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Antimicrobial Susceptibility of 39,816 Pathogens Isolated from Patients in Canadian Hospitals: CANWARD Study 2007-2015

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CANADIAN ANTIMICROBIAL RESISTANCE ALLIANCE CARA

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REVISED ABSTRACT

Background: CANWARD is a national, annual, Public Health Agency of Canada (PHAC) endorsed surveillance study assessing pathogens causing infections in Canadian hospitals and their antimicrobial resistance patterns.

Methods: From 2007 to 2015, 39,816 pathogens were collected from tertiary-care hospitals across Canada. Antimicrobial susceptibility testing was performed using CLSI broth microdilution with >45 marketed and investigational agents.

Results: Specimen source composition of the 39,816 isolates was 43.7% blood, 32.7% respiratory, 13.4% urine and 10.2% wound specimens. Patient demographic characteristics were: 54.5/45.5% male/female; 13.1/44.4/42.5% patients aged ≤17/18-64/≥65 years; and 38.0/24.9/19.0/18.1% patients located in medical and surgical wards/emergency rooms/ICUs/clinics. The most common pathogens were: *E. coli* (EC 19.6%), MSSA (16.6%), *P. aeruginosa* (PA 8.9%), *S. pneumoniae* (SPN 6.4%), *K. pneumoniae* (KP 6.1%), MRSA (4.6%), *H. influenzae* (4.1%), and *Enterococcus* spp. (4.0%). Susceptibility rates (SR) for EC were: 99.9% for meropenem (MER) and tigecycline (TGC), 99.7% ertapenem (ERT), 97.6% piperacillin-tazobactam (PTZ), 93.5% ceftobiprole, 92.1% ceftriaxone (CTR), 90.5% gentamicin (GEN), 76.9% ciprofloxacin (CIP) and 73.1% TMP-SMX (SXT). SR for PA were: 94.6% colistin, 84.4% PTZ, 83.0% ceftazidime (CAZ), 80.8% MER, 78.7% GEN and 74.7% CIP. SR for MRSA were: 100% for linezolid (LZD) and telavancin (TLV), 99.9% daptomycin (DAP) and vancomycin, 99.5% ceftobiprole, 99.1% TGC, and 93.7% SXT. Rates of resistant organisms between 2007-2015 increased significantly for ESBL-producing EC (3.4%-12.3%) as well as VRE (1.8%-4.4%), whereas MRSA rates (26.1%-19.4%) 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 colistin, PTZ, CAZ and MER. 99-100% of MRSA were susceptible DAP, LZD, TLV, ceftobiprole and vancomycin.

INTRODUCTION

Antibiotic resistant infections is a Canadian and global crisis (1,2). Resistant pathogens including methicillin-resistant *Staphylococcus aureus* (MRSA - community associated (CA) and healthcare associated (HA), vancomycin-resistant *Enterococcus species* (VRE), penicillin-resistant *Streptococcus pneumoniae* (PRSP), 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 severely limited as these organisms frequently display a multidrug resistant (MDR) phenotype.

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 2007-2015, 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 2007-2015, inclusive.
- To assess the activity of antimicrobials against respiratory, urinary, bacteremic and wound/IV site pathogens in Canadian patients affiliated with hospitals from 2007-2015, inclusive.

REFERENCES

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MATERIALS & METHODS

Participating Sites:
From January 2007 to December 2015, 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) in major population centres in 8 of the 10 provinces in Canada were recruited. 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 to October 2015, 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, as well as anaerobes, were excluded. 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 and 2015; 7714, 5283, 5374, 4960, 3788, 2803, 3511, 3174 and 3206 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 (M7-A10, 2015). Antimicrobial 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. 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 2007-2015

Gender	N	% Total
Female	18,107	45.5
Male	21,706	54.5
	39,813*	

*demographics incomplete for 3 isolates

Age Group	N	% Total
≤17 yrs	5,199	13.1
18 – 64 yrs	17,685	44.4
≥65 yrs	16,929	42.5
	39,813*	

*demographics incomplete for 3 isolates

Ward Type	N	% Total
Clinic	7,189	18.1
ER	9,929	24.9
ICU	7,543	19.0
Medical	11,838	29.7
Surgical	3,310	8.3
	39,809*	

*demographics incomplete for 7 isolates

Specimen Source	N	% Total
Blood	17,421	43.7
Respiratory	13,001	32.7
Urine	5,326	13.4
Wound	4,068	10.2
	39,816	

