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Antimicrobial Susceptibility of 56,936 Pathogens Isolated from Patients in Canadian Hospitals: 15 Years of the CANWARD Study 2007-2021

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Introduction

Antimicrobial-resistant Gram-positive organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA, community associated [CA] and healthcare associated [HA]), vancomycin-resistant *Enterococcus species* (VRE), penicillin-resistant *Streptococcus pneumoniae*, and Gram-negative bacilli such as extended-spectrum β-lactamase (ESBL)-producing *Escherichia coli* and *Klebsiella* species as well as fluoroquinolone-resistant and carbapenem-resistant Enterobacterales and *Pseudomonas aeruginosa* are increasing in prevalence in Canada and around the world (1, 2). Available therapeutic options for the treatment of these antimicrobial-resistant organisms are limited as these organisms frequently display a multidrug-resistant (MDR) phenotype and sometimes an extremely drug-resistant (XDR) phenotype (1, 2).

CANWARD (a collaboration between the Canadian Antimicrobial Resistance Alliance and the National Microbiology Laboratory) is a national ongoing surveillance study which assesses pathogens and antimicrobial resistance patterns in respiratory, bloodstream, urinary, and wound/IV site infection isolates from patients receiving care in medical/surgical wards, intensive care units, emergency rooms and outpatient clinics of Canadian hospitals.

Materials and Methods

Participating Sites

From January 2007 to October 2021, tertiary-care medical centres in major population centres in 8 of the 10 provinces in Canada were recruited (1, 2). These sites were geographically distributed in a population-based fashion.

Bacterial Isolates

Tertiary-care medical centres submitted pathogens from patients attending hospital clinics, emergency rooms, medical and surgical wards, and intensive care units. Each study site was asked to submit clinical isolates (consecutive, one per patient, per infection site) from inpatients and outpatients with respiratory, urine, wound, and bloodstream infections. Isolate identification was performed by the submitting site and confirmed at the reference site. Isolates were shipped on Amies semi-solid transport media to the coordinating laboratory (Health Sciences Centre, Winnipeg, Canada), subcultured onto appropriate media, and stocked in skim milk at -80ºC until minimum inhibitory concentration (MIC) testing was carried out. From 2007-2021, between 2231 and 7718 isolates were collected in each year of the study (1, 2).

Antimicrobial Susceptibilities

The *in vitro* activity of selected antimicrobials was determined by broth microdilution in accordance with CLSI guidelines (3). MICs were determined using 96-well custom designed microtitre plates. These plates contained doubling antimicrobial dilutions in 100µL/well of cation adjusted Mueller-Hinton broth (or MHB supplemented with lysed horse blood, where required) and inoculated to achieve a final concentration of approximately 5 x 10^5 CFU/mL. Colony counts were performed periodically to confirm inocula. Quality control was performed using ATCC QC organisms including *S. pneumoniae* 49619, *S. aureus* 29213, *E. faecalis* 29212, *E. coli* 25922, and *P. aeruginosa* 27853. MICs were interpreted using CLSI breakpoints (4).

Results

Table 1. Antimicrobial activity against the most common Gram-positive cocci isolated from Canadian hospitals

