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Antimicrobial Susceptibility of 42,938 Pathogens Isolated from Patients in Canadian Hospitals: CANWARD Study 2007-2016

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REVISED ABSTRACT

Background: CANWARD is a national, annual, ongoing surveillance study assessing pathogens causing infections in Canadian hospitals and their antimicrobial resistance patterns.

Methods: From 2007 to 2016, 42,938 pathogens were collected from patients attending hospital clinics, emergency rooms, medical and surgical wards, and intensive care units in tertiary-care hospitals across Canada. Antimicrobial susceptibility testing was performed using CLSI broth microdilution methods with >40 marketed and investigational antimicrobial agents.

Results: Specimen source composition of the 42,938 isolates was 43.5% blood, 33.1% respiratory, 13.2% urine and 10.2% wound specimens. Patient demographic characteristics were: 54.6/45.4% male/female; 13.1/44.2/42.7% patients aged ≤17/18-64/≥65 years; and 38.1/24.8/19.0/18.1% patients located in medical and surgical wards/emergency rooms/ICUs/clinics. The most common pathogens were: *E. coli* (EC 19.6%), methicillin-susceptible *Staphylococcus aureus*-MSSA (16.6%), *Pseudomonas aeruginosa* (PA 9.0%), *Streptococcus pneumoniae* (SPN 6.1%), *Klebsiella pneumoniae* (KP 6.1%), *Enterococcus* spp. (5.4%), methicillin-resistant *S. aureus*-MRSA (4.6%), and *Haemophilus influenzae* (4.1%). Susceptibility rates (SR) for EC were: 99.9% for meropenem (MER) and tigecycline (TGC), 99.7% ertapenem (ERT), 97.6% piperacillin-tazobactam (PTZ), 91.8% ceftriaxone (CTR), 90.5% gentamicin (GEN), 77.0% ciprofloxacin (CIP) and 73.2% TMP-SMX (SXT). SR for PA were: 98.3% ceftolozane/tazobactam (C/T), 94.8% colistin, 84.1% PTZ, 82.9% ceftazidime (CAZ), 81.1% MER, 79.4% GEN and 75.2% CIP. SR for MRSA were: 100% for linezolid (LZD) and telavancin (TLV), 99.9% daptomycin (DAP) and vancomycin, 99.2% TGC, and 93.9% SXT. Rates of resistant organisms between 2007-2016 increased significantly for ESBL-producing EC (3.4%-12.4%) as well as VRE (1.8%-2.8%), whereas MRSA rates (26.1%-16.5%) significantly declined.

Conclusions: EC, MSSA, PA, SPN, KP, and MRSA are the most common pathogens in Canadian hospitals. SR for EC were highest for MER, TGC, ERT and PTZ. SR for PA were highest for C/T, colistin, PTZ, CAZ and MER. 99-100% of MRSA were susceptible DAP, LZD, TLV, and vancomycin.

INTRODUCTION

Infections caused by 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* (PRSP), and Gram-negative bacilli such as extended spectrum B-lactamase (ESBL) producing *Escherichia coli* and *Klebsiella species* and fluoroquinolone-resistant and carbapenem-resistant Enterobacteriaceae and *Pseudomonas aeruginosa* are increasing in prevalence in Canada and around the world (1,2). Available therapeutic options for the treatment of these antibiotic resistant organisms are limited as these organisms frequently display a multidrug resistant (MDR) and potentially and extremely drug resistant (XDR) phenotype (1,2).

The ongoing goal of the CANWARD study is to assess pathogens associated with and antimicrobial resistance patterns in respiratory, bacteremic, urinary, and wound/IV site infections in Canadian hospitalized patients on medical/surgical wards (W), Emergency rooms (ER), outpatient clinics (C) and intensive care units (ICU).

PURPOSE

- To determine the pathogens associated with respiratory, urinary, bacteremic and wound/IV site infections in Canadian patients affiliated with hospitals from 2007-2016, inclusive.
- To determine the prevalence of antimicrobial resistance in pathogens associated with respiratory, urinary, bacteremic and wound/IV site infections in Canadian patients affiliated with hospitals from 2007-2016, inclusive.
- To assess the activity of antimicrobials against respiratory, urinary, bacteremic and wound/IV site pathogens in Canadian patients affiliated with hospitals from 2007-2016, inclusive.

REFERENCES

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MATERIALS & METHODS

Participating Sites:

From January 2007 to October 2016, sentinel hospital sites (12 in 2007, 10 in 2008, 15 in 2009, 14 in 2010, 15 in 2011, 12 in 2012, 15 in 2013, 13 in 2014 and 13 in 2015, 13 in 2016) in major population centres in 8 of the 10 provinces in Canada were recruited (see Appendix and references 1 and 2). These sites were geographically distributed in a population based fashion: (BC [1 site], Alberta [1 site], Saskatchewan [1 site], Manitoba [1 site], Ontario [3-5 sites], Quebec [2-4 sites], Maritimes [1-2 sites]).

Bacterial Isolates:

Tertiary-care medical centres submitted pathogens from patients attending hospital clinics, emergency rooms, medical and surgical wards, and intensive care units. From January 2007 through October 2016, inclusive, 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. The medical centres submitted "clinically significant" isolates from patients with a presumed infectious disease. Surveillance swabs, eye, ear, nose and throat swabs were excluded. We also excluded anaerobic organisms. Isolate identification was performed by the submitting site and confirmed at the reference site as required, based on morphological characteristics and antimicrobial susceptibility patterns. 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 -80°C until minimum inhibitory concentration (MIC) testing was carried out. In 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016; 7718, 5283, 5374, 4960, 3788, 2802, 3511, 3174, 3206 and 3126 isolates were collected, respectively (1,2).