RESULTS

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

Organism (no. tested) / Antimicrobial Agent	% S	% I	% R	MIC (µg/mL) MIC50	MIC90	Range
***Staphylococcus aureus*, MSSA (n=6594)**						
Cefoxitin	99.54%		0.46%	4	4	0.12 - 32
Ceftobiprole	100%			0.25	0.5	≤0.06 - 2
Ceftriaxone				4	4	≤ 0.25 - 256
Ciprofloxacin	86.31%	2.99%	10.69%	0.5	4	≤ 0.06 - > 16
Clarithromycin	75.67%	0.44%	23.89%	0.25	> 32	≤ 0.03 - > 32
Clindamycin	93.24%	0.41%	6.35%	≤ 0.12	≤ 0.25	≤ 0.12 - > 8
Daptomycin	100%			0.25	0.25	≤ 0.03 - 1
Doxycycline	99.02%	0.72%	0.26%	≤ 0.12	≤ 0.12	≤ 0.12 - 16
Gentamicin	98.01%	0.09%	1.90%	≤ 0.5	≤ 0.5	≤ 0.5 - >32
Levofloxacin	90.10%	0.33%	9.57%	0.25	1	≤ 0.06 - > 32
Linezolid	100%			2	2	≤ 0.12 - 4
Moxifloxacin	90.32%	0.74%	8.93%	≤ 0.06	0.25	≤ 0.06 - > 16
Nitrofurantoin	100%			16	16	≤ 0.5 - 32
Telavancin	100%			0.03	0.06	0.008 - 0.12
Tigecycline	99.91%			0.12	0.25	≤ 0.03 - 1
Tobramycin	97.35%	0.29%	2.36%	≤ 0.5	≤ 0.5	≤ 0.5 - > 64
Trimethoprim Sulfa	99.44%		0.56%	≤ 0.12	≤ 0.12	≤ 0.12 - > 8
Vancomycin	100%			1	1	≤ 0.12 - 2
***Staphylococcus aureus*, MRSA (n=1851)**						
Cefoxitin	0.13%		99.87%	> 32	> 32	1 - > 32
Ceftobiprole	99.54%		0.45%	1	2	0.5 - 4
Ceftriaxone				> 64	> 64	2 - > 256
Ciprofloxacin	16.96%	0.38%	82.66%	> 16	> 16	≤ 0.06 - > 16
Clarithromycin	14.97%	0.38%	84.65%	> 32	> 32	≤ 0.03 - > 32
Clindamycin	53.47%	0.05%	46.48%	≤ 0.25	> 8	≤ 0.12 - > 8
Daptomycin	99.95%		0.05%	0.25	0.5	0.06 - 2
Doxycycline	97.43%	1.08%	1.49%	≤ 0.12	1	≤ 0.12 - 16
Gentamicin	92.60%	0.27%	7.13%	≤ 0.5	1	≤ 0.5 - > 32
Levofloxacin	14.06%		85.94%	> 32	> 32	0.12 - > 32
Linezolid	100.00%			2	2	≤ 0.12 - 4
Moxifloxacin	17.61%	3.46%	78.93%	8	> 16	≤ 0.06 - > 16
Nitrofurantoin	100%			16	16	8 - 32
Telavancin				0.06	0.06	0.03 - 0.12
Tigecycline	99.14%			0.25	0.5	≤ 0.03 - 2
Tobramycin	57.92%	0.95%	41.14%	≤ 0.5	> 64	≤ 0.5 - > 64
Trimethoprim Sulfa	93.73%		6.27%	≤ 0.12	≤ 0.12	≤ 0.12 - > 8
Vancomycin	99.89%	0.11%		1	1	≤ 0.12 - 4
***Staphylococcus epidermidis* (n=855)**						
Amoxicillin 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	100%			0.5	1	≤ 0.06 - 4
Ceftriaxone				8	> 64	≤ 0.25 - > 256
Ciprofloxacin	45.99%	1.42%	52.59%	4	> 16	≤ 0.06 - > 16
Clarithromycin	33.77%	1.30%	64.94%	> 32	> 32	≤ 0.03 - > 32
Clindamycin	56.20%	1.42%	42.38%	≤ 0.25	> 8	≤ 0.12 - > 8
Daptomycin	100.00%			0.12	0.25	≤ 0.03 - 1
Doripenem				1	16	≤ 0.03 - > 32
Doxycycline	96.06%	2.25%	1.69%	0.25	1	≤ 0.12 - 32
Ertapenem				4	> 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	47.88%	7.19%	44.93%	1	> 16	≤ 0.06 - > 16
Pip -Tazo				≤ 1	32	≤ 1 - 128
Telavancin				0.06	0.12	0.03 - 0.25
Tigecycline				0.12	0.5	≤ 0.03 - 1
Tobramycin	60.23%	12.22%	27.56%	2	32	≤ 0.5 - > 64
Trimethoprim Sulfa	59.32%		40.68%	1	8	≤ 0.12 - > 8
Vancomycin	100%			1	2	≤ 0.12 - 4
***Streptococcus pneumoniae* (n=2502)**						
Amoxicillin Clavulanate	97.86%	1.26%	0.88%	≤ 0.06	0.12	≤ 0.06 - 16
Ceftobiprole	99.82%		0.18%	≤ 0.03	0.06	≤ 0.03 - 1
Ceftriaxone	99.37%	0.46%	0.17%	≤ 0.12	≤ 0.12	≤ 0.06 - 4
Cefuroxime	93.50%	1.93%	4.57%	≤ 0.25	0.5	≤ 0.25 - > 16
Chloramphenicol	98.60%		1.40%	2	4	≤ 0.12 - 32
Ciprofloxacin	96.76%		3.24%	1	2	≤ 0.06 - > 16
Clarithromycin	78.56%	3.57%	17.86%	≤ 0.03	4	≤ 0.03 - > 32
Clindamycin	92.85%	0.55%	6.60%	≤ 0.12	≤ 0.12	≤ 0.12 - > 64
Daptomycin				0.06	0.12	≤ 0.03 - 0.5
Doxycycline	86.59%	1.26%	12.15%	≤ 0.25	2	≤ 0.25 - > 16
Ertapenem	98.95%	1.01%	0.04%	≤ 0.06	0.12	≤ 0.06 - 4
Imipenem	93.50%	4.59%	1.91%	≤ 0.03	≤ 0.03	≤ 0.03 1
Levofloxacin	98.99%	0.17%	0.84%	1	1	≤ 0.06 - 32
Linezolid	100%			1	1	≤ 0.12 - 2
