

Antimicrobial resistance of clinical isolates of bacteria in the first half of 2024

The antimicrobial susceptibility of major bacteria isolated from various clinical specimens sent to the Seoul Clinical Laboratories (SCL) in January-June 2024 were analyzed by hospital type. Request for bacteria cultures were received 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 using a VITEK 2 (bioMérieux, Marcy-l'Étoile, France) instrument according to the criteria of the Clinical and Laboratory Standards Institute (CLSI). From June 2023, some test agents have changed due to changes in the VITEK 2 susceptibility test card. Additional test agents are indicated in green, and data on deleted agents were excluded. 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 2024

Antimicrobial agents	<i>Escherichia coli</i>			<i>Klebsiella pneumoniae</i>			<i>K. (Enterobacter) aerogenes</i>			<i>Klebsiella oxytoca</i>		
	SMH (12812)	GH (5015)	LTCH (1007)	SMH (1566)	GH (1046)	LTCH (435)	SMH (423)	GH (112)	LTCH (13)	SMH (158)	GH (76)	LTCH (15)
	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	30 69	27 72	8 91	0 100	0 100	0 100	0 100	0 100	0 100	0 100	0 100	0 100
Amox-clavulanate	74 13	71 13	45 24	59 25	62 24	27 48	0 100	0 100	0 100	92 7	96 4	93 7
Pip-tazobactam	92 7	90 8	72 24	59 34	61 34	24 68	84 11	84 14	69 23	95 4	96 4	80 13
Cefazolin	64 36	56 44	21 79	53 47	57 43	19 81	0 100	0 100	0 100	52 48	42 58	40 60
Cefotaxime	70 30	62 38	23 77	52 47	57 43	19 81	86 13	83 15	69 31	95 4	92 8	87 13
Ceftazidime	76 13	70 17	31 51	56 40	59 38	23 73	87 12	85 14	77 15	96 2	97 1	93 7
Cefepime	78 16	71 22	30 57	59 38	61 38	26 72	99 1	97 2	100 0	100 0	99 0	93 7
Ertapenem	99 1	99 0	95 4	85 12	85 14	68 29	99 1	98 1	100 0	99 0	100 0	100 0
Imipenem	99 0	100 0	96 3	86 11	86 12	69 25	99 0	98 1	100 0	99 0	100 0	100 0
Meropenem	99 0	100 0	96 3	88 11	87 13	71 26	100 0	99 1	100 0	100 0	100 0	100 0
Ciprofloxacin	31 50	27 55	6 87	46 48	51 44	14 83	94 3	93 4	92 8	85 11	87 8	73 27
Amikacin	97 2	96 3	84 13	93 6	94 5	88 11	100 0	100 0	100 0	100 0	100 0	93 7
Gentamicin	76 24	74 26	61 39	76 23	81 19	58 40	99 1	98 2	92 8	96 4	97 0	100 0
Tobramycin	74 20	70 23	46 48	64 33	68 30	33 61	99 1	98 1	100 0	95 3	97 1	100 0
Cotrimoxazole	65 35	65 35	52 48	66 34	70 30	40 60	98 2	98 2	100 0	92 8	96 4	87 13
Nitrofurantoin	96 1	95 2	91 4	19 42	20 44	13 59	16 17	19 12	20 40	83 0	89 0	100 0