Antimicrobial Susceptibilities:

Following 2 subcultures from frozen stock, the in vitro activity of selected antimicrobials was determined by broth microdilution in accordance with the Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2015 M7-A10). Antimicrobial minimum inhibitory concentration (MIC) interpretive standards were defined according to CLSI breakpoints (M100S, 2015). Susceptibility testing could not be performed with all agents due to lack of space on the susceptibility panels. Antimicrobial agents were obtained as laboratory grade powders from their respective manufacturers. Stock solutions were prepared and dilutions made as described by CLSI (M7-A10, 2015). The MICs of the antimicrobial agents for the isolates were determined using 96-well custom designed microtitre plates. These plates contained doubling antimicrobial dilutions in 100µl/well of cation adjusted Mueller-Hinton broth and inoculated to achieve a final concentration of approximately 5 x 10^5 CFU/ml then incubated in ambient air for 24 hours prior to reading. 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.

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RESULTS

Table 1. National demographics of patients/isolates from CANWARD 2007-2016

Gender	N	% Total
Female	19,498	45.4
Male	23,437	54.6
	42,935*	

*demographics unknown for 3 isolates

Age Group	N	% Total
≤17 years	5,607	13.0
18 – 64 years	19,003	44.3
≥65 years	18,325	42.7
	42,935*	

*demographics unknown for 3 isolates

Ward Type	N	% Total
Clinic	7,753	18.1
ER	10,634	24.8
ICU	8,141	19.0
Medical	12,819	29.9
Surgical	3,584	8.2
	42,931*	

*demographics unknown for 7 isolates

Specimen Source	N	% Total
Blood	18,686	43.5
Respiratory	14,212	33.1
Urine	5,649	13.2
Wound	4,391	10.2
	42,938	

RESULTS

Table 2. Antimicrobial activity against the most common Gram-positive cocci isolated from Canadian hospitals