Meropenem	95.08%	3.15%	1.77%	≤ 0.06	≤ 0.06	≤ 0.06 - 2
Moxifloxacin	99.03%	0.46%	0.50%	0.12	0.25	≤ 0.06 - 8
Penicillin	82.44%	13.21%	4.35%	≤ 0.03	0.25	≤ 0.03 - > 8
Pip -Tazo				≤ 1	≤ 1	≤ 1 - 8
Telavancin				0.008	0.015	≤ 0.002 - 0.03
Tigecycline	99.75%			≤ 0.03	0.06	≤ 0.015 - 0.25
Trimethoprim Sulfa	84.78%	6.40%	8.82%	≤ 0.12	2	≤ 0.12 - > 8
Vancomycin	100%			≤ 0.25	0.25	≤ 0.12 - 1
***Streptococcus agalactiae* (n=653)**						
Amoxicillin Clavulanate				≤ 0.06	≤ 0.06	≤ 0.06 - 0.25
Ceftobiprole	100%			≤ 0.03	≤ 0.03	≤ 0.03 - 0.06
Ceftriaxone	100%			≤ 0.12	≤ 0.12	≤ 0.06 - 0.25
Cefuroxime				≤ 0.25	≤ 0.25	≤ 0.25 - 0.5
Chloramphenicol	97.42%	2.58%		2	4	0.5 - 8
Ciprofloxacin				0.5	2	0.25 - > 16
Clarithromycin	69.64%	4.74%	25.63%	≤ 0.03	32	≤ 0.03 - > 32
Clindamycin	82.73%	0.84%	16.43%	≤ 0.12	> 64	≤ 0.12 - > 64
Daptomycin	100%			0.12	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	95.54%		4.46%	0.5	1	0.25 - > 32
Linezolid	100%			1	2	≤ 0.12 - 2
Meropenem	100%			≤ 0.06	≤ 0.06	≤ 0.06 - 0.12
Moxifloxacin				0.12	0.25	≤ 0.06 - 16
Penicillin	99.72%		0.28%	0.06	0.12	≤ 0.03 - 0.25
Pip -Tazo				≤ 1	≤ 1	≤ 1 - ≤ 1
Telavancin	100%			0.03	0.06	0.03 - 0.06
Tigecycline	99.72%			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* (n=597)**						
Amoxicillin Clavulanate				≤ 0.06	≤ 0.06	≤ 0.06 - 0.5
Ceftobiprole	100%			≤ 0.03	≤ 0.03	≤ 0.03 - 0.12
Ceftriaxone	99.82%		0.18%	≤ 0.12	≤ 0.12	≤ 0.06 - 1
Cefuroxime				≤ 0.25	≤ 0.25	≤ 0.25 - 0.5
Chloramphenicol	98.62%	1.38%		2	4	0.5 - 8
Ciprofloxacin				0.5	1	≤ 0.06 - 8
Clarithromycin	89.54%	2.13%	8.33%	≤ 0.03	0.5	≤ 0.03 - > 32
Clindamycin	98.23%		1.77%	≤ 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	99.82%	0.18%		0.5	1	≤ 0.06 - 4
Linezolid	100%			1	1	≤ 0.12 - 2
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
Trimethoprim Sulfa				≤ 0.12	≤ 0.12	≤ 0.12 - > 8
Vancomycin	100%			0.5	0.5	≤ 0.12 - 1
***Enterococcus faecalis* (n=1152)**						
Amoxicillin Clavulanate				0.5	1	≤ 0.06 - 32
Cefazolin				32	64	≤ 0.5 - > 128
Ceftazidime				> 32	> 32	≤ 0.5 - > 32
Ceftobiprole	99.82%		0.18%	0.5	1	≤ 0.06 - 8
Ceftriaxone				> 64	> 64	≤ 0.25 - > 256
Ciprofloxacin	61.40%	9.74%	28.86%	1	> 16	0.25 - > 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	35.47%	46.23%	18.30%	8	16	≤ 0.12 - 32
Ertapenem				8	16	0.25 - > 32
Gentamicin				8	> 32	≤ 0.5 - > 32
Imipenem				1	2	0.25 - 4
Levofloxacin	65.62%	1.05%	33.33%	2	> 32	0.25 - > 32
Linezolid	96.56%	3.44%		2	2	0.5 - 4
Meropenem				4	8	≤ 0.06 - > 32
Moxifloxacin				0.25	16	≤ 0.06 - > 16
Nitrofurantoin	99.70%	0.30%		8	8	2 - 64
Pip -Tazo				4	4	≤ 1 - > 512
Tigecycline	98.19%			0.12	0.25	≤ 0.03 - 1
Tobramycin				16	> 64	≤ 0.5 - > 64
Trimethoprim Sulfa				≤ 0.12	0.5	≤ 0.12 - > 8
Vancomycin	100%			1	2	0.25 - 4
***Enterococcus faecium* (n=443)**						
Amoxicillin Clavulanate				> 32	> 32	≤ 0.06 - > 32
Cefazolin				> 128	> 128	≤ 0.5 - > 128
Ceftazidime				> 32	> 32	8 - > 32
Ceftobiprole	8.21%		91.79%	> 16	> 16	0.25 - > 16
Ceftriaxone				> 64	> 64	0.5 - > 256
Ciprofloxacin	7.11%	1.83%	91.06%	> 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	78.51%	5.70%	15.79%	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	90.85%	8.70%	0.46%	2	2	≤ 0.12 - 16
Meropenem				> 32	> 32	0.25 - > 64
Moxifloxacin				> 16	> 16	0.12 - > 16
Nitrofurantoin	41.86%	27.13%	31.01%	64	128	4 - > 512
Pip -Tazo				> 512	> 512	≤ 1 - > 512
Tigecycline				0.12	0.12	≤ 0.03 - 2
Tobramycin				64	> 64	8 - > 64
Trimethoprim Sulfa				0.5	> 8	≤ 0.12 - > 8
Vancomycin	77.80%		22.20%	1	> 32	≤ 0.12 - > 32