Organism (no. tested) / Antimicrobial Agent	% S	% I	% R	MIC (µg/mL)			
				MIC_{50}	MIC_{90}	Range Min	Range Max
***Staphylococcus aureus*, MSSA (9,397)**							
Cefoxitin[a]	100			4	4	0.12	4
Ceftobiprole[b]	100			≤ 1	≤ 1	≤ 1	2
Ceftriaxone				4	4	≤ 1	> 64
Ciprofloxacin	87.2	3.0	9.8	0.5	2	≤ 0.06	> 16
Clarithromycin	75.6	0.6	23.7	0.25	> 32	≤ 0.03	> 32
Clindamycin	93.9	0.4	5.7	≤ 0.12	≤ 0.12	≤ 0.12	> 8
Daptomycin	99.9*		0.1†	0.25	0.5	≤ 0.03	> 16
Doxycycline	98.9	0.7	0.4	≤ 0.12	0.25	≤ 0.12	32
Gentamicin	98.2	0.1	1.7	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Lefamulin	98.4		1.6	0.12	0.12	0.03	> 8
Levofloxacin	90.1	0.3	9.6	0.25	1	≤ 0.06	> 32
Linezolid	99.9*		0.1	2	4	≤ 0.12	> 16
Nitrofurantoin	99.9	0.1†	0.1†	16	16	≤ 0.5	> 512
Tigecycline[c]	99.6		0.4	0.25	0.25	≤ 0.03	2
Trimethoprim Sulfa	99.5		0.5	≤ 0.12	≤ 0.12	≤ 0.12	> 8
Vancomycin	100			1	1	≤ 0.12	2
***Staphylococcus aureus*, MRSA (2,513)**							
Cefoxitin[a]			100	> 32	> 32	8	> 32
Ceftobiprole[b]	100			≤ 1	2	≤ 1	4
Ceftriaxone				> 64	> 64	≤ 1	> 64
Ciprofloxacin	20.3	0.4	79.3	> 16	> 16	≤ 0.06	> 16
Clarithromycin	17.4	0.5	82.1	> 32	> 32	≤ 0.03	> 32
Clindamycin	58.8	0.1	41.1	≤ 0.12	> 8	≤ 0.12	> 8
Daptomycin	99.8		0.2	0.25	0.5	0.06	4
Doxycycline	97.8	0.9	1.4	≤ 0.12	1	≤ 0.12	16
Gentamicin	93.4	0.4	6.2	≤ 0.5	1	≤ 0.5	> 32
Lefamulin	98.9		1.1	0.12	0.25	0.03	0.5
Levofloxacin	14.1		85.9	> 32	> 32	0.12	> 32
Linezolid	99.9*		0.1†	2	2	≤ 0.12	> 16
Nitrofurantoin	99.8	0.1	0.1	16	16	8	128
Tigecycline[c]	98.7		1.3	0.25	0.5	≤ 0.03	2
Trimethoprim Sulfa	94.7		5.3	≤ 0.12	≤ 0.12	≤ 0.12	> 8
Vancomycin	99.9	0.1		1	1	≤ 0.12	4
***Staphylococcus epidermidis* (1,253)**							
Amox-Clav				1	8	≤ 0.06	32
Cefazolin				1	32	≤ 0.5	> 128
Cefepime				4	64	≤ 0.25	> 32
Cefoxitin				8	> 32	≤ 0.06	> 32
Ceftobiprole				≤ 1	≤ 1	≤ 1	4
Ceftriaxone				8	> 64	≤ 1	> 64
Ciprofloxacin	47.4	1.5	51.0	4	> 16	≤ 0.06	> 16
Clarithromycin	34.3	1.3	64.4	32	> 32	≤ 0.03	> 32
Clindamycin	59.3	1.4	39.3	≤ 0.12	> 8	≤ 0.12	> 8
Daptomycin	99.8		0.2	0.25	0.25	≤ 0.03	2
Doxycycline	95.2	2.4	2.4	0.5	1	≤ 0.12	32
Ertapenem				2	> 32	≤ 0.03	> 32
Gentamicin	61.5	5.6	32.8	≤ 0.5	> 32	≤ 0.5	> 32
Levofloxacin	44.2	1.6	54.2	4	> 32	0.12	> 32
Linezolid	100			1	1	≤ 0.12	4
Meropenem				1	32	≤ 0.12	> 32
Moxifloxacin	48.0	8.8	43.2	1	> 16	≤ 0.06	> 16
Pip-Tazo				≤ 1	16	≤ 1	256
Tigecycline				0.12	0.5	≤ 0.03	2
Trimethoprim Sulfa	61.6		38.4	0.5	8	≤ 0.12	> 8
Vancomycin	100			1	2	≤ 0.12	4
***Streptococcus pneumoniae* (3,068)**							
Amox-Clav	97.6	1.3	1.0	≤ 0.06	0.12	≤ 0.06	16
Ceftobiprole[b]	99.9			≤ 0.06	≤ 0.06	≤ 0.06	1
Ceftriaxone	99.4	0.4	0.2	≤ 0.12	≤ 0.12	≤ 0.12	4
Cefuroxime	91.9	1.2	6.9	≤ 0.25	0.5	≤ 0.25	> 16
Chloramphenicol	97.5		2.5	2	4	≤ 0.12	32
Ciprofloxacin				1	2	≤ 0.06	> 16
Clarithromycin	78.3	3.2	18.6	≤ 0.03	4	≤ 0.03	> 32
Clindamycin	92.4	0.5	7.1	≤ 0.12	≤ 0.12	≤ 0.12	> 64
Daptomycin				0.06	0.12		
Doxycycline	86.3	1.2	12.6	≤ 0.25	2	≤ 0.25	> 16
Ertapenem	99.0	0.9	0.1	≤ 0.06	0.12	≤ 0.06	4
Imipenem	93.0	5.0	1.9	≤ 0.03	0.06	≤ 0.03	1
Lefamulin	100			0.06	0.12	≤ 0.015	0.25
Levofloxacin	99.1	0.1	0.7	1	1	≤ 0.06	32
Linezolid	99.9*		0.1†	1	1	≤ 0.12	4
Meropenem	94.9	3.2	1.9	≤ 0.06	0.12	≤ 0.06	2
Penicillin	82.5	12.9	4.7	≤ 0.03	0.25	≤ 0.03	> 8
Pip-Tazo				≤ 1	≤ 1	≤ 1	16