Organism (n) / Antimicrobial Agent	% S	% I	% R	MIC_{50}	MIC_{90}	Range Min	Range Max
***Staphylococcus aureus*, MSSA (n=7146)**							
Cefoxitin	99.56%		0.44%	4	4	0.12	32
Ceftobiprole[a]	100%			0.5	0.5	≤ 0.06	2
Ceftriaxone				4	4	≤ 0.25	256
Ciprofloxacin	86.45%	2.96%	10.60%	0.5	4	≤ 0.06	> 16
Clarithromycin	75.97%	0.53%	23.50%	0.25	> 32	≤ 0.03	> 32
Clindamycin	93.47%	0.41%	6.12%	≤ 0.12	≤ 0.12	≤ 0.12	> 8
Daptomycin	100%			0.25	0.25	≤ 0.03	1
Doxycycline	99.00%	0.75%	0.25%	≤ 0.12	≤ 0.12	≤ 0.12	16
Gentamicin	98.09%	0.08%	1.82%	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Levofloxacin	90.10%	0.33%	9.57%	0.25	1	≤ 0.06	> 32
Linezolid	99.93%		0.07%	2	4	≤ 0.12	8
Moxifloxacin	90.43%	0.76%	8.82%	≤ 0.06	0.25	≤ 0.06	> 16
Nitrofurantoin	99.96%	0.04%		16	16	≤ 0.5	64
Telavancin	100%			0.06	0.06	0.008	0.12
Tigecycline[b]	99.89%			0.12	0.25	≤ 0.03	1
Tobramycin	97.34%	0.33%	2.33%	≤ 0.5	≤ 0.5	≤ 0.5	> 64
TMP-SMX	99.47%		0.53%	≤ 0.12	≤ 0.12	≤ 0.12	> 8
Vancomycin	100%			1	1	≤ 0.12	2
***Staphylococcus aureus*, MRSA (n=1963)**							
Cefoxitin	0.12%		99.88%	> 32	> 32	1	> 32
Ceftobiprole	99.71%		0.29%	1	2	0.25	4
Ceftriaxone				> 64	> 64	2	> 256
Ciprofloxacin	17.42%	0.36%	82.22%	> 16	> 16	≤ 0.06	> 16
Clarithromycin	15.13%	0.41%	84.46%	> 32	> 32	≤ 0.03	> 32
Clindamycin	53.89%	0.05%	46.06%	≤ 0.12	> 8	≤ 0.12	> 8
Daptomycin	99.90%		0.10%	0.25	0.5	0.06	4
Doxycycline	97.53%	1.06%	1.41%	≤ 0.12	1	≤ 0.12	16
Gentamicin	92.92%	0.25%	6.83%	≤ 0.5	1	≤ 0.5	> 32
Levofloxacin	14.06%		85.94%	> 32	> 32	0.12	> 32
Linezolid	100%			2	4	≤ 0.12	4
Moxifloxacin	18.03%	3.52%	78.45%	8	> 16	≤ 0.06	> 16
Nitrofurantoin	100%			16	16	8	32
Telavancin	100%			0.06	0.06	0.015	0.12
Tigecycline	99.18%			0.25	0.5	≤ 0.03	2
Tobramycin	59.11%	0.82%	40.07%	≤ 0.5	> 64	≤ 0.5	> 64
TMP-SMX	94.09%		5.91%	≤ 0.12	≤ 0.12	≤ 0.12	> 8
Vancomycin	99.85%	0.15%		1	1	≤ 0.12	4
***Staphylococcus epidermidis* (n=945)**							
Amox Clavulanate				1	8	≤ 0.06	32
Cefazolin				1	64	≤ 0.5	> 128
Cefepime				4	64	≤ 0.25	128
Cefoxitin				8	> 32	≤ 0.06	> 32
Ceftobiprole				0.5	1	≤ 0.03	4
Ceftriaxone				8	> 64	≤ 0.25	>64
Ciprofloxacin	46.80%	1.49%	51.71%	4	> 16	≤ 0.06	> 16
Clarithromycin	33.62%	1.49%	64.89%	> 32	> 32	≤ 0.03	> 32
Clindamycin	57.52%	1.49%	40.98%	≤ 0.12	> 8	≤ 0.12	> 8
Daptomycin	100%			0.12	0.25	≤ 0.03	1
Doripenem				1	16	≤ 0.03	> 32
Doxycycline	96.63%	1.80%	1.57%	0.25	1	≤ 0.12	32
Ertapenem				2	> 32	≤ 0.03	> 32
Gentamicin				≤ 0.5	> 32	≤ 0.5	> 32
Levofloxacin	44.24%	1.56%	54.21%	4	> 32	0.12	> 32
Linezolid	100%			0.5	1	≤ 0.12	4
Meropenem				2	32	≤ 0.03	64
Moxifloxacin	48.51%	8.21%	43.28%	1	> 16	≤ 0.06	> 16
Pip-Tazo				≤ 1	16	≤ 1	128
Telavancin	98.98%		1.02%	0.06	0.12	0.015	0.25
Tigecycline				0.12	0.25	≤ 0.03	1
Tobramycin	63.12%	12.44%	24.43%	≤ 0.5	32	≤ 0.5	> 64
TMP-SMX	60.34%		39.66%	1	8	≤ 0.12	> 8
Vancomycin	100%			1	2	≤ 0.12	4
***Streptococcus pneumoniae* (n=2626)**							
Amox Clavulanate	97.96%	1.20%	0.84%	≤ 0.06	0.12	≤ 0.06	16
Ceftobiprole	99.89%		0.11%	≤ 0.03	0.06	≤ 0.03	1
Ceftriaxone	99.40%	0.44%	0.16%	≤ 0.06	≤ 0.06	≤ 0.06	4
Cefuroxime	93.48%	1.88%	4.64%	≤ 0.25	≤ 0.25	≤ 0.25	> 16
Chloramphenicol	98.78%		1.22%	2	4	≤ 0.12	32
Ciprofloxacin	96.92%		3.08%	1	2	≤ 0.06	> 16
Clarithromycin	78.45%	3.49%	18.07%	≤ 0.03	4	≤ 0.03	> 32
Clindamycin	92.83%	0.52%	6.65%	≤ 0.12	≤ 0.12	≤ 0.12	> 64
Daptomycin				0.06	0.12	≤ 0.03	0.5
Doxycycline	86.73%	1.28%	11.98%	≤ 0.25	2	≤ 0.25	> 16
Ertapenem	99.00%	0.96%	0.04%	≤ 0.06	0.12	≤ 0.06	4
Imipenem	93.79%	4.43%	1.77%	≤ 0.03	≤ 0.03	≤ 0.03	1
Levofloxacin	99.04%	0.16%	0.80%	1	1	≤ 0.06	32
Linezolid	99.32%		0.68%	1	1	≤ 0.12	4
Meropenem	95.15%	3.13%	1.72%	≤ 0.06	≤ 0.06	≤ 0.06	2
Moxifloxacin	99.08%	0.44%	0.48%	0.12	0.25	≤ 0.06	8
Penicillin	82.58%	13.24%	4.18%	≤ 0.03	0.25	≤ 0.03	> 8
Pip-Tazo				≤ 1	≤ 1	≤ 1	8
Telavancin				0.008	0.015	≤ 0.002	0.03
Tigecycline	99.72%		0.28%	≤ 0.015	0.06	≤ 0.015	0.25