S=susceptible, I=intermediate, R=resistant. Pip-Tazo: piperacillin-tazobactam. For tigecycline, FDA approved breakpoints used. Not all isolates tested with ceftobiprole.
EUCAST breakpoints applied for ceftobiprole (µg/mL): *S. aureus* (S) ≤2, (R) >2; *S. pneumoniae* (S) ≤0.5, (R) >0.5; Non-species specific (S) ≤4, (R) >4.

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

Organism (n) / Antimicrobial Agent	% S	% I	% R	MIC (µg/mL) MIC50	MIC90	Range
***Escherichia coli* (n=7786)**						
Amikacin	99.65%	0.23%	0.12%	≤ 2	4	≤ 2 - > 64
Amox-Clav	85.82%	10.13%	4.05%	4	16	≤ 0.06 - > 32
Cefazolin	70.48%	12.02%	17.50%	2	32	≤ 0.5 - > 128
Cefepime	95.27%	2.16%	2.57%	≤ 0.25	≤ 1	≤ 0.25 - > 64
Cefoxitin	92.57%	3.64%	3.79%	4	8	≤ 0.06 - > 32
Ceftazidime	93.90%	0.82%	5.29%	≤ 0.25	1	≤ 0.25 - > 32
Ceftobiprole	93.48%		6.52%	≤ 0.06	≤ 0.06	≤ 0.06 - > 16
Ceftriaxone	92.07%	0.30%	7.63%	≤ 0.25	≤ 1	≤ 0.25 - > 256
Ciprofloxacin	76.94%	0.22%	22.84%	≤ 0.06	> 16	≤ 0.06 - > 16
Colistin				0.25	0.5	≤ 0.06 - > 16
Doripenem	99.97%	0.01%	0.01%	≤ 0.03	≤ 0.12	≤ 0.03 - 16
Doxycycline	72.03%	5.74%	22.23%	2	32	0.25 - > 256
Ertapenem	99.72%	0.16%	0.12%	≤ 0.03	≤ 0.06	≤ 0.03 - > 32
Gentamicin	90.46%	0.42%	9.12%	≤ 0.5	4	-
Imipenem	99.93%	0.03%	0.03%	0.12	0.25	≤ 0.03 - 8
Levofloxacin	78.78%	0.66%	20.56%	≤ 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	96.42%	2.29%	1.29%	16	32	≤ 0.5 - 512
Pip-Tazo	97.65%	1.13%	1.22%	2	4	≤ 1 - > 512
Tigecycline	99.90%	0.10%		0.25	0.5	0.06 - 4
Tobramycin	91.01%	3.76%	5.23%	≤ 0.5	4	≤ 0.5 - > 64
Trimethoprim Sulfa	73.11%		26.89%	≤ 0.12	> 8	≤ 0.12 - > 8
ESBL *E. coli* (n=472)						
Amikacin	97.46%	2.12%	0.42%	2	8	≤ 1 - > 64
Amox-Clav	52.12%	38.77%	9.11%	8	16	1 - > 32
Cefazolin		0.21%	99.79%	> 128	> 128	4 - > 128
Cefepime	31.45%	31.00%	37.56%	8	> 32	≤ 0.25 - > 64
Cefoxitin	82.63%	8.47%	8.90%	8	16	0.5 - > 32
Ceftazidime	35.08%	8.59%	56.32%	16	> 32	≤ 0.5 - > 32
Ceftobiprole	2.49%		97.51%	> 16	> 16	0.12 - > 16
Ceftriaxone	2.54%	1.27%	96.19%	> 64	> 64	≤ 0.25 - > 64
Ciprofloxacin	12.29%	0.42%	87.29%	> 16	> 16	≤ 0.06 - > 16
Colistin				0.25	1	≤ 0.06 - > 16
Doripenem	99.75%		0.25%	≤ 0.03	≤ 0.12	≤ 0.03 - 16
Doxycycline	29.87%	14.94%	55.19%	16	64	0.25 - > 256
Ertapenem	97.66%	1.06%	1.28%	≤ 0.06	0.12	≤ 0.03 - > 32
Gentamicin	58.26%	1.27%	40.47%	1	> 32	≤ 0.5 - > 32
Imipenem	99.65%		0.35%	0.12	0.25	0.06 - 8
Levofloxacin	12.90%	1.29%	85.81%	16	32	≤ 0.06 - > 32
Meropenem	99.79%		0.21%	≤ 0.03	≤ 0.12	≤ 0.03 - 32
Moxifloxacin				16	> 16	≤ 0.06 - > 16
