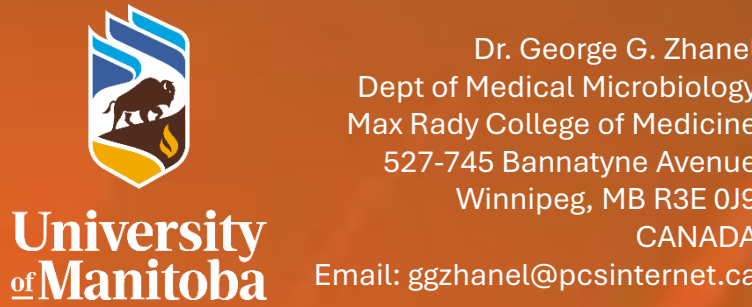




G. Zhanel^{1*}, M. Baxter¹, P. Lagacé-Wiens¹, R. Davidson², J. Blondeau³, A. Brahami¹, J. Karlowsky¹, A. Walkty¹, M. McCracken⁴, L. Mataseje⁴, G. Golding⁴, H. Adam¹, and the Canadian Antimicrobial Resistance Alliance (CARA)

¹Department of Medical Microbiology and Infectious Diseases, Max Rady College of Medicine, University of Manitoba, Winnipeg, Manitoba, Canada; ²Department of Microbiology, Queen Elizabeth II Health Sciences Centre, Halifax, Nova Scotia, Canada; ³Department of Microbiology, Royal University Hospital, Saskatoon, Saskatchewan, Canada; ⁴National Microbiology Laboratory, Winnipeg, Manitoba, Canada



Introduction

Antimicrobial-resistant Gram-positive organisms such as MRSA and VRE along with Gram-negative organisms such as extended-spectrum β -lactamase producing (ESBL) Enterobacterales, carbapenem-resistant Enterobacterales (CRE), and carbapenem-resistant *Pseudomonas aeruginosa* are increasing in prevalence in Canada and around the world (1). Available therapeutic options for the treatment of these antimicrobial resistant organisms are limited as these organisms frequently display a multidrug-resistant (MDR) phenotype (1).

CANWARD (a collaboration between the Canadian Antimicrobial Resistance Alliance and the National Microbiology Laboratory) is a national, ongoing surveillance study which assesses pathogens associated with, and antimicrobial resistance patterns in respiratory, bacteremic, urinary, and wound/IV site infections in Canadian hospitalized patients on medical/surgical wards, intensive care units, emergency rooms and outpatient clinics (1-3).

Materials and Methods

Participating Sites

From 2007-2023, tertiary-care medical centres in major population centres in 8 of the 10 provinces in Canada were recruited (2,3). 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 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. From 2007-2023, a total of 61066 isolates were collected and 56287 underwent antimicrobial susceptibility testing (2,3).

Antimicrobial Susceptibilities

The *in vitro* activity of selected antimicrobials was determined by broth microdilution in accordance with (CLSI) guidelines (2,3). Antimicrobial minimum inhibitory concentration (MIC) interpretive standards were defined according to CLSI breakpoints (2,3).

Acknowledgements

The authors would like to thank the investigators and laboratory site staff at each medical centre that participated in the CANWARD study.

The CANWARD Study was supported in part by the University of Manitoba, Shared Health, the National Microbiology Laboratory, Avir, Paladin Labs, Sandoz, Sterimax, Verity and Xediton. This study was also supported in part by a research grant from Investigator-Initiated Studies Program of Merck Canada Inc. The opinions expressed in this paper are those of the authors and do not necessarily represent those of Merck Canada Inc.

References

1. Zhanel GG and Adam HJ. 17 years of the CANWARD study (2007-2023). Journal of Antimicrobial Chemotherapy 2025;80 (supplement 2):2-4.
2. Zhanel GG, Baxter MR, Golden AR, Lagacé-Wiens P, Walkty A, Fuller J, Davidson RJ, Blondeau J, Poutanen S, Lavallee C, McCracken M, Golding G, Schweizer F, Bay D, Karlowsky JA and Adam HJ. 25897 Gram-positive pathogens from Canadian hospitals: 17 years of results from the CANWARD study (2007-2023). Journal of Antimicrobial Chemotherapy 2025;80 (supplement 2):5-14.
3. Zhanel GG, Baxter MR, Lagacé-Wiens P, Walkty A, Fuller J, Davidson RJ, Blondeau J, Poutanen S, Lavallée C, Mataseje L, Golding G, Schweizer F, Bay D, Denisuiik A, Li J, Karlowsky JA and Adam HJ. 34155 Gram-negative pathogens from Canadian hospitals: 17 years of results from the CANWARD study (2007-2023). Journal of Antimicrobial Chemotherapy 2025;80 (supplement 2):15-26.