TMP-SMX	84.97%	6.30%	8.73%	≤ 0.12	2	≤ 0.12	> 8
Vancomycin	100%			≤ 0.25	0.25	≤ 0.12	1
***Streptococcus agalactiae* (n=689)**							
Amox Clavulanate				≤ 0.06	≤ 0.06	≤ 0.06	0.25
Ceftobiprole				≤ 0.03	≤ 0.03	≤ 0.03	0.06
Ceftriaxone	100%			≤ 0.12	≤ 0.12	≤ 0.12	0.5
Cefuroxime				≤ 0.25	≤ 0.25	≤ 0.25	0.5
Chloramphenicol	97.72%	2.28%		2	4	0.5	8
Ciprofloxacin				0.5	1	0.25	> 16
Clarithromycin	67.34%	4.30%	28.35%	≤ 0.03	32	≤ 0.03	> 32
Clindamycin	81.77%	0.76%	17.47%	≤ 0.12	> 64	≤ 0.12	> 64
Daptomycin	100%			0.25	0.25	≤ 0.03	0.5
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	95.70%		4.30%	0.5	1	0.25	> 32
Linezolid	95.95%		4.05%	1	2	≤ 0.12	4
Meropenem	100%			≤ 0.06	≤ 0.06	≤ 0.06	0.12
Moxifloxacin				0.12	0.25	≤ 0.06	16
Penicillin	99.75%		0.25%	0.06	0.12	≤ 0.03	0.25
Pip-Tazo				≤ 1	≤ 1	≤ 1	≤ 1
Telavancin	100%			0.06	0.06	0.03	0.06
Tigecycline	99.75%		0.25%	0.06	0.06	≤ 0.015	1
TMP-SMX				≤ 0.12	≤ 0.12	≤ 0.12	1
Vancomycin	100%			0.5	0.5	≤ 0.25	1
***Streptococcus pyogenes* (n=642)**							
Amox Clavulanate				≤ 0.06	≤ 0.06	≤ 0.06	0.5
Ceftobiprole				≤ 0.03	≤ 0.03	≤ 0.03	0.12
Ceftriaxone	99.84%		0.16%	≤ 0.12	≤ 0.12	≤ 0.12	1
Cefuroxime				≤ 0.25	≤ 0.25	≤ 0.25	0.5
Chloramphenicol	98.85%	1.15%		2	4	0.5	8
Ciprofloxacin				0.5	1	≤ 0.06	8
Clarithromycin	89.80%	2.14%	8.06%	≤ 0.03	0.5	≤ 0.03	> 32
Clindamycin	98.03%		1.97%	≤ 0.12	≤ 0.12	≤ 0.12	> 64
Daptomycin	100%			0.06	0.12	≤ 0.03	0.25
Doxycycline				≤ 0.25	0.5	≤ 0.25	16
Ertapenem	100%			≤ 0.06	≤ 0.06	≤ 0.06	0.12
Imipenem				≤ 0.03	≤ 0.03	≤ 0.03	0.06
Levofloxacin	99.84%	0.16%		0.5	1	≤ 0.06	4
Linezolid	99.34%		0.66%	1	2	≤ 0.12	4
Meropenem	100%			≤ 0.06	≤ 0.06	≤ 0.06	0.12
Moxifloxacin				0.12	0.25	≤ 0.06	0.5
Penicillin	100%			≤ 0.03	≤ 0.03	≤ 0.03	0.12
Pip-Tazo				≤ 1	≤ 1	≤ 1	≤ 1
Telavancin	100%			0.03	0.06	0.015	0.06
Tigecycline	100%			0.03	0.06	≤ 0.015	0.25
TMP-SMX				≤ 0.12	≤ 0.12	≤ 0.12	> 8
Vancomycin	100%			0.5	0.5	≤ 0.12	1
***Enterococcus faecalis* (n=1255)**							
Amox Clavulanate				0.5	1	≤ 0.06	32
Cefazolin				32	64	≤ 0.5	> 128
Ceftazidime				> 32	> 32	≤ 0.5	> 32
Ceftobiprole				0.5	1	≤ 0.03	> 32
Ceftriaxone				> 64	> 64	≤ 0.25	> 256
Ciprofloxacin	62.40%	9.98%	27.62%	1	> 16	≤ 0.06	> 16
Clarithromycin				2	> 32	≤ 0.03	> 32
Clindamycin				> 8	> 8	≤ 0.12	> 8
Colistin				> 16	> 16	1	> 16
Daptomycin	100%			0.5	1	≤ 0.03	4
Doripenem				4	4	≤ 0.06	> 32
Doxycycline	36.39%	46.36%	17.25%	8	16	≤ 0.12	32
Ertapenem				8	16	0.25	> 32
Gentamicin				16	> 32	≤ 0.5	> 32
Imipenem				1	2	0.25	4
Levofloxacin	65.62%	1.05%	33.33%	2	> 32	0.25	> 32
Linezolid	90.20%	9.80%		2	2	0.5	4
Meropenem				4	8	≤ 0.06	> 32
Moxifloxacin				0.25	16	≤ 0.06	> 16
Nitrofurantoin	99.58%	0.42%		8	8	≤ 0.5	64
Pip-Tazo				4	4	≤ 1	> 512
Tigecycline	98.34%			0.12	0.25	≤ 0.03	1
Tobramycin				16	> 64	≤ 0.5	> 64
TMP-SMX				≤ 0.12	0.25	≤ 0.12	> 8
Vancomycin	100%			1	2	0.25	4
***Enterococcus faecium* (n=481)**							
Amox Clavulanate				> 32	> 32	≤ 0.06	> 32
Cefazolin				> 128	> 128	≤ 0.5	> 128
Ceftazidime				> 32	> 32	8	> 32
Ceftobiprole				> 32	> 64	0.25	128
Ceftriaxone				> 64	> 64	0.5	> 256
Ciprofloxacin	6.75%	1.90%	91.35%	> 16	> 16	0.25	> 16
Clarithromycin				> 32	> 32	≤ 0.03	> 32
Clindamycin				> 8	> 8	≤ 0.12	> 8
Colistin				> 16	> 16	4	> 16
Daptomycin	100%			1	2	≤ 0.03	4
Doripenem				> 32	> 32	0.12	> 64
Doxycycline	76.32%	6.77%	16.92%	0.5	16	≤ 0.12	32
Ertapenem				> 32	> 32	0.5	> 32
Gentamicin				8	> 32	≤ 0.5	> 32
Imipenem				> 32	> 32	0.12	> 32
Levofloxacin	9.49%	1.27%	89.24%	> 32	> 32	1	> 32
Linezolid	87.37%	12.21%	0.42%	2	4	≤ 0.12	16
Meropenem				> 32	> 32	0.25	> 64
Moxifloxacin				> 16	> 16	0.12	> 16
Nitrofurantoin	45.66%	24.86%	29.48%	64	128	≤ 0.5	> 512
Pip-Tazo				> 512	> 512	≤ 1	> 512
Tigecycline				0.12	0.12	≤ 0.03	2
Tobramycin				64	> 64	4	> 64
TMP-SMX				0.25	> 8	≤ 0.12	> 8
Vancomycin	77.68%		22.32%	0.5	> 32	≤ 0.12	> 32