Nitrofurantoin	91.12%	5.84%	3.05%	16	32	≤ 1 - 256
Pip -Tazo	92.80%	4.45%	2.75%	4	16	≤ 1 > 512
Tigecycline	99.79%	0.21%		0.5	1	0.12 - 4
Tobramycin	51.57%	9.06%	39.37%	4	32	≤ 0.5 - > 64
Trimethoprim Sulfa	32.20%		67.80%	> 8	> 8	≤ 0.12 - > 8
***Pseudomonas aeruginosa* (n=3539)**						
Amikacin	91.86%	3.65%	4.50%	4	16	≤ 1 - > 64
Amox-Clav				> 32	> 32	0.12 - > 32
Cefepime	81.68%	12.66%	5.66%	4	16	≤ 0.25 - > 128
Ceftazidime	83.05%	6.04%	10.92%	4	32	≤ 0.25 - > 32
Ceftobiprole	63.58%		36.42%	4	8	0.12 - > 16
Ceftriaxone				16	> 64	≤ 0.25 - > 256
Ciprofloxacin	74.66%	8.43%	16.91%	0.25	8	≤ 0.06 - > 16
Colistin	94.67%	4.05%	1.28%	1	2	≤ 0.06 - > 16
Doripenem	84.35%	6.28%	9.37%	0.5	4	≤ 0.03 - > 64
Ertapenem				8	> 32	0.06 - > 32
Gentamicin	78.68%	9.73%	11.60%	2	16	≤ 0.5 - > 32
Imipenem	69.14%	8.37%	22.49%	2	16	≤ 0.03 - > 32
Levofloxacin	63.46%	12.07%	24.47%	1	16	≤ 0.06 - > 32
Meropenem	80.83%	7.13%	12.05%	0.5	8	≤ 0.03 - > 64
Moxifloxacin				4	> 16	≤ 0.06 - > 16
Nitrofurantoin				> 256	> 512	16 - > 512
Pip -Tazo	84.42%	8.43%	7.15%	4	64	≤ 1 - > 512
Tigecycline				16	> 16	0.25 - > 16
Tobramycin	93.00%	1.33%	5.67%	≤ 0.5	2	≤ 0.5 - > 64
Trimethoprim Sulfa				8	> 8	≤ 0.12 - > 8
***Klebsiella pneumoniae* (n=2438)**						
Amikacin	99.67%	0.08%	0.25%	≤ 1	≤ 2	≤ 1 - > 64
Amox-Clav	94.36%	3.07%	2.57%	2	8	0.5 - > 32
Cefazolin	83.17%	6.16%	10.67%	1	8	≤ 0.5 - > 128
Cefepime	96.95%	1.32%	1.74%	≤ 0.25	≤ 1	≤ 0.25 - 128
Cefoxitin	91.47%	3.90%	4.63%	2	8	0.12 - > 32
Ceftazidime	96.06%	0.40%	3.53%	≤ 0.25	1	≤ 0.25 - > 32
Ceftobiprole	95.23%		4.77%	≤ 0.06	0.12	≤ 0.06 - > 16
Ceftriaxone	95.03%	0.45%	4.52%	≤ 0.25	≤ 1	≤ 0.25 - > 256
Ciprofloxacin	92.82%	1.31%	5.87%	≤ 0.06	0.5	≤ 0.06 - > 16
Colistin				0.5	1	≤ 0.06 - > 16
Doripenem	99.87%		0.13%	≤ 0.06	≤ 0.12	≤ 0.03 - 8
Doxycycline	81.77%	3.78%	14.44%	2	16	≤ 0.12 - > 32
Ertapenem	99.36%	0.32%	0.32%	≤ 0.03	≤ 0.06	≤ 0.03 - > 32
Gentamicin	96.96%	0.21%	2.83%	≤ 0.5	≤ 0.5	≤ 0.5 - > 32
Imipenem	99.30%	0.30%	0.40%	0.25	0.25	0.06 - 4
Levofloxacin	93.77%	1.78%	4.45%	≤ 0.06	1	≤ 0.06 - > 32
Meropenem	99.75%	0.04%	0.21%	≤ 0.03	≤ 0.12	≤ 0.03 - 16
Moxifloxacin				0.12	1	≤ 0.06 - > 16
Nitrofurantoin	40.58%	31.35%	28.07%	64	128	1 - > 512
Pip-Tazo	97.00%	1.11%	1.89%	2	8	≤ 1 - > 512
Tigecycline	95.44%	3.78%	0.78%	1	2	0.06 - 16
Tobramycin	96.92%	1.49%	1.59%	≤ 0.5	≤ 0.5	≤ 0.5 - > 64
Trimethoprim Sulfa	90.43%		9.57%	≤ 0.12	2	≤ 0.12 - > 8
***Enterobacter cloacae* (n=968)**						
Amikacin	99.90%		0.10%	≤ 1	2	≤ 1 - > 64
