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Antimicrobial resistance of clinical isolates of bacteria in 2024

The antimicrobial susceptibility of major bacteria isolated from various clinical specimens sent to the Seoul Clinical Laboratories (SCL) in January-December 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 (bioMerieux, Marcy-l'Etile, 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 *Enterobacterales* at different types of hospitals in Korea in 2024

Antimicrobial agents	*Escherichia coli*						*Klebsiella pneumoniae*					
	SMH (27030)		GH (9445)		LTCH (1967)		SMH (3417)		GH (1969)		LTCH (944)	
	S	R	S	R	S	R	S	R	S	R	S	R
Ampicillin	31	67	27	71	10	89	0	100	0	100	0	100
Amox-clavulanate	74	14	71	14	47	26	63	23	59	27	27	51
Pip-tazobactam	92	6	91	7	73	24	63	31	58	36	23	68
Cefazolin	65	36	57	43	23	77	55	45	52	48	18	82
Cefotaxime	71	29	63	37	25	75	55	45	52	47	18	82
Ceftazidime	77	12	70	17	34	48	59	37	55	41	21	74
Cefepime	79	15	71	22	33	55	63	35	58	41	25	73
Ertapenem	99	1	99	0	93	6	87	11	83	16	64	33
Imipenem	100	0	100	0	95	5	87	10	83	14	65	28
Meropenem	100	0	100	0	95	5	89	11	84	15	69	29
Ciprofloxacin	33	49	27	55	7	85	49	45	46	49	14	82
Amikacin	97	2	96	3	84	13	95	4	93	6	82	17
Gentamicin	77	23	75	25	63	37	79	21	77	23	56	43
Tobramycin	75	19	72	22	49	46	67	30	64	33	33	63
Cotrimoxazole	66	34	65	35	52	48	67	33	66	34	39	61
Nitrofurantoin	96	1	95	1	92	4	16	41	16	43	9	62

Antimicrobial agents	*K. (Enterobacter) aerogenes*						*Klebsiella oxytoca*					
	SMH (898)		GH (233)		LTCH (24)		SMH (331)		GH (147)		LTCH (27)	
	S	R	S	R	S	R	S	R	S	R	S	R
Ampicillin	0	100	0	100	0	100	0	100	0	100	0	100
Amox-clavulanate	0	100	0	100	0	100	93	6	97	3	93	7
Pip-tazobactam	88	10	85	13	58	33	95	4	96	3	81	11
Cefazolin	0	100	0	100	0	100	54	46	52	48	41	59
Cefotaxime	89	11	87	12	63	38	94	5	95	5	81	19
Ceftazidime	89	11	87	12	63	29	96	2	98	1	89	11
Cefepime	99	0	97	2	96	0	98	2	99	0	89	11
Ertapenem	99	0	98	0	92	8	99	1	99	0	100	0
Imipenem	99	0	99	0	92	4	99	1	100	0	100	0
Meropenem	100	0	99	0	96	0	99	1	100	0	100	0
Ciprofloxacin	95	2	92	4	88	13	86	11	88	8	67	30
Amikacin	100	0	100	0	96	4	99	1	99	0	93	7
Gentamicin	99	1	99	1	92	8	98	2	98	1	100	0
Tobramycin	99	1	99	0	96	4	96	2	97	2	96	4
Cotrimoxazole	99	1	99	1	100	0	95	5	96	4	85	15
Nitrofurantoin	14	18	13	15	9	27	83	0	88	0	89	0

Antimicrobial agents	*Enterobacter cloacae*						*Citrobacter freundii*					
	SMH (740)		GH (357)		LTCH (59)		SMH (582)		GH (218)		LTCH (72)	
	S	R	S	R	S	R	S	R	S	R	S	R
Ampicillin	1	98	1	99	0	100	4	96	4	96	1	99
Amox-clavulanate	2	98	1	99	0	100	5	94	4	95	3	94
Pip-tazobactam	78	18	75	23	51	37	81	15	77	18	71	22
Cefazolin	1	99	1	99	0	100	2	98	1	99	0	100
Cefotaxime	72	27	68	32	39	61	74	25	71	27	63	38
Ceftazidime	73	25	70	29	46	51	79	19	74	25	65	31
Cefepime	84	11	84	12	69	26	95	3	97	2	88	11
Ertapenem	94	2	91	3	86	7	97	3	99	0	93	7
Imipenem	97	2	98	2	93	7	97	3	100	0	93	7
Meropenem	98	1	98	2	93	7	97	2	100	0	93	7
Ciprofloxacin	70	23	72	18	37	42	55	34	61	29	39	53
Amikacin	97	3	97	2	95	3	99	1	99	0	96	4
Gentamicin	91	9	90	10	76	22	91	9	96	4	85	15
Tobramycin	88	10	89	9	66	29	85	11	91	4	81	8
Cotrimoxazole	87	13	86	14	64	36	82	18	88	12	72	28
Nitrofurantoin	27	18	32	17	35	16	94	2	91	3	96	1

