

Antimicrobial resistance of clinical isolates of bacteria in 2022

The antimicrobial susceptibility of major bacteria isolated from various clinical specimens sent to the Seoul Clinical Laboratories (SCL) in January-December 2022 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 (bioMérieux, 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 2022

Antimicrobial agents	Escherichia coli						Klebsiella pneumoniae						K. (Enterobacter) aerogenes						Klebsiella oxytoca					
	SMH		GH		LTCH		SMH		GH		LTCH		SMH		GH		LTCH		SMH		GH		LTCH	
	(21933)		(7414)		(1854)		(2878)		(1611)		(760)		(746)		(218)		(35)		(270)		(117)		(10)	
	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	35	63	29	70	9	90	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100
Piperacillin	37	59	31	65	10	88	46	49	45	50	14	83	88	9	84	11	54	37	74	10	72	14	80	20
Amox-clavulanate	78	9	72	10	46	21	60	22	59	25	25	48	0	100	0	100	0	100	94	2	92	4	100	0
Cefazolin	68	30	59	40	22	77	55	45	53	46	19	80	0	100	0	100	0	100	70	20	65	21	70	30
Cefuroxime	68	28	58	37	22	75	53	45	52	47	18	79	0	100	0	100	0	100	93	5	90	9	80	20
Cefotaxime	72	27	63	36	25	74	56	44	53	46	21	78	89	10	85	15	54	46	96	4	93	7	80	20
Ceftazidime	81	19	74	25	39	61	59	40	58	40	24	74	90	9	85	14	54	43	97	3	97	3	80	20
Cefepime	84	15	78	21	50	48	70	28	66	31	42	54	99	1	97	3	94	6	98	2	97	3	90	10
Cefoxitin	89	6	87	7	72	13	79	15	76	19	57	32	0	100	0	100	0	100	99	1	97	2	100	0
Imipenem	100	<1	99	<1	97	2	90	9	87	11	82	17	85	<1	77	<1	80	3	100	0	100	0	100	0
Meropenem	100	<1	100	<1	97	2	90	9	87	12	82	17	100	<1	99	<1	97	3	100	0	100	0	100	0
Ciprofloxacin	44	48	37	55	10	87	49	48	47	51	15	83	97	3	94	5	83	17	91	9	85	12	50	30
Levofloxacin	37	43	30	50	8	84	48	41	46	45	14	75	95	2	92	4	83	17	90	5	85	9	50	30
Doxycycline	65	23	66	22	52	33	59	37	61	35	39	56	96	3	95	5	80	20	87	10	90	9	100	0
Amikacin	99	<1	99	<1	96	3	97	2	98	1	93	5	100	<1	100	0	100	0	99	1	100	0	100	0
Gentamicin	76	24	72	27	58	42	78	21	77	23	63	37	99	1	100	<1	97	3	97	3	96	4	100	0
Tobramycin	74	8	69	11	43	39	66	22	62	26	32	47	99	<1	100	<1	94	6	96	3	96	<1	100	0
Cotrimoxazole	66	34	65	35	54	46	67	33	67	33	44	56	99	1	98	2	94	6	93	7	94	6	100	0