Amox-Clav	9.97%	13.86%	76.17%	> 32	> 32	1 - > 32
Cefazolin	2.28%	1.45%	96.28%	> 128	> 128	1 - > 128
Cefepime	95.33%	3.97%	0.70%	≤ 0.25	2	≤ 0.25 - 64
Cefoxitin	9.51%	4.93%	85.57%	> 32	> 32	1 - > 32
Ceftazidime	78.40%	1.00%	20.60%	0.5	> 32	≤ 0.25 - > 32
Ceftobiprole	87.09%		12.91%	≤ 0.06	2	≤ 0.06 - > 16
Ceftriaxone	73.42%	2.38%	24.20%	≤ 0.25	> 64	≤ 0.25 - > 256
Ciprofloxacin	93.69%	1.65%	4.65%	≤ 0.06	0.12	≤ 0.06 - > 16
Colistin				0.5	> 16	≤ 0.06 - > 16
Doripenem	99.43%	0.23%	0.34%	≤ 0.06	0.12	≤ 0.03 - > 32
Ertapenem	91.98%	4.70%	3.32%	≤ 0.06	0.5	≤ 0.03 - > 32
Gentamicin	97.52%	0.10%	2.38%	≤ 0.5	≤ 0.5	≤ 0.5 - > 32
Imipenem	97.23%	1.15%	1.62%	0.25	0.5	0.06 - > 32
Levofloxacin	94.81%	3.77%	1.42%	≤ 0.06	0.5	≤ 0.06 - 32
Meropenem	99.28%	0.41%	0.31%	≤ 0.06	0.12	≤ 0.03 - > 32
Moxifloxacin				≤ 0.06	0.5	≤ 0.06 - > 16
Nitrofurantoin	48.43%	36.93%	14.63%	64	128	2 - > 512
Pip-Tazo	85.42%	8.17%	6.41%	2	64	≤ 1 - > 512
Tigecycline	94.62%	3.31%	2.07%	1	1	0.12 - 16
Trimethoprim Sulfa	91.52%		8.48%	≤ 0.12	1	≤ 0.12 > 8
***Proteus mirabilis* (n=606)**						
Amikacin	99.50%	0.50%		2	4	≤ 1 - 32
Amox-Clav	95.20%	1.54%	3.26%	1	4	0.5 - > 32
Cefazolin	3.47%	57.92%	38.61%	4	8	1 - > 128
Cefepime	99.81%		0.19%	≤ 0.25	≤ 1	≤ 0.25 - 16
Cefoxitin	96.35%	2.11%	1.54%	4	4	1 - > 32
Ceftazidime	98.77%	0.41%	0.82%	≤ 0.25	≤ 0.5	≤ 0.25 - 32
Ceftobiprole	99.67%		0.33%	≤ 0.06	≤ 0.06	≤ 0.06 - 16
Ceftriaxone	97.69%	0.99%	1.32%	≤ 0.25	≤ 1	≤ 0.25 - > 64
Ciprofloxacin	87.29%	5.28%	7.43%	≤ 0.06	2	≤ 0.06 - > 16
Colistin				> 16	> 16	≤ 0.06 - > 16
Doripenem	100%			0.12	0.25	≤ 0.03 - 1
Doxycycline	0.84%	0.84%	98.31%	> 32	> 32	4 - > 32
Ertapenem	100%			≤ 0.03	≤ 0.06	≤ 0.03 - 0.25
Gentamicin	95.05%	1.16%	3.80%	≤ 0.5	2	≤ 0.5 - > 32
Imipenem	54.01%	30.80%	15.19%	1	4	0.12 - 8
Levofloxacin	90.31%	3.81%	5.88%	0.12	2	≤ 0.06 - > 32
Meropenem	100%			0.06	0.12	≤ 0.03 - 0.5
Moxifloxacin				0.5	16	≤ 0.06 - > 16
Nitrofurantoin	1.02%	11.73%	87.24%	128	256	32 - > 256
Pip-Tazo	100%			≤ 1	≤ 1	≤ 0.12 - 8
Tigecycline	11.06%	37.79%	51.16%	8	16	0.5 - > 16
Tobramycin	96.62%	1.27%	2.11%	≤ 0.5	1	≤ 0.5 - > 64
Trimethoprim Sulfa	83.83%		16.17%	≤ 0.12	> 8	≤ 0.12 - > 8
***Klebsiella oxytoca* (n=601)**						
Amikacin	99.83%		0.17%	≤ 1	2	≤ 1 - > 64
Amox-Clav	88.35%	6.02%	5.64%	2	16	1 - > 32
Cefazolin	26.33%	21.83%	51.83%	8	> 128	≤ 0.5 - > 128
Cefepime	97.90%	1.71%	0.38%	≤ 0.25	≤ 1	≤ 0.25 - > 64
Cefoxitin	96.99%	1.50%	1.50%	2	4	0.5 - > 32
Ceftazidime	98.40%	0.40%	1.20%	≤ 0.25	0.5	≤ 0.25 - > 32