Antimicrobial agents	*Citrobacter koseri*						*Serratia marcescens*					
	SMH (359)		GH (91)		LTCH (145)		SMH (448)		GH (176)		LTCH (79)	
	S	R	S	R	S	R	S	R	S	R	S	R
Ampicillin	0	100	0	100	0	100	0	99	1	99	0	100
Amox-clavulanate	83	16	88	5	22	60	1	99	1	99	0	100
Pip-tazobactam	82	13	89	9	16	69	90	8	97	3	77	19
Cefazolin	79	21	88	12	18	82	0	100	0	100	0	100
Cefotaxime	80	19	82	17	19	80	81	16	92	7	59	39
Ceftazidime	83	16	90	10	31	66	94	5	98	2	84	14
Cefepime	85	12	92	7	31	66	95	4	99	0	89	8
Ertapenem	94	4	99	1	69	28	97	2	99	1	91	9
Imipenem	95	4	99	1	71	26	98	1	99	1	91	9
Meropenem	96	4	99	1	72	24	99	1	99	0	91	9
Ciprofloxacin	79	15	89	9	14	71	81	15	89	6	28	52
Amikacin	97	2	99	1	67	32	99	1	100	0	87	6
Gentamicin	87	12	96	4	35	63	98	2	99	0	94	6
Tobramycin	86	13	92	8	34	63	81	3	88	1	76	15
Cotrimoxazole	96	4	99	1	72	28	99	1	100	0	96	4
Nitrofurantoin	75	4	69	7	40	21	0	100	0	100	0	100

Antimicrobial agents	*Morganella morganii*						*Proteus mirabilis*						*Providencia rettgeri*						*Providencia stuartii*					
	SMH (517)		GH (157)		LTCH (197)		SMH (2008)		GH (634)		LTCH (853)		SMH (141)		GH (51)		LTCH (110)		SMH (110)		GH (37)		LTCH (121)	
	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	1	99	0	100	40	60	39	61	4	96	1	96	2	94	0	99	0	99	0	100	0	100
Amox-clavulanate	0	100	1	99	1	99	58	18	63	14	34	30	0	100	0	96	0	100	0	100	0	100	0	99
Pip-tazobactam	95	5	97	3	65	34	96	3	97	2	89	9	53	47	90	8	63	37	96	3	95	5	93	7
Cefazolin	0	100	0	100	1	99	57	43	52	48	12	88	1	99	0	100	1	99	0	100	0	100	0	100
Cefotaxime	62	30	54	34	20	73	59	41	55	45	15	85	39	61	38	56	11	88	35	63	57	43	25	75
Ceftazidime	80	10	78	11	40	49	86	13	84	15	58	40	48	51	52	46	25	74	98	1	89	8	87	12
Cefepime	93	3	97	1	64	28	69	11	65	11	33	21	46	27	72	14	29	51	88	2	76	0	64	23
Ertapenem	98	1	99	1	78	18	99	0	100	0	99	1	97	3	98	0	73	8	99	0	100	0	80	12
Imipenem	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meropenem	100	0	99	1	80	20	99	0	99	0	99	1	96	3	100	0	96	3	99	1	100	0	96	1
Ciprofloxacin	69	28	71	27	19	79	46	53	41	58	4	96	36	63	36	62	21	77	14	86	22	76	18	82
Amikacin	96	4	97	3	57	40	78	22	80	20	39	61	53	46	52	48	17	83	58	42	70	30	73	28
Gentamicin	89	11	88	12	44	56	52	47	52	47	11	88	50	47	84	12	16	84	0	100	0	100	2	98
Tobramycin	91	8	90	9	49	48	56	40	60	36	18	77	48	48	48	10	17	76	0	100	0	100	1	98
Cotrimoxazole	80	20	88	12	52	48	56	44	53	47	29	71	80	20	80	20	37	63	49	51	78	22	53	47
Nitrofurantoin	1	99	0	100	0	99	0	100	0	100	0	100	3	97	4	96	4	96	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 2024, *Escherichia coli* was the most commonly isolated bacteria, followed by *Pseudomonas aeruginosa*, coagulase-negative *Staphylococcus,* and *Klebsiella pneumoniae*. Among the Gram-negative rods, *K. pneumoniae, Acinetobacter baumannii,* and *Proteus mirabilis* were commonly isolated in addition to *E. coli*, *P. aeruginosa*. The antimicrobial susceptibilities of *Enterobacterales* are shown in Table 1; glucose-nonfermenting Gram-negative bacilli are shown in Table 2; and staphylococci and enterococci are shown in Table 3. The cefotaxime resistance rate of *E. coli* was 29%, 37%, and 75% in SMH, GH, and LTCH, respectively, and the carbapenem resistance rate was less than 6% (Table 1). The fluoroquinolone resistance rate was about 50% in SMH and GH, but 85% in LTCH. The rate of cotrimoxazole resistance was 48% in LTCH, which was slightly higher than that of SMH and GH. The carbapenem resistance rates of *K. pneumoniae* were high at 10-11% and 14-16% in SMH and GH, respectively, and at 28-33% in LTCH, which were increased by 7-10% compared to 2023. The carbapenem resistance rates of isolates from LTCH were 18-20% for *Morganella morganii*, increased by 16-18% compared to 2023, and 24-28% for *Citrobacter koseri*, which were similar to 2023, but 0-8% for *K. (Enterobacter) aerogenes*, decreased by 13-18%. The cefotaxime resistance rate of *M. morganii*, *Providencia rettgeri* and *P. stuartii* isolated from LTCH increased by 10% compared to 2023, while the resistance rate of *Enterobacter cloacae* decreased by 9%.