S=susceptible, I=intermediate, R=resistant. Pip-Tazo: piperacillin-tazobactam. Amox Clavulanate: amoxicillin-clavulanate. All MICs interpreted using CLSI breakpoints, with the exception of tigecycline (FDA breakpoints) and ceftobiprole (EUCAST). [a] EUCAST breakpoints applied for ceftobiprole (µg/mL): *S. aureus* (S) ≤2, (R) >2; *S. pneumoniae* (S) ≤0.5, (R) >0.5. Not all isolates tested with ceftobiprole.

Table 3. Antimicrobial activity against the most common Gram-negative bacilli isolated from Canadian hospitals

Organism (n) / Antimicrobial Agent	%S	%I	%R	MIC_{50}	MIC_{90}	Range Min	Range Max
***Escherichia coli* (n=8387)**							
Amikacin	99.67%	0.23%	0.11%	≤ 2	4	≤ 2	> 64
Amox Clavulanate	85.24%	10.66%	4.10%	4	16	≤ 0.06	> 32
Cefazolin	70.88%	11.63%	17.49%	2	32	≤ 0.5	> 128
Cefepime	95.06%	2.32%	2.62%	≤ 0.25	≤ 0.25	≤ 0.25	> 64
Cefoxitin	92.55%	3.85%	3.60%	4	8	≤ 0.06	> 32
Ceftazidime	93.70%	0.86%	5.43%	≤ 0.25	1	≤ 0.25	> 32
Ceftobiprole[a]	76.83%		23.17%	≤ 0.06	≤ 0.06	≤ 0.06	> 128
Ceftolozane-Tazo	99.64%	0.20%	0.17%	≤ 0.12	0.25	≤ 0.12	>64
Ceftriaxone	91.75%	0.31%	7.94%	≤ 0.25	≤ 1	≤ 0.25	> 256
Ciprofloxacin	77.02%	0.20%	22.78%	≤ 0.06	> 16	≤ 0.06	> 16
Colistin	99.77%		0.23%	0.25	0.5	≤ 0.06	16
Doxycycline	72.42%	5.82%	21.76%	2	32	0.25	> 256
Ertapenem	99.74%	0.15%	0.11%	≤ 0.03	≤ 0.03	≤ 0.03	> 32
Gentamicin	90.52%	0.39%	9.09%	≤ 0.5	2	≤ 0.5	> 32
Imipenem	99.94%	0.03%	0.03%	0.12	0.25	≤ 0.03	8
Levofloxacin	78.75%	0.66%	20.59%	≤ 0.06	16	≤ 0.06	> 32
Meropenem	99.99%		0.01%	≤ 0.03	≤ 0.12	≤ 0.03	32
Moxifloxacin				≤ 0.06	> 16	≤ 0.06	> 16
Nitrofurantoin	97.06%	1.96%	0.97%	16	32	≤ 0.5	> 256
Pip-Tazo	97.62%	1.17%	1.22%	2	4	≤ 1	> 512
Tigecycline[b]	99.96%	0.04%		0.25	0.5	0.06	4
Tobramycin	91.31%	3.46%	5.24%	≤ 0.5	4	≤ 0.5	> 64
TMP-SMX	73.18%		26.82%	≤ 0.12	> 8	≤ 0.12	> 8
ESBL *E. coli* (n=539)							
Amikacin	97.59%	2.04%	0.37%	2	8	≤ 1	> 64
Amox Clavulanate	50.65%	39.33%	10.02%	8	32	1	> 32
Cefazolin		0.19%	99.81%	> 128	> 128	4	> 128
Cefepime	31.83%	31.83%	36.35%	8	32	≤ 0.25	> 64
Cefoxitin	81.82%	9.83%	8.35%	8	16	0.5	> 32
Ceftazidime	35.39%	9.05%	55.56%	16	> 32	≤ 0.5	> 32
Ceftobiprole	1.55%		98.45%	32	64	0.12	> 128
Ceftolozane-Tazo	97.46%	1.41%	1.13%	0.25	1	≤ 0.12	>64
Ceftriaxone	2.23%	1.48%	96.29%	> 64	> 64	≤ 0.25	> 64
Ciprofloxacin	11.69%	0.37%	87.94%	> 16	> 16	≤ 0.06	> 16
Colistin	100%			0.25	1	≤ 0.06	2
Doxycycline	29.87%	15.37%	54.76%	16	64	0.25	> 256
Ertapenem	97.95%	0.93%	1.12%	≤ 0.03	0.25	≤ 0.03	> 32
Gentamicin	59.18%	1.11%	39.70%	1	> 32	≤ 0.5	> 32
Imipenem	99.72%		0.28%	0.12	0.25	0.06	8
Levofloxacin	12.90%	1.29%	85.81%	16	32	≤ 0.06	> 32
Meropenem	99.81%		0.19%	≤ 0.03	≤ 0.12	≤ 0.03	32
Moxifloxacin				16	> 16	≤ 0.06	> 16
Nitrofurantoin	92.50%	5.07%	2.44%	16	32	≤ 1	256
Pip-Tazo	93.51%	3.90%	2.60%	4	16	≤ 1	> 512
Tigecycline	99.81%	0.19%		0.5	1	0.12	4
Tobramycin	52.82%	7.63%	39.55%	4	32	≤ 0.5	> 64
TMP-SMX	31.17%		68.83%	> 8	> 8	≤ 0.12	> 8
***Pseudomonas aeruginosa* (n=3864)**							
Amikacin	91.97%	3.63%	4.40%	4	16	≤ 1	> 64
Amox Clavulanate				> 32	> 32	0.12	> 32
Cefepime	82.33%	12.19%	5.48%	4	16	≤ 0.25	> 128
Ceftazidime	82.89%	6.05%	11.06%	4	32	≤ 0.25	> 32
Ceftobiprole				4	16	0.12	> 128
Ceftolozane-Tazo	98.34%	0.73%	0.93%	0.5	1	≤ 0.06	>64
Ceftriaxone				16	> 64	≤ 0.25	> 256
Ciprofloxacin	75.40%	8.18%	16.42%	0.25	8	≤ 0.06	> 16