Conclusions

1. The current prevalence of MRSA in Canada is ~25% with HA-MRSA decreasing and CA-MRSA increasing. 99.9-100% susceptibilities occurred with ceftobiprole, dalbavancin, daptomycin, linezolid and vancomycin.
2. VRE were 6.1% of all *Enterococcus* spp. and 23.0% of all *E. faecium*. VREF rates were very variable from year to year. Highest VREF susceptibilities occurred with daptomycin 98.4%, tigecycline 97.3% and linezolid 86.0%.
3. The current prevalence of ESBL *E. coli* is ~15% and *K. pneumoniae* ~10%. 99.9-100% susceptibilities occurred with ceftazidime/avibactam, imipenem/relebactam, and meropenem/vaborbactam, with meropenem at 99.5%.
4. CRE (Meropenem-resistant Enterobacterales) continues to be < 1.0% across Canada. The highest susceptibilities versus carbapenemase-producing ertapenem-resistant Enterobacterales were: tigecycline 83.3%, meropenem/vaborbactam 79.2%, ceftazidime/avibactam 79.2% and imipenem/relebactam 66.7%.
5. 21.5% of all *P. aeruginosa* isolates were carbapenem-resistant. Carbapenemase genes were only identified in 3 (0.8%) isolates. The highest susceptibilities versus carbapenem-resistant *P. aeruginosa* were: ceftolozane/tazobactam 78.4%, imipenem/relebactam 63.3%, tobramycin 70.6% and ceftazidime/avibactam 60.1%.

Results

Table 2. ESBL *E. coli* (n=1007).

Antibiotic	% S
ceftazidime/avibactam	99.9
ceftolozane/tazobactam	96.0
ceftriaxone	1.2
gentamicin	64.3
imipenem/relebactam	100
levofloxacin	11.6
meropenem	99.5
meropenem/vaborbactam	100
piperacillin/tazobactam	83.6
tigecycline	99.9
trimethoprim/sulfamethoxazole	34.1

Table 3. MRSA (n=2697).

Antibiotic	% S
ceftobiprole	100
clarithromycin	18.7
clindamycin	60.6
dalbavancin	99.9
daptomycin	99.9
doxycycline	97.8
levofloxacin	14.1
linezolid	99.9
tigecycline	98.2
trimethoprim/sulfamethoxazole	94.7
vancomycin	99.9

Table 4. Carbapenemase-producing ertapenem-resistant Enterobacterales (n=24).

Antibiotic	% S
ceftazidime/avibactam	79.2
ceftolozane/tazobactam	12.5
ceftriaxone	4.2
gentamicin	54.2
imipenem/relebactam	66.7
meropenem	20.8
meropenem/vaborbactam	79.2
tigecycline	83.3
trimethoprim/sulfamethoxazole	29.2

Table 5. Carbapenem-resistant *P. aeruginosa* (n=371).

Antibiotic	% S
ceftazidime	29.1
ceftazidime/avibactam	60.1
ceftolozane/tazobactam	78.4
ciprofloxacin	42.6
imipenem/relebactam	63.3
meropenem	0
meropenem/vaborbactam	39.1
piperacillin/tazobactam	29.6
tobramycin	70.6

Results

Figure 1. Annual proportion of *S. aureus* isolates identified as MRSA in Canadian hospitals.