Antimicrobial agents	<i>Enterobacter cloacae</i>			<i>Citrobacter freundii</i>			<i>Citrobacter koseri</i>			<i>Serratia marcescens</i>		
	SMH (305)	GH (136)	LTCH (34)	SMH (238)	GH (91)	LTCH (29)	SMH (160)	GH (54)	LTCH (61)	SMH (194)	GH (65)	LTCH (42)
	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	2 98	2 98	0 100	4 96	3 96	3 97	0 100	0 100	0 100	1 99	2 98	0 98
Amox-clavulanate	3 97	2 98	0 100	5 94	4 96	3 97	78 20	94 4	23 59	2 98	2 98	0 100
Pip-tazobactam	73 22	69 30	62 29	79 17	73 22	52 41	78 18	94 6	16 64	89 8	97 2	79 17
Cefazolin	2 98	2 98	0 100	3 97	1 99	0 100	74 26	92 8	23 77	0 100	0 100	0 100
Cefotaxime	67 33	62 38	47 53	76 24	69 31	48 52	74 25	83 17	25 74	82 15	94 6	60 36
Ceftazidime	65 33	64 36	56 38	77 21	70 29	48 45	78 21	91 9	26 72	94 5	100 0	79 21
Cefepime	82 12	85 11	82 15	96 2	97 2	86 10	79 18	94 4	33 66	95 3	100 0	86 10
Ertapenem	93 2	89 2	91 0	97 3	97 2	90 10	91 7	100 0	62 33	97 2	100 0	93 7
Imipenem	98 1	98 2	100 0	97 3	98 2	90 10	94 6	100 0	64 31	98 2	100 0	93 7
Meropenem	99 1	98 2	100 0	97 3	98 2	90 10	94 6	100 0	66 26	98 2	100 0	93 7
Ciprofloxacin	70 25	65 22	44 41	65 26	62 27	62 31	73 21	94 4	15 80	81 15	89 6	24 64
Amikacin	96 3	98 2	94 3	98 1	99 1	97 3	98 2	98 2	74 25	98 2	100 0	88 10
Gentamicin	89 11	86 13	82 15	94 6	93 7	90 10	83 17	96 4	34 62	98 2	100 0	95 5
Tobramycin	86 13	85 14	71 24	91 7	90 6	86 7	79 20	96 4	31 66	80 3	85 2	76 19
Cotrimoxazole	87 13	86 14	71 29	86 14	86 14	86 14	96 4	100 0	84 16	99 1	100 0	95 5
Nitrofurantoin	34 16	26 22	48 10	93 1	86 4	96 0	76 4	79 0	25 33	0 100	0 100	0 100

Antimicrobial agents	<i>Morganella morganii</i>						<i>Proteus mirabilis</i>						<i>Providencia rettgeri</i>						<i>Providencia stuartii</i>					
	SMH (211)		GH (61)		LTCH (87)		SMH (919)		GH (357)		LTCH (430)		SMH (52)		GH (26)		LTCH (51)		SMH (55)		GH (16)		LTCH (52)	
	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	100	0	98	0	100	36	64	36	64	3	97	2	94	0	100	0	100	0	100	0	100	0	100
Amox-clavulanate	0	100	0	100	0	100	58	16	63	14	33	31	0	100	0	100	0	100	0	100	0	100	0	98
Pip-tazobactam	94	6	97	3	65	32	96	4	97	2	87	11	40	60	92	4	66	34	98	2	94	6	90	10
Cefazolin	0	100	0	100	0	100	52	48	48	52	9	91	2	98	0	100	2	98	0	100	0	100	0	100
Cefotaxime	59	31	58	35	19	76	54	46	52	48	12	87	27	73	32	60	4	92	28	70	56	44	22	78
Ceftazidime	80	11	83	12	39	51	85	14	83	15	59	39	39	59	48	48	20	78	96	2	94	0	88	10
Cefepime	93	3	98	0	62	27	65	10	64	10	33	20	39	37	72	16	31	51	87	8	81	0	65	24
Ertapenem	99	1	100	0	82	16	99	0	100	0	99	1	88	12	100	0	65	8	98	0	100	0	80	10
Imipenem	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meropenem	100	0	98	0	81	19	99	0	100	0	98	1	86	12	100	0	96	2	100	0	100	0	90	2
Ciprofloxacin	71	26	63	33	11	85	41	58	38	62	3	97	24	73	28	68	20	80	6	94	19	81	14	86
Amikacin	97	3	95	5	52	45	74	26	79	21	39	60	45	53	44	56	17	83	48	52	75	25	76	24
Gentamicin	90	10	83	17	34	66	48	51	50	48	9	90	37	59	88	12	14	86	0	100	0	100	2	98
Tobramycin	94	5	87	12	39	55	51	45	58	38	16	79	37	57	44	8	14	76	0	100	0	100	0	98
Cotrimoxazole	84	17	83	17	45	55	53	47	51	49	28	72	65	35	80	20	39	61	42	58	88	13	45	55
Nitrofurantoin	1	99	0	100	0	100	0	100	0	100	0	100	2	98	0	100	0	100	0	100	0	100	0	100