Tigecycline[c]	99.7		0.3	0.03	0.06	≤ 0.015	0.25
Trimethoprim Sulfa	85.0	6.1	8.9	≤ 0.12	2	≤ 0.12	> 8
Vancomycin	100			0.25	0.25	≤ 0.12	1
***Streptococcus agalactiae* (904)**							
Amox-Clav				≤ 0.06	0.12	≤ 0.06	0.25
Ceftobiprole				≤ 0.06	≤ 0.06	≤ 0.06	≤ 0.06
Ceftriaxone	100			≤ 0.12	≤ 0.12	≤ 0.12	0.5
Cefuroxime				≤ 0.25	≤ 0.25	≤ 0.25	0.5
Chloramphenicol	97.3	2.3	0.4	4	4	0.5	64
Ciprofloxacin				0.5	1	0.25	> 16
Clarithromycin	64.3	3.4	32.3	≤ 0.03	> 32	≤ 0.03	> 32
Clindamycin	80.2	0.8	19.0	≤ 0.12	> 64	≤ 0.12	> 64
Daptomycin	100			0.25	0.25	≤ 0.03	1
Doxycycline				8	16	≤ 0.25	> 16
Ertapenem	100			≤ 0.06	≤ 0.06	≤ 0.06	0.12
Imipenem				≤ 0.03	≤ 0.03	≤ 0.03	0.12
Levofloxacin	96.7		3.3	1	1	0.25	> 32
Linezolid	97.9		2.1	1	2	≤ 0.12	4
Meropenem	100			≤ 0.06	≤ 0.06	≤ 0.06	0.12
Moxifloxacin				0.12	0.25	≤ 0.06	16
Penicillin	99.8		0.2	0.06	0.12	≤ 0.03	0.25
Pip-Tazo				≤ 1	≤ 1	≤ 1	≤ 1
Tigecycline[c]	99.8		0.2	0.06	0.06	≤ 0.015	1
Trimethoprim Sulfa				≤ 0.12	≤ 0.12	≤ 0.12	1
Vancomycin	100			0.5	0.5	≤ 0.25	1
***Streptococcus pyogenes* (808)**							
Amox-Clav				≤ 0.06	≤ 0.06	≤ 0.06	1
Ceftobiprole				≤ 0.06	≤ 0.06	≤ 0.06	0.5
Ceftriaxone	100			≤ 0.12	≤ 0.12	≤ 0.12	0.25
Cefuroxime				≤ 0.25	≤ 0.25	≤ 0.25	1
Chloramphenicol	97.4	2.1	0.5	2	4	0.5	64
Ciprofloxacin				0.5	1	≤ 0.06	> 16
Clarithromycin	89.1	1.7	9.2	≤ 0.03	0.5	≤ 0.03	> 32
Clindamycin	97.8	0.1	2.1	≤ 0.12	≤ 0.12	≤ 0.12	> 64
Daptomycin	100			0.06	0.12	≤ 0.03	0.25
Doxycycline				≤ 0.25	1	≤ 0.25	> 16
Ertapenem	100			≤ 0.06	≤ 0.06	≤ 0.06	1
Imipenem				≤ 0.03	≤ 0.03	≤ 0.03	0.25
Levofloxacin	99.7	0.1	0.1	0.5	1	≤ 0.06	16
Linezolid	99.4		0.6	1	2	≤ 0.12	4
Meropenem	100			≤ 0.06	≤ 0.06	≤ 0.06	0.25
Moxifloxacin				0.12	0.25	≤ 0.06	4
Penicillin	99.9		0.1	≤ 0.03	≤ 0.03	≤ 0.03	0.25
Pip-Tazo				≤ 1	≤ 1	≤ 1	4
Tigecycline[c]	100			0.03	0.06	≤ 0.015	0.25
Trimethoprim Sulfa				≤ 0.12	≤ 0.12	≤ 0.12	> 8
Vancomycin	100			0.5	0.5	≤ 0.12	1
***Enterococcus faecalis* (1,655)**							
Amox-Clav				0.5	1	≤ 0.06	> 32
Ceftobiprole				≤ 1	≤ 1	≤ 1	> 32
Ciprofloxacin	64.1	10.9	25.1	1	> 16	≤ 0.06	> 16
Clarithromycin				2	> 32	≤ 0.03	> 32
Daptomycin	98.2	1.8		1	2	≤ 0.03	4
Doxycycline	35.4	38.6	25.9	8	16	≤ 0.12	32
Ertapenem				16	16	0.25	> 32
Imipenem				1	2	0.25	> 32
Levofloxacin	65.6	1.0	33.3	2	> 32	0.25	> 32
Linezolid	92.3	7.7		2	2	0.25	4
Meropenem				4	8	≤ 0.12	> 32
Moxifloxacin				0.25	16	≤ 0.06	> 16
Nitrofurantoin	99.3	0.5	0.2	8	16	≤ 0.5	128
Pip-Tazo				4	4	≤ 1	> 512
Tigecycline[c]	97.0		3.0	0.12	0.25	≤ 0.03	1
Trimethoprim Sulfa				≤ 0.12	0.5	≤ 0.12	> 8
Vancomycin	100			1	2	0.25	4
***Enterococcus faecium* (681)**							
Amox-Clav				> 32	> 32	≤ 0.06	> 32
Ceftobiprole				> 32	> 32	≤ 1	> 32
Ciprofloxacin	7.0	1.5	91.5	> 16	> 16	0.25	> 16
Clarithromycin				> 32	> 32	≤ 0.03	> 32
Daptomycin	94.8	4.7	0.4	1	2	≤ 0.03	16
Doxycycline	63.3	10.1	26.6	4	16	≤ 0.12	32
Ertapenem				> 32	> 32	0.5	> 32
Imipenem				> 32	> 32	0.12	> 32
Levofloxacin	9.5	1.3	89.2	> 32	> 32	1	> 32
Linezolid	88.9	10.2	0.9	2	4	≤ 0.12	> 16
Meropenem				> 32	> 32	0.25	> 32
Moxifloxacin				> 16	> 16	0.12	> 16
Nitrofurantoin	32.7	31.6	35.7	64	128	≤ 0.5	> 512
Pip-Tazo				> 512	> 512	≤ 1	> 512
Tigecycline				0.12	0.12	≤ 0.03	2
Trimethoprim Sulfa				0.25	> 8	≤ 0.12	> 8
Vancomycin	77.0	0.1	22.8	0.5	> 32	≤ 0.12	> 32