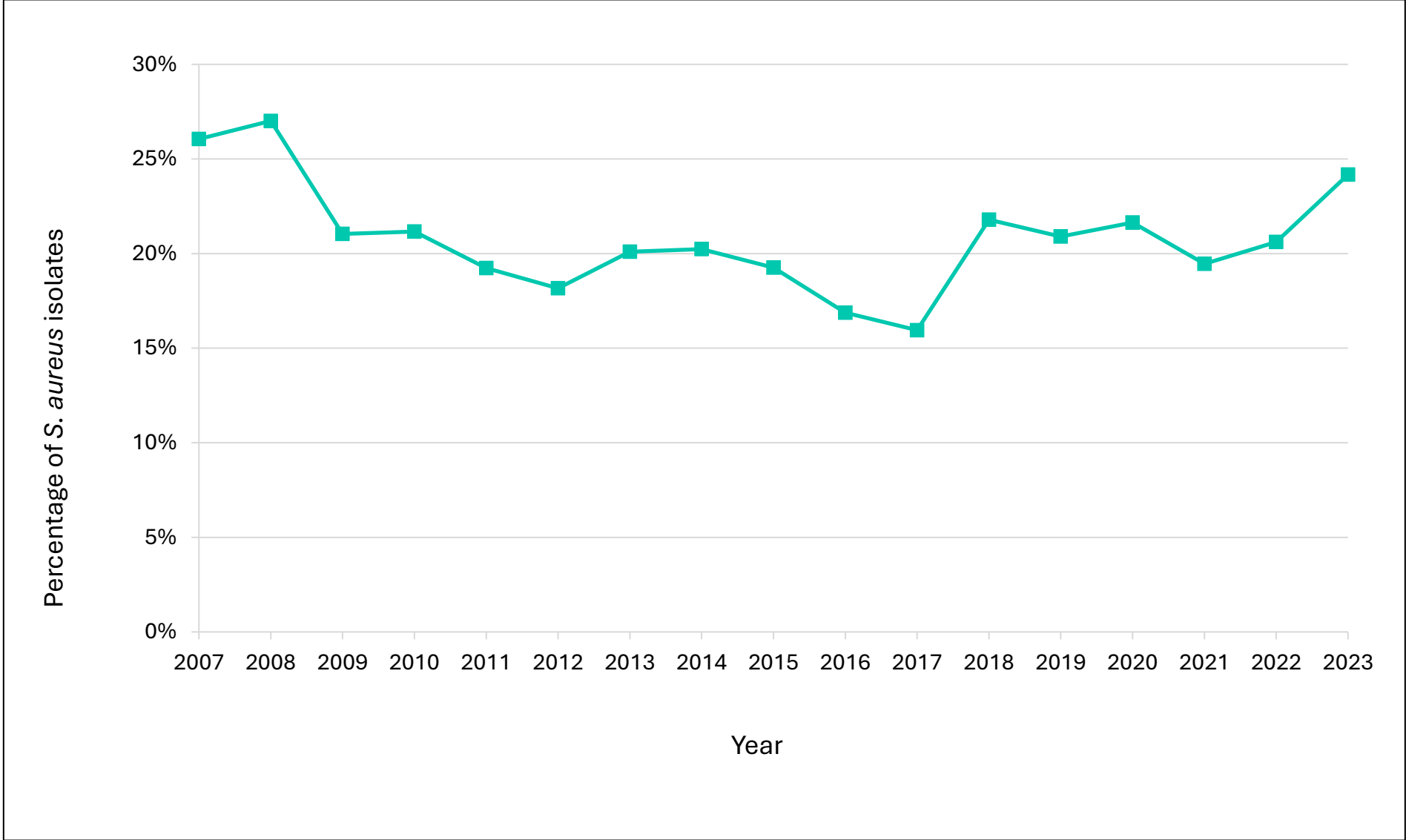


Figure 2. Annual proportion of CA-MRSA and HA-MRSA genotypes in Canadian hospitals.