Antimicrobial agents	Enterobacter cloacae			Citrobacter freundii			Citrobacter koseri			Serratia marcescens				
	SMH	GH	LTCH	SMH	GH	LTCH	SMH	GH	LTCH	SMH	GH	LTCH		
	(488)	(320)	(42)	(486)	(150)	(46)	(317)	(78)	(81)	(319)	(147)	(51)		
	S	R	S	R	S	R	S	R	S	R	S	R	S	R
Ampicillin	0	95	0	96	0	93	<1	100	1	97	0	100	0	100
Piperacillin	66	24	62	26	45	45	71	26	69	25	61	35	<1	97
Amox-clavulanate	0	95	0	96	0	93	<1	100	1	97	0	100	83	9
	0	95	0	96	0	93	0	100	0	99	0	100	81	19
Cefazolin	0	95	0	96	0	93	0	100	0	99	0	100	85	15
Cefuroxime	2	93	2	94	0	93	<1	100	1	97	0	100	20	70
Cefotaxime	70	25	66	28	31	60	69	22	69	22	11	81	0	100
Ceftazidime	74	21	71	24	50	40	0	100	0	99	0	100	0	100
Cefepime	87	7	88	8	76	14	0	100	1	97	0	100	88	10
Cefoxitin	0	95	0	96	0	93	69	22	69	22	11	81	97	3
Imipenem	94	<1	91	3	83	10	99	1	99	<1	96	2	98	1
Meropenem	95	<1	93	3	83	10	88	10	94	5	51	40	98	2
Ciprofloxacin	73	20	68	24	50	40	0	100	1	97	0	100	0	100
Levofloxacin	70	14	66	15	48	24	86	5	83	10	37	46	93	1
Doxycycline	81	9	78	10	60	19	99	1	100	0	68	32	94	0
Amikacin	94	<1	95	<1	93	0	99	1	100	0	68	32	99	1
Gentamicin	89	6	90	5	79	14	99	1	100	0	68	32	100	0
Tobramycin	87	7	86	7	71	17	99	1	100	0	68	32	99	1
Cotrimoxazole	83	13	83	13	62	31	99	1	100	0	68	32	99	1

Antimicrobial agents	<i>Morganella morganii</i>			<i>Proteus mirabilis</i>			<i>Providencia rettgeri</i>			<i>Providencia stuartii</i>		
	SMH (370)	GH (139)	LTCH (132)	SMH (1578)	GH (488)	LTCH (693)	SMH (133)	GH (50)	LTCH (126)	SMH (160)	GH (36)	LTCH (132)
	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	37 63	29 71	4 96	0 100	0 100	0 100	0 100	0 100	0 100
Piperacillin	65 22	72 22	30 58	47 50	40 56	7 90	37 61	60 35	26 61	26 71	39 56	28 66
Amox-clavulanate	<1 100	0 100	0 100	60 12	57 15	41 22	0 100	0 100	0 99	0 100	0 100	0 100
Cefazolin	<1 100	0 100	0 100	51 46	42 55	7 90	0 100	0 100	0 99	0 100	0 100	0 100
Cefuroxime	<1 100	0 100	0 100	56 44	49 50	15 83	41 57	63 33	27 67	23 73	39 56	20 61
Cefotaxime	71 24	75 18	37 52	55 45	46 53	11 88	37 59	56 33	26 71	31 68	44 53	33 60
Ceftazidime	80 16	84 12	60 30	72 27	66 33	37 62	45 53	65 33	33 64	94 4	94 6	89 10
Cefepime	96 4	98 1	88 8	71 26	64 33	45 49	66 28	83 17	77 17	96 3	92 3	92 2
Cefoxitin	31 18	36 15	32 29	89 4	81 9	71 14	70 25	77 13	75 22	96 2	92 8	87 10
Imipenem	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Meropenem	100 0	100 0	98 2	99 <1	99 0	100 0	94 5	98 2	99 0	100 0	97 0	99 0
Ciprofloxacin	66 33	70 30	30 69	39 61	31 67	4 96	33 62	48 46	17 77	4 93	0 94	0 99
Levofloxacin	66 23	70 19	31 57	38 56	32 64	4 94	29 63	25 52	14 79	3 93	0 97	0 97
Doxycycline	46 50	47 49	39 59	<1 100	0 100	0 100	<1 99	0 100	<1 98	0 100	0 100	0 100
Amikacin	98 1	99 0	88 10	80 19	80 18	52 45	48 51	75 25	41 56	65 35	86 14	85 14
Gentamicin	85 14	90 8	55 41	50 45	44 50	13 82	56 38	79 17	35 56	0 100	0 100	0 100
Tobramycin	86 6	88 7	61 25	55 31	51 30	21 62	53 39	79 17	31 63	0 100	0 100	0 100
Cotrimoxazole	76 24	84 16	50 50	53 47	48 52	29 71	74 26	81 19	45 55	41 59	58 42	35 65