Amox-Clav, Amoxicillin-Clavulanate; Pip-Tazo, Piperacillin-Tazobactam; Trimethoprim-Sulfa, Trimethoprim-Sulfamethoxazole
* Actual value ≥99.9%; † Actual value <0.1%.
[a] Cefoxitin used as a surrogate to determine oxacillin susceptibility.
[b] For ceftobiprole, Health Canada breakpoints applied. Not all isolates tested with ceftobiprole.
[c] For tigecycline, FDA breakpoints applied.

Table 2. Antimicrobial activity against the most common Gram-negative bacilli isolated from Canadian hospitals

Organism (no. tested) / Antimicrobial Agent	% S	% I	% R	MIC (µg/mL)			
				MIC_{50}	MIC_{90}	Range Min	Range Max
***Escherichia coli* (11,090)**							
Amikacin	99.6	0.2	0.1	≤ 2	4	≤ 2	> 64
Amox-Clav	81.8	12.5	5.8	4	16	≤ 0.06	> 32
Cefazolin	68.5	11.8	19.7	2	128	≤ 0.5	> 128
Cefepime	92.9	2.7	4.4	≤ 1	≤ 1	≤ 1	> 32
Cefoxitin	91.1	4.8	4.1	4	8	≤ 0.06	> 32
Ceftazidime	91.5	1.3	7.2	≤ 0.25	2	≤ 0.25	> 32
Ceftobiprole[a]	91.7	0.1	8.2	≤ 1	≤ 1	≤ 1	> 32
Ceftol-Tazo	99.2	0.2	0.6	0.25	0.5	≤ 0.12	> 64
Ceftriaxone	89.8	0.3	9.9	≤ 1	≤ 1	≤ 1	> 64
Ciprofloxacin	73.9	1.6	24.5	≤ 0.06	> 16	≤ 0.06	> 16
Colistin		99.6	0.4	0.25	0.5	≤ 0.06	> 16
Doxycycline	72.3	6.2	21.6	2	32	0.25	> 256
Ertapenem	99.7	0.2	0.2	≤ 0.06	≤ 0.06	≤ 0.06	> 32
Gentamicin	90.5	0.4	9.1	≤ 0.5	4	≤ 0.5	> 32
Imipenem	99.9	0.1†	0.1†	0.25	0.25	≤ 0.03	> 32
Levofloxacin	76.7	1.6	21.7	≤ 0.06	16	≤ 0.06	> 32
Meropenem	99.9*		0.1†	≤ 0.12	≤ 0.12	≤ 0.12	> 32
Moxifloxacin				≤ 0.06	> 16	≤ 0.06	> 16
Nitrofurantoin	97.2	1.8	1.0	16	32	≤ 0.5	> 512
Pip-Tazo	95.6	1.6	2.8	2	4	≤ 1	> 512
Tigecycline[b]	99.9*	0.1†		0.25	0.5	≤ 0.03	4
Tobramycin	91.2	3.1	5.7	≤ 0.5	4	≤ 0.5	> 64
Trimethoprim Sulfa	72.7		27.3	≤ 0.12	> 8	≤ 0.12	> 8
ESBL *E. coli* (903)							
Amikacin	97.7	1.9	0.4	≤ 2	8	≤ 2	> 64
Amox-Clav	49.5	38.4	12.1	16	32	1	> 32
Cefazolin		0.1	99.9	> 128	> 128	4	> 128
Cefepime	26.2	29.4	44.4	8	> 32	≤ 1	> 32
Cefoxitin	78.8	12.6	8.6	8	16	0.5	> 32
Ceftazidime	29.0	10.9	60.1	16	> 32	≤ 0.5	> 32
Ceftobiprole[a]	2.9	1.6	95.5	> 32	> 32	0.12	> 32
Ceftol-Tazo	96.4	1.4	2.3	0.5	1	≤ 0.12	> 64
Ceftriaxone	1.6	1.3	97.1	> 64	> 64	≤ 1	> 64
Ciprofloxacin	11.7	0.9	87.4	> 16	> 16	≤ 0.06	> 16
Colistin		99.6	0.4	0.25	1	≤ 0.06	8
Doxycycline	32.2	15.7	52.1	16	> 32	0.25	> 256
Ertapenem	97.4	1.2	1.4	≤ 0.06	0.25	≤ 0.06	> 32
Gentamicin	63.8	1.3	34.9	1	> 32	≤ 0.5	> 32