Ceftobiprole	75.68%		24.32%	0.25	8	≤ 0.06 - >16
Ceftriaxone	91.17%	1.67%	7.17%	≤ 0.25	1	≤ 0.25 - > 64
Ciprofloxacin	97.33%	1.00%	1.67%	≤ 0.06	≤ 0.06	≤ 0.06 - > 16
Colistin				0.25	1	≤ 0.06 - > 16
Doripenem	100%			≤ 0.06	≤ 0.12	≤ 0.03 - 1
Doxycycline	95.26%	1.98%	2.77%	1	2	≤ 0.12 - 32
Ertapenem	99.62%		0.38%	≤ 0.03	≤ 0.06	≤ 0.03 - 2
Gentamicin	98.17%	0.67%	1.17%	≤ 0.5	≤ 0.5	≤ 0.5 - > 32
Imipenem	100%			0.25	0.5	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				0.12	0.25	≤ 0.06 - > 16
Nitrofurantoin	84.80%	14.04%	1.17%	32	64	4 - 128
Pip-Tazo	88.50%	0.83%	10.67%	2	128	≤ 1 - > 512
Tigecycline	99.33%	0.50%	0.17%	0.5	1	0.06 - 8
Tobramycin	99.60%	0.40%		≤ 0.5	≤ 0.5	≤ 0.5 - 8
Trimethoprim Sulfa	95.33%		4.67%	≤ 0.12	≤ 0.12	≤ 0.12 - > 8
***Stenotrophomonas maltophilia* (n=607)**						
Amikacin				> 64	> 64	≤ 1 - > 64
Amox-Clav				> 32	> 32	2 - > 32
Cefazolin				> 128	> 128	2 - > 128
Cefepime				32	> 64	≤ 0.25 - > 128
Cefoxitin				> 32	> 32	4 - > 32
Ceftazidime	24.60%	8.27%	67.14%	> 32	> 32	1 - > 32
Ceftobiprole			100%	> 16	> 16	8 - > 16
Ceftriaxone				> 64	256	2 - > 256
Ciprofloxacin				2	16	≤ 0.06 - > 16
Colistin				8	> 16	0.25 - > 16
Doripenem				> 32	> 64	≤ 0.06 - > 64
Doxycycline				2	4	0.5 - > 32
Ertapenem				> 32	> 32	0.12 - > 32
Gentamicin				32	> 32	≤ 0.5 - > 32
Levofloxacin	66.94%	12.81%	20.25%	2	8	≤ 0.06 - > 32
Meropenem				> 32	64	≤ 0.06 - > 64
Moxifloxacin				0.5	4	≤ 0.06 - > 16
Nitrofurantoin				> 256	> 512	32 - > 512
Pip-Tazo				256	> 512	≤ 1 - > 512
Tigecycline				1	8	0.25 - 16
Trimethoprim Sulfa	85.52%		14.48%	0.5	8	≤ 0.12 - > 8
***Acinetobacter baumannii* (n=156)**						
Amikacin	95.51%		4.49%	≤ 2	4	≤ 1 - > 64
Amox-Clav				16	32	0.25 - > 32
Cefazolin				> 128	> 128	16 - > 128
Cefepime	86.72%	3.91%	9.38%	2	16	≤ 0.25 - > 128
Cefoxitin				> 32	> 32	2 - > 32
Ceftazidime	82.44%	5.34%	12.21%	8	32	1 - > 32
Ceftobiprole	91.14%		8.86%	0.5	2	≤ 0.06 - >16
Ceftriaxone	47.44%	43.59%	8.97%	16	32	1 - > 256
Ciprofloxacin	92.31%	1.28%	6.41%	0.25	1	≤ 0.06 - 32
Colistin	97.95%		2.05%	1	2	0.25 > 16
Doripenem	95.86%		4.14%	0.25	1	≤ 0.03 - > 32
Ertapenem				4	16	0.12 - > 32
Gentamicin	93.59%	1.28%	5.13%	≤ 0.5	2	≤ 0.5 - > 32
Levofloxacin	92.19%		7.81%	0.12	1	≤ 0.06 - > 16
Meropenem	94.23%	1.92%	3.85%	0.5	2	0.06 - > 32
Moxifloxacin				≤ 0.06	0.25	≤ 0.06 - > 16
Nitrofurantoin				> 256	> 512	128 - > 512
Pip-Tazo	84.62%	7.69%	7.69%	≤ 1	64	≤ 1 - > 512
Tigecycline				0.5	1	0.12 - > 16
Trimethoprim Sulfa	89.74%		10.26%	0.25	4	≤ 0.12 - > 8

