

Antimicrobial resistance of clinical isolates of bacteria in the first half of 2023

The antimicrobial susceptibility of major bacteria isolated from various clinical specimens sent to the Seoul Clinical Laboratories (SCL) in January-June 2023 were analyzed by hospital type. Bacteria cultures were requested from general hospitals (GH) with more than 100 beds, small and medium-sized hospitals (SMH) with fewer than 100 beds, and long-term care hospitals (LTCH). Bacterial identification was performed using MALDI TOF MS Biotyper (Bruker Daltonics GmbH, Bremen, Germany). Antimicrobial susceptibility was tested by a VITEK 2 (bioMerieux, Marcy-l'Etoile, France) instrument according to the criteria of the Clinical and Laboratory Standards Institute (CLSI). All susceptibility data for infection control and duplicated data from the same patient were excluded.

Table 1. Antimicrobial susceptibility (%) of frequently isolated Enterobacteriales at different types of hospitals in Korea in the first half of 2023

Antimicrobial agents	<i>Escherichia coli</i>			<i>Klebsiella pneumoniae</i>			<i>K. (Enterobacter) aerogenes</i>			<i>Klebsiella oxytoca</i>		
	SMH (12004)	GH (4181)	LTCH (1052)	SMH (1430)	GH (785)	LTCH (375)	SMH (394)	GH (94)	LTCH (13)	SMH (135)	GH (76)	LTCH (6)
	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R
Ampicillin	31 67	27 71	9 90	0 100	0 100	0 100	0 100	0 100	0 100	0 100	0 100	0 100
Piperacillin	33 64	30 68	11 87	42 52	43 52	10 86	85 12	71 20	50 50	73 17	79 9	40 40
Amox-clavulanate	76 11	72 12	48 16	58 23	61 22	24 43	<1 99	0 100	0 100	88 7	93 5	83 17
Cefazolin	65 34	57 42	23 76	50 50	53 47	17 83	1 99	0 100	0 100	68 24	67 21	17 83
Cefuroxime	65 30	58 37	21 76	50 48	51 47	17 81	<1 99	0 100	10 90	88 11	91 7	60 20
Cefotaxime	71 28	63 36	25 75	52 47	54 46	20 79	86 14	73 27	46 54	94 6	97 1	83 17
Ceftazidime	85 13	81 17	27 73	55 43	60 38	24 73	87 13	74 26	46 54	96 4	97 3	83 17
Cefepime	88 7	84 10	29 70	65 29	64 30	39 50	99 1	98 2	85 15	99 0	100 0	100 0
Cefoxitin	88 8	86 8	73 13	77 16	79 16	55 35	0 100	0 100	0 100	96 3	99 1	80 0
Imipenem	99 <1	99 1	97 2	89 10	88 10	77 20	90 0	83 1	77 15	99 1	100 0	100 0
Meropenem	100 <1	99 1	98 2	90 10	88 11	77 22	100 0	99 0	85 15	99 1	100 0	100 0
Ciprofloxacin	44 49	39 54	9 89	46 51	48 49	15 83	96 3	97 3	77 15	91 8	87 9	67 17
Levofloxacin	35 45	31 50	8 87	45 45	48 44	14 76	94 2	94 4	80 10	89 4	84 4	40 20
Doxycycline	65 23	66 21	53 32	61 35	63 33	41 52	94 6	93 6	70 20	89 6	85 13	80 20
Amikacin	99 0	99 1	96 2	97 3	96 3	95 4	100 0	100 0	92 8	100 0	100 0	100 0
Gentamicin	75 25	74 26	58 42	78 21	75 25	60 39	99 1	100 0	92 8	98 2	97 3	100 0
Tobramycin	73 10	70 13	43 39	62 24	65 25	32 47	99 1	97 3	77 15	98 2	96 1	100 0
Cotrimoxazole	65 35	64 36	53 47	68 32	67 33	40 60	99 1	97 3	77 23	93 7	96 4	83 17