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 2022, *Escherichia coli* was the most commonly isolated bacteria, followed by *Klebsiella pneumoniae*, *Enterococcus faecium* and *Pseudomonas aeruginosa*. Among the Gram-negative rods, in addition to *E. coli* and *K. pneumoniae*, *P. aeruginosa*, *Acinetobacter baumannii*, and *Proteus mirabilis* were also commonly isolated. The antimicrobial susceptibilities of Enterobacteriales 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 27%, 36%, and 74% 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 46% in LTCH, which was slightly higher than those of SMH and GH. The carbapenem resistance rate was high in *K. pneumoniae* among Enterobacteriales, and the rates were 9-12% in SMH and GH, and 17% in LTCH. Among *Citrobacter koseri* isolated from LTCH, the carbapenem resistance rate was as high as 32%, but the resistance mechanism could not be identified because the isolate was not stored.

Table 2. Antimicrobial susceptibility (%) of frequently isolated glucose nonfermenting gram-negative bacilli at different types of hospitals in Korea in 2022

Antimicrobial agents	<i>Acinetobacter baumannii</i>			<i>Acinetobacter spp.</i>			<i>Pseudomonas aeruginosa</i>			<i>Stenotrophomonas maltophilia</i>		
	SMH (1145)	GH (1124)	LTCH (1484)	SMH (775)	GH (455)	LTCH (357)	SMH (3577)	GH (2068)	LTCH (3141)	SMH (562)	GH (456)	LTCH (386)
	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	17 82	9 91	3 96	58 18	55 25	46 41	46 39	51 35	33 51	- -	- -	- -
Amp-sulbactam	24 51	11 68	10 62	79 8	79 6	71 19	- -	- -	- -	- -	- -	- -
Pip-Tazobactam	18 82	9 91	4 96	42 27	41 32	22 54	47 41	53 35	34 53	- -	- -	- -
Ceftazidime	19 80	10 89	6 93	54 15	53 13	51 28	56 36	60 31	49 37	- -	- -	- -
Cefepime	18 81	9 90	3 95	74 18	62 29	62 31	59 33	64 27	54 36	- -	- -	- -
Aztreonam	- -	- -	- -	- -	- -	- -	50 27	53 28	47 28	- -	- -	- -
Imipenem	20 80	9 91	5 95	72 14	67 26	62 34	54 46	61 39	45 55	- -	- -	- -
Meropenem	19 80	9 91	5 95	74 16	65 28	57 37	54 43	61 34	44 50	- -	- -	- -
Amikacin	76 22	70 26	70 25	84 7	91 3	80 15	71 27	76 23	67 31	- -	- -	- -
Gentamicin	31 66	21 77	16 79	67 15	70 21	60 30	60 33	68 27	51 41	- -	- -	- -
Ciprofloxacin	16 84	9 91	3 97	53 38	53 39	28 68	43 55	51 46	26 71	75 ^a 19	83 11	72 23
Cotrimoxazole	33 67	26 74	19 81	77 18	83 11	63 36	- -	- -	- -	85 15	91 9	85 15

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

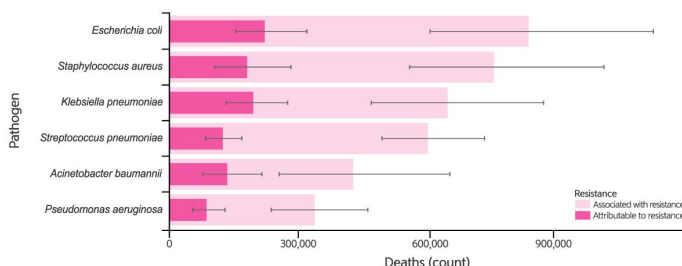
The resistance rates of *A. baumannii* were 51-68% for ampicillin-sulbactam, 80-95% for carbapenem, and 22-26% for amikacin. By contrast, the resistance rates of non-*baumannii* *Acinetobacter* isolates were 6-19% for ampicillin-sulbactam, 14-37% for carbapenem, and 3-15% for amikacin (Table 2). The resistance rates of *P. aeruginosa* were 35-51% for piperacillin, 31-37% for ceftazidime, and 34-55% for carbapenem. *Stenotrophomonas maltophilia* resistance rates were 11-23% for levofloxacin and 9-15% 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 2022