Colistin	94.98%		5.02%	1	2	≤ 0.06	> 16
Doripenem	84.33%	6.27%	9.39%	0.5	4	≤ 0.03	> 64
Ertapenem				8	> 32	0.06	> 32
Gentamicin	79.65%	9.24%	11.11%	2	16	≤ 0.5	> 32
Imipenem	69.65%	9.00%	21.34%	2	16	≤ 0.03	> 32
Levofloxacin	63.48%	12.06%	24.46%	1	16	≤ 0.06	> 32
Meropenem	81.18%	6.89%	11.94%	0.5	8	≤ 0.03	> 64
Moxifloxacin				2	> 16	≤ 0.06	> 16
Nitrofurantoin				> 512	> 512	16	> 512
Pip-Tazo	84.15%	8.49%	7.35%	4	64	≤ 1	> 512
Tigecycline				16	> 16	0.25	> 16
Tobramycin	93.15%	1.32%	5.53%	≤ 0.5	2	≤ 0.5	> 64
TMP-SMX				8	> 8	≤ 0.12	> 8
***Klebsiella pneumoniae* (n=2624)**							
Amikacin	99.69%	0.08%	0.23%	≤ 1	2	≤ 1	> 64
Amox Clavulanate	93.78%	3.30%	2.92%	2	8	≤ 0.06	> 32
Cefazolin	83.06%	6.07%	10.87%	1	8	≤ 0.5	> 128
Cefepime	96.46%	1.47%	2.07%	≤ 0.25	≤ 1	≤ 0.25	128
Cefoxitin	91.42%	3.81%	4.78%	4	8	0.12	> 32
Ceftazidime	95.66%	0.37%	3.97%	≤ 0.25	1	≤ 0.25	> 32
Ceftobiprole	80.69%		19.31%	≤ 0.06	≤ 1	≤ 0.06	> 128
Ceftolozane-Tazo	98.07%	0.34%	1.60%	0.25	0.5	≤ 0.12	>64
Ceftriaxone	94.66%	0.46%	4.88%	≤ 0.25	≤ 1	≤ 0.25	> 256
Ciprofloxacin	92.45%	1.45%	6.10%	≤ 0.06	0.5	≤ 0.06	> 16
Colistin	98.01%		1.99%	0.5	1	≤ 0.06	> 16
Doxycycline	82.34%	3.87%	13.79%	2	16	≤ 0.12	> 32
Ertapenem	99.24%	0.34%	0.42%	≤ 0.03	≤ 0.03	≤ 0.03	> 32
Gentamicin	96.80%	0.19%	3.01%	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Imipenem	99.24%	0.34%	0.42%	0.25	0.25	0.06	16
Levofloxacin	93.77%	1.78%	4.45%	≤ 0.06	1	≤ 0.06	> 32
Meropenem	99.69%	0.08%	0.23%	≤ 0.03	≤ 0.12	≤ 0.03	16
Moxifloxacin				0.12	1	≤ 0.06	> 16
Nitrofurantoin	42.53%	32.37%	25.10%	64	128	1	> 512
Pip-Tazo	96.68%	1.26%	2.06%	2	8	≤ 1	> 512
Tigecycline	95.65%	3.63%	0.73%	1	2	0.06	16
Tobramycin	96.13%	1.85%	2.02%	≤ 0.5	≤ 0.5	≤ 0.5	> 64
TMP-SMX	90.15%		9.85%	≤ 0.12	2	≤ 0.12	> 8
***Enterobacter cloacae* (n=1060)**							
Amikacin	99.91%		0.09%	≤ 2	2	≤ 1	> 64
Amox Clavulanate	9.18%	12.80%	78.02%	> 32	> 32	1	> 32
Cefazolin	2.07%	1.41%	96.52%	> 128	> 128	1	> 128
Cefepime	95.48%	3.68%	0.84%	≤ 0.25	2	≤ 0.25	64
Cefoxitin	8.88%	4.75%	86.38%	> 32	> 32	1	> 32
Ceftazidime	78.15%	0.89%	20.96%	0.5	> 32	≤ 0.25	> 32
Ceftobiprole	74.48%		25.52%	≤ 0.06	2	≤ 0.06	> 64
Ceftolozane-Tazo	85.39%	4.55%	10.06%	0.25	8	≤ 0.12	> 64
Ceftriaxone	73.66%	2.16%	24.18%	≤ 0.25	> 64	≤ 0.25	> 256
Ciprofloxacin	93.79%	1.69%	4.52%	≤ 0.06	0.12	≤ 0.06	> 16
Colistin	81.90%		18.10%	0.5	> 16	≤ 0.06	> 16
Ertapenem	92.05%	4.75%	3.20%	0.06	0.5	≤ 0.03	> 32
Gentamicin	97.46%	0.09%	2.45%	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Imipenem	97.34%	1.33%	1.33%	0.25	0.5	0.06	> 32
Levofloxacin	94.81%	3.77%	1.42%	≤ 0.06	0.5	≤ 0.06	32
Meropenem	99.34%	0.38%	0.28%	≤ 0.06	0.12	≤ 0.03	> 32
Moxifloxacin				≤ 0.06	0.5	≤ 0.06	> 16
Nitrofurantoin	47.69%	38.72%	13.59%	64	128	2	> 512
Pip-Tazo	85.42%	8.28%	6.30%	2	64	≤ 1	> 512
Tigecycline	94.83%	3.20%	1.98%	0.5	1	0.12	16
TMP-SMX	91.44%		8.56%	≤ 0.12	1	≤ 0.12	> 8
***Proteus mirabilis* (n=647)**							
Amikacin	99.38%	0.62%		2	4	≤ 1	32
Amox Clavulanate	95.20%	1.60%	3.20%	1	4	0.5	> 32
Cefazolin	4.02%	58.11%	37.87%	4	8	1	> 128
Cefepime	99.82%		0.18%	≤ 0.25	≤ 1	≤ 0.25	16
Cefoxitin	96.09%	2.49%	1.42%	4	4	≤ 0.06	> 32
Ceftazidime	98.67%	0.57%	0.76%	≤ 0.25	≤ 0.5	≤ 0.25	32
Ceftobiprole	80.48%		19.52%	≤ 0.06	≤ 0.06	≤ 0.06	16
Ceftolozane-Tazo	99.64%	0.36%		0.5	0.5	≤ 0.12	4
Ceftriaxone	97.68%	1.08%	1.24%	≤ 0.25	≤ 1	≤ 0.25	> 64