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

In the first half of 2024, *Escherichia coli* was the most commonly isolated bacteria, followed by *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Enterococcus faecium*, and coagulase-negative *Staphylococcus*. 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 30%, 38%, and 77% in SMH, GH, and LTCH, respectively, similar to the first generation cephalosporin resistance rates, and the carbapenem resistance rate was less than 4% (Table 1). The cefepime resistance rate was 57% in LTCH, which was higher than in SMH and GH. The fluoroquinolone resistance rate was about 50% in SMH and GH, but more than 80% in LTCH. The rate of cotrimoxazole resistance was 48% in LTCH, which was 13% higher than in SMH and GH. The carbapenem resistance rates were high at 25-29% for *K. pneumoniae* and 26-33% for *Citrobacter koseri* isolated from LTCH. Carbapenem-resistant *K. pneumoniae* was also high in SMH and GH, 11-12% and 12-14%, respectively. Cefotaxime resistance rates of *Citrobacter freundii*, *Morganella morganii*, *Providencia rettgeri*, and *Providencia stuartii* isolated from LTCH increased by 13-16% compared to 2023.

Table 2. Antimicrobial susceptibility (%) of frequently isolated glucose nonfermenting gram-negative bacilli at different types of hospitals in Korea in the first half of 2024

Antimicrobial agents	<i>Acinetobacter baumannii</i>						<i>Acinetobacter spp.</i>						<i>Pseudomonas aeruginosa</i>						<i>Stenotrophomonas maltophilia</i>					
	SMH (598)		GH (496)		LTCH (721)		SMH (568)		GH (250)		LTCH (308)		SMH (2033)		GH (1096)		LTCH (1920)		SMH (391)		GH (260)		LTCH (320)	
	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R
Amp-sulbactam	23	60	15	68	10	69	80	14	83	10	74	17	-	-	-	-	-	-	-	-	-	-	-	-
Pip-tazobactam	18	82	9	91	4	96	57	38	55	42	37	61	47	47	53	38	35	57	-	-	-	-	-	-
Ceftazidime	19	81	12	88	8	92	70	19	71	12	65	25	63	32	67	30	57	36	-	-	-	-	-	-
Cefepime	-	-	-	-	-	-	-	-	-	-	-	-	58	26	64	25	51	30	-	-	-	-	-	-
Imipenem	18	82	9	91	5	95	71	27	68	31	60	37	49	50	58	40	37	60	-	-	-	-	-	-
Meropenem	18	81	9	91	5	95	70	28	67	32	61	35	50	44	59	35	38	53	-	-	-	-	-	-
Amikacin	36	64	23	77	23	73	84	13	88	7	71	18	-	-	-	-	-	-	-	-	-	-	-	-
Gentamicin	24	72	16	82	13	80	73	22	77	17	63	25	-	-	-	-	-	-	-	-	-	-	-	-
Tobramycin	27	73	18	82	22	78	72	27	79	19	69	31	68	31	71	29	54	46	-	-	-	-	-	-
Ciprofloxacin	13	86	8	92	3	97	54	43	52	46	32	66	41	55	50	47	26	72	-	-	-	-	-	-
Levofloxacin	14	83	9	89	3	92	57	27	65	24	37	32	-	-	-	-	-	-	78	16	79	13	74	18
Cotrimoxazole	28	72	18	82	15	85	75	25	84	16	70	30	-	-	-	-	-	-	85	15	89	11	84	16
Tetracycline	18	35	22	22	9	37	56	35	82	18	63	38	-	-	-	-	-	-	-	-	-	-	-	-
Minocycline	86	5	96	2	87	5	94	4	99	1	92	3	-	-	-	-	-	-	94	3	95	3	96	2

Abbreviation: Amp, ampicillin; Pip, piperacillin.