Antimicrobial agents	<i>Enterobacter cloacae</i>			<i>Citrobacter freundii</i>			<i>Citrobacter koseri</i>			<i>Serratia marcescens</i>		
	SMH (259)	GH (120)	LTCH (36)	SMH (238)	GH (94)	LTCH (30)	SMH (176)	GH (39)	LTCH (52)	SMH (156)	GH (71)	LTCH (43)
	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R
Ampicillin	0 98	1 98	0 100	6 94	1 99	3 93	0 100	0 100	0 100	0 99	0 100	0 100
Piperacillin	64 29	63 32	25 72	70 26	75 21	63 29	0 97	3 94	0 100	89 6	87 6	54 31
Amox-clavulanate	0 100	2 98	0 100	7 93	1 99	7 93	83 10	90 10	15 60	1 99	0 100	0 100
Cefazolin	0 100	1 99	0 100	1 99	1 99	3 97	81 19	82 18	8 92	0 100	0 100	0 100
Cefuroxime	1 98	4 96	0 97	8 91	1 99	0 96	72 21	71 18	4 96	0 100	0 100	0 100
Cefotaxime	68 31	68 33	22 72	80 19	76 24	70 30	82 18	84 16	10 90	88 11	89 10	47 49
Ceftazidime	70 30	71 29	36 64	82 18	79 20	70 30	83 17	87 13	13 87	97 3	96 4	81 12
Cefepime	84 12	87 13	61 25	98 1	100 0	97 3	83 17	95 5	19 71	96 3	97 3	79 7
Cefoxitin	0 100	1 99	0 100	3 95	1 99	4 96	90 6	85 6	40 38	1 97	0 100	0 100
Imipenem	98 1	93 5	92 8	98 <1	98 0	93 3	95 4	100 0	69 21	93 4	96 0	81 12
Meropenem	99 1	96 4	92 8	99 <1	100 0	97 3	95 5	100 0	71 25	96 4	100 0	88 12
Ciprofloxacin	73 22	73 24	28 67	65 31	69 26	57 33	81 17	90 8	19 75	81 18	83 14	28 65
Levofloxacin	70 13	74 19	16 47	62 24	64 22	50 29	80 6	91 6	11 40	81 107	85 8	28 41
Doxycycline	82 13	76 16	56 34	74 22	79 16	75 25	93 5	97 3	81 11	93 3	90 3	95 3
Amikacin	100 0	98 3	97 3	98 2	99 1	97 3	96 2	95 5	81 19	98 2	100 0	95 5
Gentamicin	89 11	90 9	67 31	90 10	95 4	97 3	85 15	92 8	33 67	97 3	99 1	91 9
Tobramycin	88 10	88 6	47 42	89 5	91 3	87 10	85 10	92 8	29 31	87 4	93 1	79 12
Cotrimoxazole	87 13	89 11	56 44	85 15	88 12	90 10	97 3	97 3	77 23	99 1	100 0	98 2

Antimicrobial agents	<i>Morganella morganii</i>			<i>Proteus mirabilis</i>			<i>Providencia rettgeri</i>			<i>Providencia stuartii</i>		
	SMH (220)	GH (50)	LTCH (70)	SMH (800)	GH (273)	LTCH (469)	SMH (66)	GH (18)	LTCH (66)	SMH (67)	GH (13)	LTCH (61)
	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R
Ampicillin	<1 100	0 100	0 100	35 65	32 69	4 96	0 100	0 100	0 98	0 100	0 100	0 100
Piperacillin	70 18	60 29	18 69	45 52	44 52	8 89	45 54	43 50	25 62	37 60	33 67	25 66
Amox-clavulanate	1 99	0 100	3 97	62 10	60 14	46 19	0 100	0 100	0 98	0 100	0 100	0 100
Cefazolin	<1 100	0 100	1 97	49 48	45 52	9 90	0 100	0 100	2 97	0 100	0 100	0 100
Cefuroxime	1 99	0 100	3 95	54 46	55 44	16 81	46 54	43 50	28 66	34 61	33 67	27 61
Cefotaxime	71 22	70 22	23 64	54 46	49 51	11 88	45 55	44 56	19 73	40 55	46 54	34 57
Ceftazidime	85 13	80 16	47 48	85 14	85 13	58 40	55 45	50 50	34 63	94 4	100 0	89 11
Cefepime	93 2	98 0	80 12	69 13	67 16	49 20	56 24	72 6	55 27	84 3	77 15	70 13
Cefoxitin	50 10	48 4	31 35	88 3	84 5	74 11	65 31	93 7	70 28	98 2	83 17	93 7
Imipenem	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Meropenem	100 0	100 0	99 1	99 <1	100 0	100 0	86 14	100 0	98 0	100 0	100 0	98 2
Ciprofloxacin	63 35	62 38	24 75	40 59	33 67	3 96	44 56	39 56	26 66	13 87	15 77	2 98
Levofloxacin	61 27	60 18	23 66	41 55	32 60	4 94	29 55	29 57	9 68	6 89	8 75	2 96
Doxycycline	45 49	51 44	31 68	0 100	0 100	0 100	3 97	0 100	0 100	0 100	0 100	0 100
Amikacin	99 1	96 4	88 9	80 19	80 19	50 47	58 39	50 50	28 71	73 27	77 15	89 10
Gentamicin	82 15	84 16	46 49	50 47	46 49	15 79	52 36	89 11	25 72	0 100	0 100	0 100
Tobramycin	83 5	88 6	61 18	55 32	52 31	18 64	50 41	83 11	26 68	0 100	0 92	0 100
Cotrimoxazole	72 28	74 26	47 53	51 49	49 51	28 72	64 36	83 17	52 48	36 64	77 23	39 61

Abbreviation: SMH, small and medium-sized hospital; GH, general hospital; LTCH, long-term care hospital; (), No. tested; S, susceptible; R, resistant; Amox, amoxicillin; -, Not tested. Intrinsic resistances are blue shaded.