Imipenem	99.7		0.3	0.25	0.25	0.06	8
Levofloxacin	11.6	1.3	87.1	16	32	≤ 0.06	> 32
Meropenem	99.7		0.3	≤ 0.12	≤ 0.12	≤ 0.12	32
Moxifloxacin				16	> 16	≤ 0.06	> 16
Nitrofurantoin	92.6	4.9	2.5	16	32	≤ 1	512
Pip-Tazo	92.8	4.2	3.0	4	16	≤ 1	> 512
Tigecycline[b]	99.9	0.1		0.5	1	0.12	4
Tobramycin	58.1	7.0	35.0	1	32	≤ 0.5	> 64
Trimethoprim Sulfa	33.0		67.0	> 8	> 8	≤ 0.12	> 8
***Klebsiella pneumoniae* (3,680)**							
Amikacin	99.7	0.1	0.2	≤ 2	≤ 2	≤ 2	> 64
Amox-Clav	91.9	4.2	3.9	2	8	≤ 0.06	> 32
Cefazolin	81.9	6.1	12.0	1	8	≤ 0.5	> 128
Cefepime	94.7	1.4	4.0	≤ 1	≤ 1	≤ 1	> 32
Cefoxitin	90.7	4.1	5.2	4	8	0.12	> 32
Ceftazidime	93.9	0.5	5.6	≤ 0.25	1	≤ 0.25	> 32
Ceftobiprole[a]	93.3	0.5	6.2	≤ 1	≤ 1	≤ 1	> 32
Ceftol-Tazo	97.6	0.4	2.1	0.25	1	≤ 0.12	> 64
Ceftriaxone	93.2	0.4	6.4	≤ 1	≤ 1	≤ 1	> 64
Ciprofloxacin	87.1	3.6	9.4	≤ 0.06	0.5	≤ 0.06	> 16
Colistin		97.8	2.2	0.5	1	≤ 0.06	> 16
Doxycycline	80.4	4.3	15.2	2	16	≤ 0.12	> 32
Ertapenem	99.0	0.4	0.6	≤ 0.06	≤ 0.06	≤ 0.06	> 32
Gentamicin	96.5	0.2	3.3	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Imipenem	98.9	0.5	0.6	0.25	0.5	0.06	> 32
Levofloxacin	87.5	4.4	8.1	≤ 0.06	1	≤ 0.06	> 32
Meropenem	99.6	0.1	0.4	≤ 0.12	≤ 0.12	≤ 0.12	> 32
Moxifloxacin				0.12	1	≤ 0.06	> 16
Nitrofurantoin	41.6	36.2	22.3	64	128	≤ 1	> 512
Pip-Tazo	91.8	4.3	3.9	2	8	≤ 1	> 512
Tigecycline[b]	95.6	3.5	0.8	1	2	0.06	> 16
Tobramycin	94.9	2.1	3.0	≤ 0.5	≤ 0.5	≤ 0.5	> 64
Trimethoprim Sulfa	89.0		11.0	≤ 0.12	> 8	≤ 0.12	> 8
***Stenotrophomonas maltophilia* (1,072)**							
Cefepime				32	> 32	≤ 1	> 32
Ceftazidime	22.7	7.1	70.2	> 32	> 32	0.5	> 32
Ceftobiprole				> 32	> 32	≤ 1	> 32
Ceftol-Tazo				32	> 64	≤ 0.12	> 64
Ciprofloxacin				4	16	≤ 0.06	> 16
Colistin				8	> 16	0.12	> 16
Doxycycline				2	8	0.25	> 32
Levofloxacin	66.8	12.9	20.3	2	8	≤ 0.06	> 32
Moxifloxacin				1	4	≤ 0.06	> 16
Nitrofurantoin				> 512	> 512	32	> 512
Tigecycline				2	8	0.12	> 16
Trimethoprim Sulfa	98.0		2.0	0.25	1	≤ 0.12	> 8
***Acinetobacter baumannii* (235)**							
Amikacin	95.6		4.4	≤ 2	4	≤ 2	> 64
Cefepime	83.1	6.8	10.1	4	32	≤ 0.25	> 128
Ceftazidime	78.1	10.5	11.4	8	32	0.5	> 32
Ceftobiprole				≤ 1	4	≤ 1	> 32
Ceftol-Tazo				0.5	8	≤ 0.12	> 64
Ceftriaxone	42.6	47.2	10.2	16	64	≤ 0.25	> 256
Ciprofloxacin	92.8	0.9	6.4	0.25	1	≤ 0.06	32
Gentamicin	91.9	1.7	6.4	≤ 0.5	2	≤ 0.5	> 32