The resistance rates of *Acinetobacter baumannii* were 60-69% for ampicillin-sulbactam, 81-95% for carbapenem, 83-97% for fluoroquinolone and 64-77% for amikacin, and the rates increased by 4-7%, 0-6%, 0-9%, and 22-32%, respectively, compared to 2023. By contrast, the resistance rates of non-*baumannii* *Acinetobacter* isolates were 10-17% for ampicillin-sulbactam and 7-18% for amikacin. The carbapenem resistance rates were 27-37%, decreased by 13-16% compared to 2023 (Table 2). The resistance rates of *P. aeruginosa* were 30-36% for ceftazidime, 38-57% for piperacillin-tazobactam, 35-60% for carbapenem, and 47-72% for ciprofloxacin, which were similar to the resistance rates of isolates in 2023. Both *Acinetobacter* and *P. aeruginosa* had high resistance rates among isolates from LTCH. *Stenotrophomonas maltophilia* resistance rates were 13-18% for levofloxacin, 11-16% for cotrimoxazole, and 2-3% for minocycline.

Table 3. Antimicrobial susceptibility (%) of *Staphylococcus* and *Enterococcus* at different types of hospitals in Korea in the first half of 2024

Antimicrobial agents	<i>Acinetobacter baumannii</i>						<i>Acinetobacter</i> spp.						<i>Pseudomonas aeruginosa</i>						<i>Stenotrophomonas maltophilia</i>					
	SMH		GH		LTCH		SMH		GH		LTCH		SMH		GH		LTCH		SMH		GH		LTCH	
	(598)		(496)		(721)		(568)		(250)		(308)		(2033)		(1096)		(1920)		(391)		(260)		(320)	
	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R
Amp-sulbactam	23	60	15	68	10	69	80	14	83	10	74	17	-	-	-	-	-	-	-	-	-	-	-	-
Pip-tazobactam	18	82	9	91	4	96	57	38	55	42	37	61	47	47	53	38	35	57	-	-	-	-	-	-
Ceftazidime	19	81	12	88	8	92	70	19	71	12	65	25	63	32	67	30	57	36	-	-	-	-	-	-
Cefepime	-	-	-	-	-	-	-	-	-	-	-	-	58	26	64	25	51	30	-	-	-	-	-	-
Imipenem	18	82	9	91	5	95	71	27	68	31	60	37	49	50	58	40	37	60	-	-	-	-	-	-
Meropenem	18	81	9	91	5	95	70	28	67	32	61	35	50	44	59	35	38	53	-	-	-	-	-	-
Amikacin	36	64	23	77	23	73	84	13	88	7	71	18	-	-	-	-	-	-	-	-	-	-	-	-
Gentamicin	24	72	16	82	13	80	73	22	77	17	63	25	-	-	-	-	-	-	-	-	-	-	-	-
Tobramycin	27	73	18	82	22	78	72	27	79	19	69	31	68	31	71	29	54	46	-	-	-	-	-	-
Ciprofloxacin	13	86	8	92	3	97	54	43	52	46	32	66	41	55	50	47	26	72	-	-	-	-	-	-
Levofloxacin	14	83	9	89	3	92	57	27	65	24	37	32	-	-	-	-	-	-	78	16	79	13	74	18
Cotrimoxazole	28	72	18	82	15	85	75	25	84	16	70	30	-	-	-	-	-	-	85	15	89	11	84	16
Tetracycline	18	35	22	22	9	37	56	35	82	18	63	38	-	-	-	-	-	-	-	-	-	-	-	-
Minocycline	86	5	96	2	87	5	94	4	99	1	92	3	-	-	-	-	-	-	94	3	95	3	96	2

The oxacillin resistance rate of *Staphylococcus aureus* (MRSA) was 48% and 54% in SMH and GH, respectively, and 90% in LTCH. The resistance rates were 30-54% for clindamycin, 2-3% for cotrimoxazole, and 0% for vancomycin, teicoplanin, tigecycline, and linezolid (Table 3). The antimicrobial resistance of coagulase-negative *Staphylococcus* was similar to those of *S. aureus*, but the resistance rates to cotrimoxazole were high, ranging from 8% to 16%. The ampicillin resistance rate of *Enterococcus faecalis* was less than 2%, whereas that of *E. faecium* was 92-97%. Vancomycin and teicoplanin resistance rates were less than 2% for *E. faecalis*, but 34-48% for *E. faecium*. Nitrofurantoin resistance rate was less than 1% for *E. faecalis*, but was 77-88% for *E. faecium*. The resistance rates of Gram-positive cocci were similar to 2023, but teicoplanin resistance rates of *E. faecium* isolated in SMH and LTCH increased by 15% and 11%, respectively.

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