In the first half of 2023, *E. coli* was the most commonly isolated bacteria, followed by *P. aeruginosa*, coagulase-negative *Staphylococcus* and *S. aureus*. Among the Gram-negative rods, *K. pneumoniae* and *A. baumannii* were commonly isolated in addition to *E. coli*. The antimicrobial susceptibilities of *Enterobacterales* are shown in Table 1, glucose-nonfermented Gram-negative rods are shown in Table 2, and staphylococci and enterococci are shown in Table 3. The cefotaxime resistance rates of *E. coli* were 28%, 36%, and 75% in SMH, GH, and LTCH, respectively, similar to the first and second generation cephalosporin resistance rates, and the carbapenem resistance rate was less than 2% (Table 1). The fluoroquinolone resistance rate was about 50% in SMH and GH, but more than 80% in LTCH. The rate of cotrimoxazole resistance was 47% in LTCH, which was slightly higher than those of SMH and GH. The carbapenem resistance rates were high in *K. pneumoniae* and *Citrobacter koseri* isolated from LTCH, and were 20-22% and 21-25%, respectively. The cefotaxime resistance rates of *Enterobacter cloacae*, *C. koseri*, and *Morganella morganii* isolated from LTCH increased by 5-14% compared to 2022.

Table 2. Antimicrobial susceptibility (%) of frequently isolated glucose nonfermenting gram-negative bacilli at different types of hospitals in Korea in the first half of 2023

Antimicrobial agents	<i>Acinetobacter baumannii</i>			<i>Acinetobacter spp.</i>			<i>Pseudomonas aeruginosa</i>			<i>Stenotrophomonas maltophilia</i>		
	SMH (598)	GH (474)	LTCH (841)	SMH (418)	GH (232)	LTCH (267)	SMH (1883)	GH (1007)	LTCH (1661)	SMH (344)	GH (248)	LTCH (286)
	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R
Piperacillin	11 88	11 88	3 96	48 38	42 42	33 48	41 41	53 33	32 52	- -	- -	- -
Amp-sulbactam	20 53	16 61	11 57	75 14	75 12	57 28	- -	- -	- -	- -	- -	- -
Pip-Tazobactam	13 87	12 88	4 96	49 47	47 48	27 68	42 42	56 34	34 53	- -	- -	- -
Ceftazidime	14 85	12 87	5 95	52 32	51 22	42 42	35 35	60 32	49 38	- -	- -	- -
Cefepime	12 86	12 88	3 96	62 35	56 41	52 45	32 32	65 28	54 34	- -	- -	- -
Aztreonam	- -	- -	- -	- -	- -	- -	28 28	56 25	45 30	- -	- -	- -
Imipenem	14 86	12 88	5 95	63 34	61 37	51 45	45 45	61 39	43 56	- -	- -	- -
Meropenem	13 87	12 88	5 95	62 36	54 44	45 49	41 41	62 35	43 50	- -	- -	- -
Amikacin	75 21	74 22	70 25	85 13	94 6	78 17	29 29	74 25	65 33	- -	- -	- -
Gentamicin	25 71	25 71	16 76	64 30	61 33	53 35	34 34	67 28	49 45	- -	- -	- -
Ciprofloxacin	12 88	10 89	3 97	49 48	51 48	22 75	43 55	52 45	27 71	77 ^a 15	82 13	76 16
Cotrimoxazole	23 77	23 77	16 84	70 30	79 21	62 38	- -	- -	- -	89 11	89 11	87 13

Abbreviation: Amp, ampicillin; Pip, piperacillin. ^aLevofloxacin.

The resistance rates of *A. baumannii* were 53-61% for ampicillin-sulbactam, 86-95% for carbapenem, and 21-25% for amikacin. By contrast, the resistance rates of non-*baumannii* *Acinetobacter* isolates were 12-28% for ampicillin sulbactam, 34-49% for carbapenem, and 6-17% for amikacin, and the rates increased by 7-22%, 10-20%, and 2-4%, respectively, compared to 2022 (Table 2). The resistance rates of *P. aeruginosa* were 33-52% for piperacillin, 32-38% for ceftazidime, and 35-56% for carbapenem. *S. maltophilia* resistance rates were 13-16% for levofloxacin and 11-13% for cotrimoxazole. Glucose-nonfermented Gram-negative rods isolated from LTCH showed a high resistance rate.