Levofloxacin	92.2		7.8	0.12	1	≤ 0.06	> 16
Meropenem	94.0	2.1	3.8	0.5	2	0.06	> 32
Moxifloxacin				≤ 0.06	0.5	≤ 0.06	> 16
Nitrofurantoin				> 512	> 512	128	> 512
Pip-Tazo	79.6	10.6	9.8	4	64	≤ 1	> 512
Tigecycline				0.5	2	0.12	> 16
Trimethoprim Sulfa	90.6		9.4	≤ 0.12	2	≤ 0.12	> 8
***Pseudomonas aeruginosa* (5,454)**							
Amikacin	92.0	3.4	4.6	4	16	≤ 2	> 64
Cefepime	79.7	12.6	7.8	4	16	≤ 1	> 32
Ceftazidime	78.0	7.1	14.8	4	32	≤ 0.25	> 32
Ceftobiprole				4	16	≤ 1	> 32
Ceftol-Tazo	97.0	1.5	1.6	0.5	2	≤ 0.12	> 64
Ciprofloxacin	67.3	9.3	23.4	0.25	4	≤ 0.06	> 16
Colistin		96.1	3.9	1	2	≤ 0.06	> 16
Gentamicin	81.8	8.1	10.1	2	16	≤ 0.5	> 32
Imipenem	64.4	10.0	25.7	2	16	≤ 0.03	> 32
Levofloxacin	52.9	10.6	36.5	1	16	≤ 0.06	> 32
Meropenem	78.1	6.9	15.0	0.5	8	≤ 0.12	> 32
Moxifloxacin				2	> 16	≤ 0.06	> 16
Nitrofurantoin				> 512	> 512	≤ 0.5	> 512
Pip-Tazo	80.2	9.7	10.1	4	128	≤ 1	> 512
Tigecycline				16	> 16	0.06	> 16
Tobramycin	93.3	1.5	5.2	≤ 0.5	2	≤ 0.5	> 64
Trimethoprim Sulfa				8	> 8	≤ 0.12	> 8
***Enterobacter cloacae* (1,517)**							
Amikacin	99.9		0.1	≤ 2	≤ 2	≤ 2	> 64
Cefepime	93.5	4.8	1.6	≤ 1	2	≤ 1	> 32
Ceftazidime	76.2	1.0	22.8	0.5	> 32	≤ 0.25	> 32
Ceftobiprole[a]	85.2	3.5	11.3	≤ 1	4	≤ 1	> 32
Ceftol-Tazo	82.1	4.5	13.4	0.25	8	≤ 0.12	> 64
Ceftriaxone	72.2	1.9	25.9	≤ 1	> 64	≤ 1	> 64
Ciprofloxacin	92.7	0.9	6.5	≤ 0.06	0.12	≤ 0.06	> 16
Colistin		81.3	18.7	0.5	> 16	≤ 0.06	> 16
Ertapenem	90.2	5.8	4.1	≤ 0.06	0.5	≤ 0.06	> 32
Gentamicin	97.6	0.3	2.1	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Imipenem	94.6	4.0	1.4	0.5	1	0.06	> 32
Levofloxacin	92.9	1.2	5.9	≤ 0.06	0.5	≤ 0.06	32
Meropenem	99.4	0.3	0.3	≤ 0.12	≤ 0.12	≤ 0.12	> 32
Moxifloxacin				≤ 0.06	0.5	≤ 0.06	> 16
Nitrofurantoin	38.5	43.5	18.0	64	128	≤ 1	> 512
Pip-Tazo	79.3	4.2	16.6	2	64	≤ 1	> 512
Tigecycline[b]	94.9	3.3	1.8	0.5	1	0.12	16
Trimethoprim Sulfa	92.0		8.0	≤ 0.12	1	≤ 0.12	> 8
***Proteus mirabilis* (860)**							
Amikacin	99.3	0.7		4	8	≤ 2	32
Amox-Clav	95.5	1.5	3.0	1	4	0.5	> 32
Cefazolin	3.6	59.4	37.0	4	8	1	> 128
Cefepime	99.5	0.1	0.4	≤ 1	≤ 1	≤ 1	> 32
Cefoxitin	96.3	2.3	1.4	4	4	≤ 0.06	> 32
Ceftazidime	98.8	0.4	0.8	≤ 0.25	≤ 0.25	≤ 0.25	> 32
Ceftobiprole[a]	99.0	0.1	0.9	≤ 1	≤ 1	≤ 1	> 32
Ceftol-Tazo	99.6	0.2	0.2	0.5	1	≤ 0.12	8
Ceftriaxone	97.7	0.8	1.5	≤ 1	≤ 1	≤ 1	> 64