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

Antimicrobial agents	*Acinetobacter baumannii*						*Acinetobacter* spp.						*Pseudomonas aeruginosa*						*Stenotrophomonas maltophilia*					
	SMH (1150)		GH (1024)		LTCH (1446)		SMH (1240)		GH (634)		LTCH (734)		SMH (4397)		GH (2483)		LTCH (3948)		SMH (876)		GH (619)		LTCH (671)	
	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	28	56	20	61	14	62	82	11	84	9	78	14	-	-	-	-	-	-	-	-	-	-	-	-
Pip-tazobactam	23	77	14	86	6	94	58	36	51	43	33	61	52	42	57	35	36	55	-	-	-	-	-	-
Ceftazidime	24	76	16	84	10	90	70	18	66	13	68	23	67	29	71	26	58	35	-	-	-	-	-	-
Cefepime	-	-	-	-	-	-	-	-	-	-	-	-	62	24	67	21	52	28	-	-	-	-	-	-
Imipenem	22	77	13	86	7	93	69	29	64	34	56	40	51	46	59	38	37	60	-	-	-	-	-	-
Meropenem	23	77	15	85	7	92	74	24	66	32	59	36	54	39	62	31	39	52	-	-	-	-	-	-
Amikacin	38	61	31	69	23	73	85	11	84	8	71	17	-	-	-	-	-	-	-	-	-	-	-	-
Gentamicin	28	68	24	73	14	80	76	20	73	22	62	26	-	-	-	-	-	-	-	-	-	-	-	-
Tobramycin	31	69	25	75	22	78	77	23	74	25	68	32	71	29	74	26	55	45	-	-	-	-	-	-
Ciprofloxacin	20	80	13	87	5	95	56	41	52	46	35	63	47	50	55	42	27	70	-	-	-	-	-	-
Levofloxacin	20	77	14	84	5	90	62	24	60	30	39	31	-	-	-	-	-	-	80	15	82	12	75	18
Cotrimoxazole	32	68	24	76	18	82	77	23	83	17	69	31	-	-	-	-	-	-	86	14	88	12	85	15
Tetracycline	28	31	30	18	9	37	60	33	72	25	32	55	-	-	-	-	-	-	-	-	-	-	-	-
Minocycline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	89	7	90	7	89	8

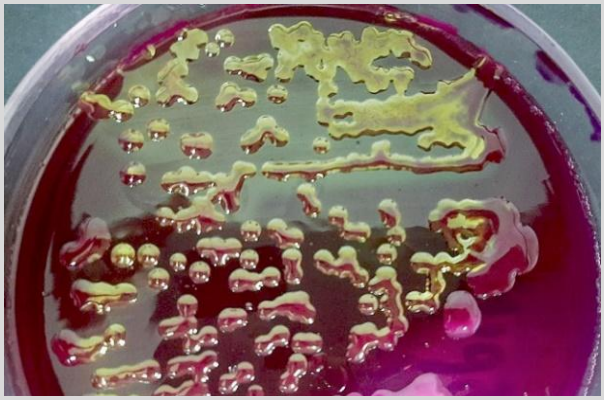
Abbreviation: Amp, ampicillin; Pip, piperacillin.

