (10.9% to 47.4%), among which AMK was the most effective (32.6% to 47.4%), indicating that antimicrobial-resistant *A. baumannii* is a growing problem in China (19).

FIG 4 Comparison of antimicrobial susceptibilities of *E. coli* and *K. pneumoniae* IAI isolates from the Jiang-Zhe area with those of isolates from other regions of China.

FIG 5 Comparison of the overall antimicrobial susceptibilities of *E. coli*, *K. pneumoniae*, *P. mirabilis*, and *K. oxytoca* in hospital-acquired IAI isolates with those of the community-acquired isolates.

Our analysis of differences in susceptibilities among *E. coli* and *K. pneumoniae* IAI isolates revealed higher susceptibility rates in the northeastern and southern regions of China and showed that the lowest susceptibility rates occurred in central and southwestern China, with susceptibilities to the third- and fourth-generation cephalosporins, CAZ, CRO, CTX, and FEP, being particularly low in *E. coli* (Fig. 4). The ESBL-positive rates, especially those for *K. pneumoniae*, were higher in central and eastern China, particularly in the Jiang-Zhe area, than in the other regions. The susceptibilities of *K. pneumoniae* to all of the antibiotics tested, including carbapenems, were lower in the Jiang-Zhe area than in the other regions (Fig. 5). The Jiang-Zhe area is the most highly developed region in China. Therefore, it is possible that higher incomes and more widely available medical care may have contributed to the overuse of antimicrobials in the region (20, 21).

The emergence of localized carbapenem-resistant *Enterobacteriaceae* has been reported for Verona integron-encoded metallo- β -lactamase-producing bacterial strains in Greece (22) and for carbapenemase-producing *K. pneumoniae* in the United States (23). A recent study showed that carbapenem-resistant *K. pneumoniae* strains were more prevalent in the northeastern region of the United States than in the Midwest, suggesting that antimicrobial-resistant bacteria had spread west following initial outbreaks in New York City between 2000 and 2005 (24). Our findings suggest that an outbreak of carbapenem-resistant *K. pneumoniae* may have occurred at a single medical center in the Jiang-Zhe area, which subsequently spread into the surrounding regions.

In conclusion, our findings showed that both hospital-acquired and community-acquired *E. coli*, *K. pneumoniae*, *P. mirabilis*, and *K. oxytoca* IAI isolates in China were most susceptible to ETP, AMK, TZP, and IPM. We also found that the prevalence of hospital-acquired ESBL-positive IAI isolates was higher than that

of community-acquired IAI isolates, which reflected the low susceptibilities of hospital-acquired isolates to third- and fourth-generation cephalosporins. Antimicrobial susceptibilities of *Enterobacteriaceae* were higher in the northwestern and southern regions of China than in the central and eastern regions. The *K. pneumoniae* IAI isolates from the Jiang-Zhe area exhibited higher levels of resistance to all 12 of the antimicrobials tested than the bacterial isolates from other regions in China.

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