Ciprofloxacin	83.0	1.2	15.8	≤ 0.06	2	≤ 0.06	> 16
Doxycycline	0.8	1.2	98.0	> 32	> 32	4	> 32
Ertapenem	99.5	0.3	0.3	≤ 0.06	≤ 0.06	≤ 0.06	4
Gentamicin	94.7	1.2	4.2	1	2	≤ 0.5	> 32
Imipenem	37.8	29.8	32.4	2	4	0.12	16
Levofloxacin	79.3	3.1	17.6	0.12	2	≤ 0.06	> 32
Meropenem	100			≤ 0.12	≤ 0.12	≤ 0.12	1
Moxifloxacin				0.5	16	≤ 0.06	> 16
Pip-Tazo	99.7	0.1	0.2	≤ 1	≤ 1	≤ 0.12	64
Tobramycin	95.1	1.6	3.3	≤ 0.5	2	≤ 0.5	> 64
Trimethoprim Sulfa	82.6		17.4	≤ 0.12	> 8	≤ 0.12	> 8
***Klebsiella oxytoca* (972)**							
Amikacin	99.9		0.1	≤ 2	≤ 2	≤ 2	> 64
Amox-Clav	87.6	5.2	7.2	2	16	0.5	> 32
Cefazolin	22.1	20.4	57.5	8	> 128	≤ 0.5	> 128
Cefepime	97.1	1.6	1.4	≤ 1	≤ 1	≤ 1	> 32
Cefoxitin	95.2	3.0	1.8	2	8	0.5	> 32
Ceftazidime	97.7	0.3	2.0	≤ 0.25	1	≤ 0.25	> 32
Ceftobiprole[a]	85.3	2.0	12.7	≤ 1	16	≤ 1	> 32
Ceftol-Tazo	98.4	1.3	0.3	0.25	1	≤ 0.12	64
Ceftriaxone	89.5	1.5	9.1	≤ 0.25	2	≤ 0.25	> 64
Ciprofloxacin	95.8	0.8	3.3	≤ 0.06	≤ 0.06	≤ 0.06	> 16
Colistin		98.2	1.8	0.5	1	≤ 0.06	> 16
Doxycycline	91.8	3.1	5.1	1	4	0.25	> 32
Ertapenem	99.7	0.1	0.2	≤ 0.06	≤ 0.06	≤ 0.06	32
Gentamicin	97.6	0.3	2.1	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Imipenem	99.8	0.2		0.25	0.5	0.06	2
Levofloxacin	94.9	1.8	3.3	≤ 0.06	0.25	≤ 0.06	> 32
Meropenem	99.9	0.1		≤ 0.12	≤ 0.12	≤ 0.12	2
Moxifloxacin				≤ 0.06	0.25	≤ 0.06	> 16
Nitrofurantoin	86.4	11.6	2.1	32	64	≤ 1	> 512
Pip-Tazo	87.8	0.7	11.5	2	128	≤ 1	> 512
Tigecycline[b]	98.5	1.3	0.2	0.5	1	0.06	8
Tobramycin	97.9	0.5	1.6	≤ 0.5	1	≤ 0.5	64
Trimethoprim Sulfa	94.7		5.3	≤ 0.12	0.25	≤ 0.12	> 8
***Klebsiella aerogenes* (388)**							
Amikacin	100			≤ 2	≤ 2	≤ 2	8
Cefepime	98.3	0.6	1.2	≤ 1	≤ 1	≤ 1	> 32
Ceftazidime	74.4	2.0	23.6	0.5	> 32	≤ 0.25	> 32
Ceftobiprole[a]	98.3		1.7	≤ 1	≤ 1	≤ 1	> 32
Ceftol-Tazo	87.4	7.9	4.7	0.5	4	≤ 0.12	64
Ceftriaxone	73.0	1.0	26.0	≤ 1	32	≤ 1	> 64
Ciprofloxacin	92.2	2.3	5.5	≤ 0.06	0.25	≤ 0.06	> 16
Colistin		98.4	1.6	0.5	0.5	0.12	> 16
Ertapenem	93.2	4.4	2.5	0.12	0.5	≤ 0.03	> 32
Gentamicin	99.7		0.3	≤ 0.5	≤ 0.5	≤ 0.5	32
Levofloxacin	92.2	1.1	6.7	≤ 0.06	0.5	≤ 0.06	16
Meropenem	99.2	0.3	0.5	≤ 0.12	≤ 0.12	≤ 0.12	> 32
Moxifloxacin				0.12	1	≤ 0.06	16
Nitrofurantoin	17.7	56.1	26.3	64	128	8	> 512
Pip-Tazo	74.0	10.4	15.6	4	32	≤ 1	512
Tigecycline[b]	96.1	2.9	1.0	1	2	0.06	8
Trimethoprim Sulfa	98.2		1.8	≤ 0.12	0.5	≤ 0.12	> 8