The resistance rates of *A. baumannii* were 56-62% for ampicillin-sulbactam, 77-93% for carbapenem, 77-95% for fluoroquinolone, similar to 2023, and 61-73% for amikacin, increased by 20% compared to 2023. By contrast, the resistance rates of non-*baumannii Acinetobacter* isolates were 9-14% for ampicillin-sulbactam, 24-40% for carbapenem, 24-63% for fluoroquinolone, and 8-17% for amikacin, and the rates decreased by 3-12%, 1-11%, 3-14%, and 1-3%, respectively, compared to 2023 (Table 2). The resistance rates of *P. aeruginosa* were 26-35% for ceftazidime, 35-55% for piperacillin-tazobactam, 31-60% for carbapenem, and 42-70% 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 12-18% for levofloxacin, 12-15% for cotrimoxazole, and 7-8% for minocycline.

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

Antimicrobial agents	*Staphylococcus aureus*						Coagulase-neg. *Staphylococcus*						*Enterococcus faecalis*						*Enterococcus faecium*					
	SMH (3589)		GH (1924)		LTCH (538)		SMH (3718)		GH (2896)		LTCH (1008)		SMH (3652)		GH (1097)		LTCH (270)		SMH (873)		GH (846)		LTCH (454)	
	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	98	2	97	3	8	92	6	94	1	99
Penicillin G	12	88	11	89	3	97	11	89	9	91	1	99	95	5	85	15	72	28	7	93	5	95	1	99
Oxacillin	52	48	48	52	12	88	41	59	31	69	6	94	-	-	-	-	-	-	-	-	-	-	-	-
Clindamycin	69	31	61	38	43	57	69	29	65	33	41	57	-	-	-	-	-	-	-	-	-	-	-	-
Erythromycin	65	35	59	41	36	64	50	48	46	53	32	68	-	-	-	-	-	-	-	-	-	-	-	-
Tetracycline	86	14	83	17	89	11	83	17	81	18	85	15	14	86	14	86	9	91	76	24	83	17	78	22
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	97	3	95	5	92	8	90	10	83	17	-	-	-	-	-	-	-	-	-	-	-	-
Ciprofloxacin	67	32	65	34	16	84	66	31	57	39	12	83	80	19	63	36	23	77	3	95	1	98	1	99
Levofloxacin	68	32	65	34	16	84	66	33	58	41	13	86	-	-	-	-	-	-	-	-	-	-	-	-
Teicoplanin	100	0	100	0	100	0	98	2	97	2	96	2	99	1	99	1	98	2	64	36	65	35	58	42
Vancomycin	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	99	1	65	35	66	34	59	42
Gentamicin	71	22	68	27	40	51	64	18	59	22	36	41	-	-	-	-	-	-	-	-	-	-	-	-
Linezolid	100	0	100	0	100	0	100	0	100	0	100	0	99	1	99	1	100	0	100	0	100	0	100	0
Rifampin	99	1	98	1	98	2	94	5	91	8	80	18	-	-	-	-	-	-	-	-	-	-	-	-
Nitrofurantoin	-	-	-	-	-	-	-	-	-	-	-	-	99	0	99	1	96	2	5	77	4	84	3	88

The oxacillin resistance rate of *Staphylococcus aureus* (MRSA) was 48% and 52% in SMH and GH, respectively, and 88% in LTCH. The resistance rates were 31-57% for clindamycin, 3-5% for cotrimoxazole, and 0% for vancomycin, teicoplanin, tigecycline, and linezolid (Table 3). The antimicrobial resistance of coagulase-negative *Staphylococcus* was similar to that of *S. aureus*, but the resistance rate to cotrimoxazole was high at 8-17%. The ampicillin resistance rate of *Enterococcus faecalis* was less than 3%, whereas that of *Enterococcus faecium* was 92-99%. Vancomycin and teicoplanin resistance rates were less than 2% for *E. faecalis*, but 34-42% for *E. faecium*. Nitrofurantoin resistance rate was less than 2% for *E. faecalis*, but was 77-88% for *E. faecium*. The resistance rates of Gram-positive cocci were similar to 2023, but the teicoplanin resistance rate of *E. faecium* isolated in SMH increased by 11%.



Hypermucoid, hypervirulent and carbapenem-resistant *Klebsiella pneumiae* isolated from a patient in Ukraine war

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