Table 3. Antimicrobial susceptibility (%) of *Staphylococcus* and *Enterococcus* at different types of hospitals in Korea in the first half of 2023

Antimicrobial agents	<i>Staphylococcus aureus</i>			Coagulase-neg. <i>Staphylococcus</i>			<i>Enterococcus faecalis</i>			<i>Enterococcus faecium</i>		
	SMH	GH	LTCH	SMH	GH	LTCH	SMH	GH	LTCH	SMH	GH	LTCH
	(1616)	(690)	(255)	(1464)	(935)	(373)	(1682)	(581)	(163)	(489)	(418)	(239)
	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R	S R
Ampicillin	- -	- -	- -	- -	- -	- -	100 <1	99 1	100 0	9 91	6 94	5 95
Penicillin G	15 85	10 90	<1 100	12 88	9 91	3 97	93 7	86 14	82 18	8 92	5 95	4 96
Oxacillin	53 47	47 53	6 94	44 56	33 67	6 94	- -	- -	- -	- -	- -	- -
Clindamycin	71 29	64 36	48 52	74 25	69 31	54 46	- -	- -	- -	- -	- -	- -
Erythromycin	65 33	61 38	37 63	55 44	48 51	43 57	- -	- -	- -	- -	- -	- -
Telithromycin	89 10	83 13	81 19	87 10	87 10	68 31	- -	- -	- -	- -	- -	- -
Tetracycline	83 17	83 17	87 13	83 17	83 17	83 17	12 87	15 85	8 92	80 20	88 12	88 12
Tigecycline	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
Cotrimoxazole	97 3	96 4	94 6	89 11	84 16	78 22	- -	- -	- -	- -	- -	- -
Ciprofloxacin	66 33	65 35	12 88	68 28	58 37	16 80	79 20	60 39	19 81	3 96	1 98	1 99
Teicoplanin	100 <1	100 0	100 0	96 1	94 0	96 1	100 <1	100 <1	99 1	86 13	80 19	77 21
Vancomycin	100 0	100 0	100 0	100 0	100 0	100 0	100 <1	99 <1	99 1	63 37	61 39	53 47
Habekacin	100 <1	100 0	100 0	100 0	100 0	100 0	- -	- -	- -	- -	- -	- -
Gentamicin	71 23	75 20	45 44	68 15	64 19	38 36	- -	- -	- -	- -	- -	- -
Linezolid	100 <1	100 <1	100 0	99 1	99 1	99 1	100 <1	100 0	100 0	100 0	100 0	100 0
Qui-dalfopristin	100 0	100 0	100 0	100 0	100 0	100 0	- -	- -	- -	78 5	83 4	79 8
Fusidic acid	70 30	74 26	86 14	33 67	27 73	31 69	- -	- -	- -	- -	- -	- -
Rifampin	99 1	98 1	99 <1	95 4	93 6	86 13	- -	- -	- -	- -	- -	- -
Nitrofurantoin	- -	- -	- -	- -	- -	- -	99 1	100 0	98 0	8 69	5 77	5 78

Abbreviation: Qui, quinupristin

The oxacillin resistance rate of *S. aureus* (MRSA) was 47% and 53% in SMH and GH, respectively, and 94% in LTCH. The cotrimoxazole resistance rate was 3-6%, and the resistance rates to vancomycin, teicoplanin, habekacin, tigecycline, linezolid, and quinipristin-dalfopristin were less than 1% (Table 3). The antimicrobial resistance of coagulase-negative *Staphylococcus* was similar to those of *S. aureus*, but the resistance rate to cotrimoxazole and fusidic acid were 11-22% and 67-73%, respectively. The ampicillin resistance rate of *E. faecalis* was less than 1%, whereas that of *E. faecium* was 91-95%. Vancomycin and teicoplanin resistance rates were less than 1% for *E. faecalis*, but 13-47% for *E. faecium*. Nitrofurantoin resistance rate was less than 1% for *E. faecalis*, but was 69-78% for *E. faecium*.

Ten Threats to Global Health

- 1 Air pollution and climate change
- 2 Noncommunicable diseases
- 3 Global influenza pandemic
- 4 Fragile and vulnerable settings
- 5 Antimicrobial resistance
- 6 Ebola and other high-threat pathogens
- 7 Weak primary health care
- 8 Vaccine hesitancy
- 9 Dengue
- 10 HIV

Source: WHO 2019

Quality, Service, Research
SCL (재)서울의과학연구소
 Seoul Clinical Laboratories

Published August 2023
 Publisher Kyoung-Ryul Lee
 Editors Kyungwon Lee, Myungsook Kim,
 Changi-Ki Kim, Eun-Ah Chang
 Published by Seoul Clinical Laboratories,
 13Heungdeok 1-ro, Giheung-gu, Yongin-si,
 Gyeonggi-do, 16954, Korea