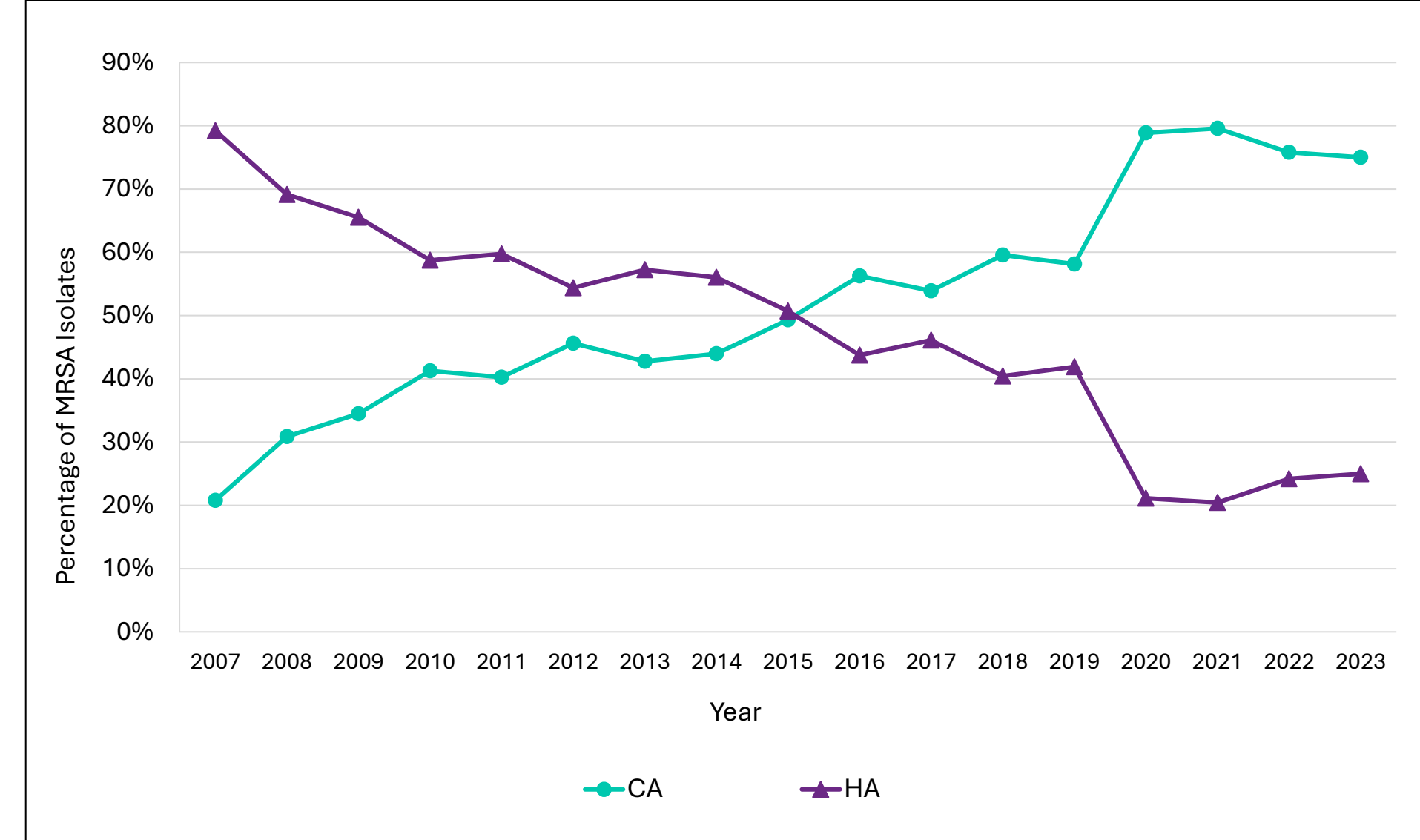
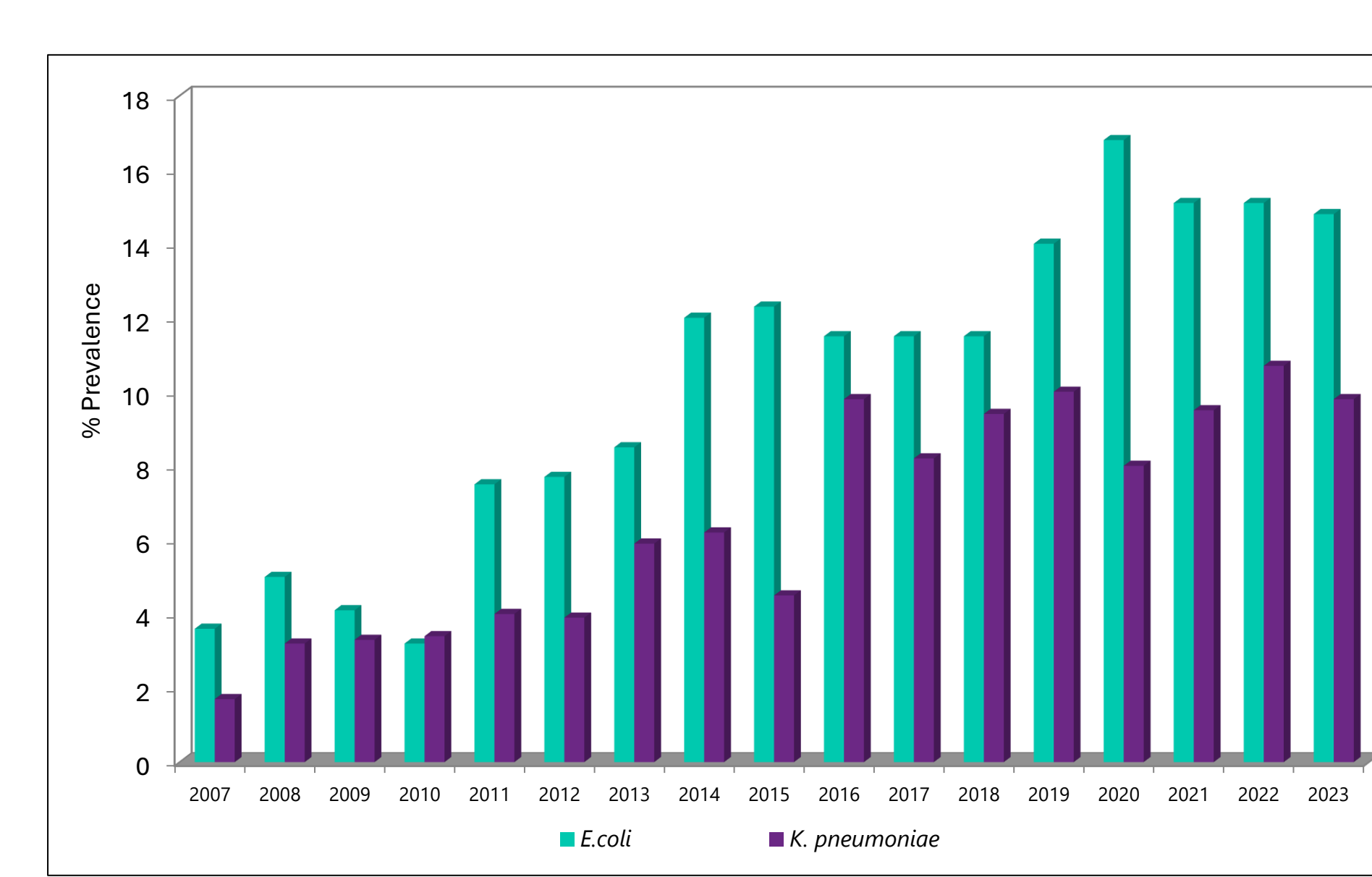