Amox-Clav, Amoxicillin-Clavulanate; Ceftol-Tazo, Ceftolozane-Tazobactam; Pip-Tazo, Piperacillin-Tazobactam; Trimethoprim-Sulfa, Trimethoprim-Sulfamethoxazole; ESBL, extended-spectrum ß-lactamase
* Actual value ≥99.9%; † Actual value <0.1%.
[a] For ceftobiprole, Health Canada breakpoints applied. Not all isolates tested with ceftobiprole.
[b] For tigecycline, FDA breakpoints applied.

Table 3. The 20 most common organisms isolated from Canadian hospitals

Rank	Organism	N	% Total
1	*Staphylococcus aureus*	11,910	20.9
	MSSA	9,397	16.5
	MRSA	2,513	4.4
2	*Escherichia coli*	11,090	19.5
3	*Pseudomonas aeruginosa*	5,454	9.6
4	*Klebsiella pneumoniae*	3,680	6.5
5	*Streptococcus pneumoniae*	3,068	5.4
6	*Haemophilus influenzae*	2,228	3.9
7	CNS / *S. epidermidis*	2,044	3.6
8	*Enterococcus faecalis*	1,655	2.9
9	*Enterobacter cloacae*	1,517	2.7
10	*Stenotrophomonas maltophilia*	1,072	1.9
11	*Klebsiella oxytoca / Raoultella* spp.	972	1.7
12	*Serratia marcescens*	908	1.6
13	*Streptococcus agalactiae*	904	1.6
14	*Proteus mirabilis*	860	1.5
15	*Streptococcus pyogenes*	808	1.4
16	*Enterococcus faecium*	681	1.2
17	*Enterococcus*, non-speciated	583	1.0
18	*Moraxella catarrhalis*	560	1.0
19	*Candida albicans*	557	1.0
20	Viridans group streptococci	482	0.8
	Other	5,903	10.4
		56,936	

Table 4. Demographics of patients / isolates from CANWARD (n=56,936)

Demographic Variable	N	% of Total
Gender[a]		
Female	25,690	45.1
Male	31,243	54.9
Age Group[b]		
≤ 17 years	6,774	11.9
18 - 64 years	25,184	44.2
≥ 65 years	24,975	43.9
Specimen Source		
Blood	24,395	42.9
Respiratory	19,670	34.5
Urine	7,085	12.4
Wound	5,786	10.2
Ward Type[c]		
Clinic	10,173	17.9
ER	13,879	24.3
ICU	10,796	19.0
Medical	17,458	30.7
Surgical	4,623	8.1

[a] Gender unknown for 3 isolates
[b] Age unknown for 3 isolates
[c] Patient location unknown for 7 isolates

Conclusions

1. Of the 56,936 pathogens obtained, the most common were: *S. aureus* 20.9% (MSSA 16.5% / MRSA 4.4%), *E. coli* 19.5%, *P. aeruginosa* 9.6%, *K. pneumoniae* 6.5%, *S. pneumoniae* 5.4%, *Enterococcus* spp. (*E. faecalis* and *E. faecium*) 4.1%, and *H. influenzae* 3.9%.
2. Isolates were obtained from blood (42.9%), respiratory (34.5%), urine (12.4%) and wound specimens (10.2%); and from patients on wards 38.8% (30.7% medical/8.1% surgical), ER 24.3%, ICU 19.0%, and clinics 17.9%.
3. ESBL-producing *E. coli* (3.4%-14.7%) and *K. pneumoniae* (1.5%-9.7%) increased significantly over time.
4. Carbapenem-resistant *E. coli* (0-0.20%) and *K. pneumoniae* (0-0.48%) remain relatively low in Canada.
5. MRSA rates decreased significantly from 26.1 to 19.2% over time.
6. VRE rates were 3.7% to 10.9%, with marked fluctuation year-to-year.
7. Susceptibility rates for *E. coli* were: 99.9% meropenem and tigecycline, 99.7% ertapenem, 99.6% amikacin, 99.2% ceftolozane-tazobactam, 95.6% piperacillin-tazobactam, 92.9% cefepime, 91.7% ceftobiprole, 90.5% gentamicin, 89.8% ceftriaxone, 73.9% ciprofloxacin, and 72.7% trimethoprim-sulfamethoxazole.
8. Susceptibility rates for *P. aeruginosa* were: 97.0% ceftolozane-tazobactam, 96.1% colistin (‘Intermediate’ category), 92.0% amikacin, 81.8% gentamicin, 78.0% ceftazidime, 80.2% piperacillin-tazobactam, 78.1% meropenem, and 67.3% ciprofloxacin.
9. Susceptibility rates for MRSA were: 100% ceftobiprole, 99.9% linezolid and vancomycin, 99.8% daptomycin, 98.9% lefamulin, 98.7% tigecycline, 97.8% doxycycline, 94.7% trimethoprim-sulfamethoxazole, 58.8% clindamycin, 20.3% ciprofloxacin and 17.4% for clarithromycin.

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