Ciprofloxacin	87.02%	5.26%	7.73%	≤ 0.06	2	≤ 0.06	> 16
Colistin	1.25%		98.75%	> 16	> 16	≤ 0.06	> 16
Doxycycline	0.72%	0.36%	98.92%	> 32	> 32	4	> 32
Ertapenem	100%			≤ 0.03	≤ 0.03	≤ 0.03	0.25
Gentamicin	94.74%	1.08%	4.17%	1	2	≤ 0.5	> 32
Imipenem	54.51%	29.96%	15.52%	1	4	0.12	16
Levofloxacin	90.34%	3.79%	5.86%	0.12	2	≤ 0.06	> 32
Meropenem	100%			0.06	0.12	≤ 0.03	0.5
Moxifloxacin				0.5	16	≤ 0.06	> 16
Nitrofurantoin	1.18%	16.47%	82.35%	128	256	32	512
Pip-Tazo	99.85%	0.15%		≤ 1	≤ 1	≤ 1	64
Tigecycline	10.82%	39.57%	49.61%	4	8	0.5	> 16
Tobramycin	96.39%	1.08%	2.53%	≤ 0.5	1	≤ 0.5	> 64
TMP-SMX	83.46%		16.54%	≤ 0.12	> 8	≤ 0.12	> 8
***Klebsiella oxytoca* (n=668)**							
Amikacin	99.85%		0.15%	≤ 1	2	≤ 1	> 64
Amox Clavulanate	89.15%	5.51%	5.34%	2	16	1	> 32
Cefazolin	27.44%	21.14%	51.42%	8	128	≤ 0.5	> 128
Cefepime	97.97%	1.52%	0.51%	≤ 0.25	≤ 1	≤ 0.25	> 64
Cefoxitin	96.83%	1.67%	1.50%	2	4	0.5	> 32
Ceftazidime	98.41%	0.35%	1.23%	≤ 0.25	0.5	≤ 0.25	> 32
Ceftobiprole	65.58%		34.42%	0.25	2	≤ 0.06	128
Ceftolozane-Tazo	100%			≤ 0.12	0.5	≤ 0.12	2
Ceftriaxone	91.60%	1.50%	6.90%	≤ 0.25	1	≤ 0.25	> 64
Ciprofloxacin	97.60%	0.90%	1.50%	≤ 0.06	≤ 0.06	≤ 0.06	> 16
Colistin	98.33%		1.67%	0.25	1	≤ 0.06	> 16
Doxycycline	95.94%	1.56%	2.50%	1	2	≤ 0.12	32
Ertapenem	99.67%		0.33%	≤ 0.03	≤ 0.06	≤ 0.03	2
Gentamicin	98.20%	0.60%	1.20%	≤ 0.5	≤ 0.5	≤ 0.5	> 32
Imipenem	100%			0.25	0.25	0.12	0.5
Levofloxacin	97.79%	0.74%	1.47%	≤ 0.06	0.25	≤ 0.06	> 32
Meropenem	100%			≤ 0.03	≤ 0.12	≤ 0.03	1
Moxifloxacin				≤ 0.06	0.25	≤ 0.06	> 16
Nitrofurantoin	87.65%	10.29%	2.06%	16	64	4	256
Pip-Tazo	89.51%	0.75%	9.75%	2	32	≤ 1	> 512
Tigecycline	99.25%	0.60%	0.15%	0.5	1	0.06	8
Tobramycin	99.38%	0.31%	0.31%	≤ 0.5	≤ 0.5	≤ 0.5	32
Trimethoprim Sulfa	95.65%		4.35%	≤ 0.12	≤ 0.12	≤ 0.12	> 8
***Stenotrophomonas maltophilia* (n=669)**							
Amikacin				> 64	> 64	≤ 1	> 64
Amox Clavulanate				> 32	> 32	2	> 32
Cefazolin				> 128	> 128	2	> 128
Cefepime				32	> 64	≤ 0.25	> 128
Cefoxitin				> 32	> 32	4	> 32
Ceftazidime	23.34%	7.54%	69.12%	> 32	> 32	1	> 32
Ceftobiprole				> 32	128	0.5	> 128
Ceftriaxone				> 64	128	2	> 256
Ciprofloxacin				2	16	≤ 0.06	> 16
Colistin				8	> 16	0.25	> 16
Doxycycline				2	4	0.25	> 32
Ertapenem				> 32	> 32	0.12	> 32
Gentamicin				32	> 32	≤ 0.5	> 32
Levofloxacin	66.80%	12.86%	20.33%	2	8	≤ 0.06	> 32
Meropenem				> 32	64	≤ 0.06	> 64
Moxifloxacin				1	4	≤ 0.06	> 16
Nitrofurantoin				> 512	> 512	32	> 512
Pip-Tazo				256	> 512	≤ 1	> 512
Tigecycline				1	8	0.12	16
TMP-SMX	98.34%		1.66%	0.5	1	≤ 0.12	> 8
***Acinetobacter baumannii* (n=171)**							
Amikacin	95.91%		4.09%	≤ 2	4	≤ 1	> 64
Amox Clavulanate				16	32	0.25	> 32
Cefazolin				> 128	> 128	16	> 128
Cefepime	86.71%	4.90%	8.39%	4	16	≤ 0.25	> 128
Cefoxitin				> 32	> 32	≤ 0.06	> 32
Ceftazidime	82.88%	6.16%	10.96%	8	32	1	> 32
Ceftobiprole				0.5	2	≤ 0.06	128
Ceftriaxone	48.54%	43.27%	8.19%	16	32	1	> 256
Ciprofloxacin	92.40%	1.17%	6.43%	0.25	1	≤ 0.06	32
Colistin	97.52%		2.48%	1	2	0.25	> 16
Ertapenem				4	16	0.12	> 32
Gentamicin	93.57%	1.17%	5.26%	≤ 0.5	2	≤ 0.5	> 32
Levofloxacin	92.19%		7.81%	0.12	1	≤ 0.06	> 16
Meropenem	94.74%	1.75%	3.51%	0.5	2	0.06	> 32
Moxifloxacin				≤ 0.06	0.25	≤ 0.06	> 16
Nitrofurantoin				> 256	> 512	128	> 512
Pip-Tazo	84.21%	8.77%	7.02%	2	64	≤ 1	> 512
Tigecycline				0.5	1	0.12	> 16
TMP-SMX	89.47%		10.53%	0.25	4	≤ 0.12	> 8