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	
	(2940)		(1497)		(405)		(3450)		(2264)		(734)		(3070)		(983)		(288)		(847)		(765)		(351)	
	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	100	<1	100	0	8	92	7	94	4	96
Penicillin G	14	86	10	90	3	97	12	87	8	91	1	97	94	6	82	18	74	26	7	93	6	94	3	97
Oxacillin	57	43	47	53	10	90	44	55	33	67	8	91	-	-	-	-	-	-	-	-	-	-	-	-
Clindamycin	73	27	67	32	44	55	67	24	68	29	47	50	-	-	-	-	-	-	-	-	-	-	-	-
Erythromycin	68	30	62	37	35	65	51	42	48	49	36	63	-	-	-	-	-	-	-	-	-	-	-	-
Telithromycin	89	9	86	11	74	25	87	10	86	11	63	33	-	-	-	-	-	-	-	-	-	-	-	-
Tetracycline	83	17	83	17	86	14	82	17	80	19	83	16	15	85	16	84	10	90	81	19	88	12	89	11
Tigecycline	100	0	100	0	100	0	98	0	99	0	98	0	100	0	100	0	100	0	100	0	100	0	100	0
Cotrimoxazole	97	3	96	4	92	8	85	14	83	17	67	32	-	-	-	-	-	-	-	-	-	-	-	-
Ciprofloxacin	72	27	64	35	14	85	68	28	57	39	14	80	79	21	60	40	20	80	4	95	1	98	1	99
Teicoplanin	100	0	100	0	100	0	93	<1	92	<1	90	<1	100	<1	100	<1	98	2	81	17	81	17	76	20
Vancomycin	100	0	100	0	100	0	99	0	99	0	99	0	100	<1	99	<1	97	3	60	40	66	34	58	42
Habekacin	100	0	100	0	100	0	99	<1	99	0	99	0	-	-	-	-	-	-	-	-	-	-	-	-
Gentamicin	76	20	73	23	52	40	66	16	60	21	39	39	-	-	-	-	-	-	-	-	-	-	-	-
Linezolid	100	<1	100	0	100	<1	99	<1	99	<1	99	<1	100	0	100	0	100	0	100	0	100	0	99	<1
Qui-dalfopristin	100	0	100	0	100	0	99	<1	99	0	99	<1	-	-	-	-	-	-	80	5	77	8	71	12
Fusidic acid	71	29	73	27	82	18	28	71	24	76	29	70	-	-	-	-	-	-	-	-	-	-	-	-
Rifampin	99	<1	99	<1	96	3	94	4	92	6	81	17	-	-	-	-	-	-	-	-	-	-	-	-
Nitrofurantoin	-	-	-	-	-	-	-	-	-	-	-	-	98	1	98	1	96	1	6	79	4	86	3	86

Abbreviation: Qui, quinupristin

The oxacillin resistance rates of *S. aureus* (MRSA) were 43% and 53% in SMH and GH, respectively, and 90% in LTCH. The clindamycin resistance rate was 27-55%, the cotrimoxazole resistance rate was 3-8%, and the resistance rates to vancomycin, teicoplanin, habekacin, tigecycline, linezolid, and quinupristin-dalfopristin were less than 1% (Table 3). The antimicrobial resistance of coagulase-negative *Staphylococcus* was similar to those of *S. aureus*, but the resistance rates to cotrimoxazole and fusidic acid were 14-32% and 70-76%, respectively. The ampicillin resistance rate of *Enterococcus faecalis* was less than 1%, whereas that of *E. faecium* was 92-96%. Vancomycin and teicoplanin resistance rates were less than 3% for *E. faecalis*, but 17-42% for *E. faecium*. Tigecycline and linezolid resistance rates for *Enterococcus* were 0% and less than 1%, respectively. Nitrofurantoin resistance rate was less than 1% for *E. faecalis*, but was 79-86% for *E. faecium*.



Escherichia coli, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa* were the most common pathogens of antibiotic resistance-related deaths in 2019.

Source: Lancet 2022;399:629-55