Colistin (Polymyxin E). ESBL=extended spectrum ß-lactamase. For tigecycline, FDA approved breakpoints used. Not all isolates tested with ceftobiprole. Breakpoints applied for ceftobiprole: Enterobacteriaceae (S) ≤0.25, (R) >0.25 .

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

Rank	Organism	n	% of Total
1	*Escherichia coli*	7,786	19.6
2	*Staphylococcus aureus,* MSSA	6,594	16.6
3	*Pseudomonas aeruginosa*	3,539	8.9
4	*Streptococcus pneumoniae*	2,502	6.3
5	*Klebsiella pneumoniae*	2,438	6.1
6	*Staphylococcus aureus,* MRSA	1,851	4.6
7	*Haemophilus influenzae*	1,626	4.1
8	*CNS / Staphylococcus epidermidis*	1,519	3.8
9	*Enterococcus faecalis*	1,152	2.9
10	*Enterobacter cloacae*	968	2.4
11	*Streptococcus agalactiae*	653	1.6
12	*Stenotrophomonas maltophilia*	607	1.5
13	*Proteus mirabilis*	606	1.5
14	*Klebsiella oxytoca*	601	1.5
15	*Streptococcus pyogenes*	597	1.5
16	*Serratia marcescens*	586	1.5
17	*Enterococcus,* non-speciated	582	1.5
18	*Candida albicans*	467	1.2
19	*Enterococcus faecium*	443	1.1
20	*Moraxella catarrhalis*	429	1.1
	Other	4,270	10.7
		39,816	

CNS: coagulase-negative staphylococci

CONCLUSIONS

- Of the 39,816 pathogens obtained, the most common were: *E. coli* 19.6%, *S. aureus* (MSSA) 16.6%, *P. aeruginosa* 8.9%, *S. pneumoniae* 6.3%, *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 (43.7%), respiratory (32.7%), urine (13.4%) and wound specimens (10.2%) from patients on wards 38.0% (29.7% medical/8.3% surgical), ER 24.9%, ICU 19.0% and clinics 18.1% .
- Susceptibility rates for *E. coli* were: 99.9% meropenem and tigecycline, 99.7% ertapenem, 99.7% amikacin, 97.7% piperacillin/tazobactam, 95.3% cefepime, 93.5% ceftobiprole, 92.1% ceftriaxone, 90.5% gentamicin, 76.9% ciprofloxacin and 73.1% trimethoprim/sulfamethoxazole.
- Susceptibility rates for *P. aeruginosa* were: 94.7% colistin, 91.9% amikacin, 84.4% doripenem, 84.4% piperacillin/tazobactam, 83.1% ceftazidime, 80.8% meropenem, 78.7% gentamicin and 74.7% ciprofloxacin.
- Susceptibility rates for MRSA were: 100% linezolid and telavancin, 99.9% daptomycin, 99.9% vancomycin, 99.5% ceftobiprole, 99.1% tigecycline, 93.7% trimethoprim/sulfamethoxazole, 53.5% clindamycin, 17.0% ciprofloxacin and 15.0% for clarithromycin.