Colistin (Polymyxin E). ESBL=extended spectrum ß-lactamase. Pip-Tazo: piperacillin-tazobactam. Amox Clavulanate: amoxicillin-clavulanate. Ceftolozane-Tazo: ceftolozane-tazobactam. All MICs interpreted using CLSI breakpoints, with the exception of tigecycline (FDA) and ceftobiprole (EUCAST). EUCAST breakpoints applied for ceftobiprole (µg/mL): Enterobacteriaceae (S) ≤0.25, (R) >0.25. Not all isolates tested with ceftobiprole.

Table 4. The 20 most common organisms isolated from Canadian hospitals

Rank	Organism	n	% of Total
1	*Escherichia coli*	8,387	19.5
2	*Staphylococcus aureus*, MSSA	7,146	16.6
3	*Pseudomonas aeruginosa*	3,864	9.0
4	*Streptococcus pneumoniae*	2,626	6.1
5	*Klebsiella pneumoniae*	2,624	6.1
6	*Staphylococcus aureus*, MRSA	1,963	4.6
7	*Haemophilus influenzae*	1,764	4.1
8	CNS / *Staphylococcus epidermidis*	1,616	3.8
9	*Enterococcus faecalis*	1,255	2.9
10	*Enterobacter cloacae*	1,060	2.5
11	*Streptococcus agalactiae*	689	1.6
12	*Stenotrophomonas maltophilia*	669	1.6
13	*Klebsiella oxytoca*	668	1.4
14	*Proteus mirabilis*	647	1.5
15	*Serratia marcescens*	647	1.5
16	*Streptococcus pyogenes*	642	1.5
17	*Enterococcus*, non-speciated	582	1.4
18	*Enterococcus faecium*	481	1.1
19	*Candida albicans*	478	1.1
20	*Moraxella catarrhalis*	468	1.1
	Other	4,729	11.0
		42,938	

CNS: coagulase-negative staphylococci

CONCLUSIONS

- Of the 42,938 pathogens obtained, the most common were: *E. coli* 19.5%, *S. aureus* (MSSA), 16.6%, *P. aeruginosa* 9.0%, *S. pneumoniae* 6.1%, *K. pneumoniae* 6.1%, MRSA 4.6%, *H. influenzae* 4.1% and *Enterococcus* spp. (*E. faecalis* and *E. faecium*) 4.0%.
- Isolates were obtained from blood (43.5%), respiratory (33.1%), urine (13.2%) and wound specimens (10.2%) from patients on W 38.1% (29.9% medical/8.2% surgical), ER 24.8%, ICU 19.0%, and C 18.1%.
- Susceptibility rates for *E. coli* were: 99.9% meropenem, and tigecycline, 99.7% ertapenem, 99.7% amikacin, 97.6% piperacillin/tazobactam (P/T), 95.1% cefepime, 91.7% ceftriaxone, 90.5% gentamicin, 77.0% ciprofloxacin , 76.8% ceftobiprole, and 73.2% trimethoprim/sulfamethoxazole (T/S).
- Susceptibility rates for *P. aeruginosa* were: 98.3% ceftolozane/tazobactam, 95.0% colistin, 92.0% amikacin, 84.3% doripenem, 84.1% piperacillin/tazobactam, 82.9% ceftazidime, 81.2% meropenem, 79.6% gentamicin and 75.4% ciprofloxacin.
- Susceptibility rates for MRSA were: 100% linezolid and telavancin, 99.9% daptomycin, 99.8% vancomycin, 99.7% ceftobiprole, 99.2% tigecycline, 94.1% T/S, 53.9% clindamycin, 17.4% ciprofloxacin and 15.1% for clarithromycin.

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