Figure 3. Prevalence of ESBL-producing *E. coli* and *K. pneumoniae* in Canada.



VRE

VRE were 6.1% of all *Enterococcus* spp. and 23.0% of all *E. faecium*. VRE (*E. faecium*) rates were very variable from year to year with 12.1% in 2007–2008 and 36.3% in 2021–2023.

Table 1. Antimicrobial susceptibilities versus VRE (n=186).

Antibiotic	% S
ciprofloxacin	0
daptomycin	98.4
linezolid	86.0
tigecycline (FDA BP)	97.3
vancomycin	0

Carbapenem-Resistant Enterobacterales (CRE)

Meropenem-resistant Enterobacterales continues to be < 1.0% across Canada.

0.7% of all Enterobacterales were ertapenem-resistant (CRE). Carbapenemase-producing Enterobacterales (CPE) accounted for only a small proportion of CRE isolates (predominantly KPC-positive *K. pneumoniae* [ST834, ST16, ST258] and *E. coli* [ST131]).

Most non-CPE CRE isolates were *Enterobacter cloacae*. CPE isolates were more frequently MDR and harboured more antimicrobial resistance genes than did non-CPE isolates.

Carbapenem-Resistant *Pseudomonas aeruginosa*

21.5% (371/1,725) of all *P. aeruginosa* isolates (CANWARD 2018-2023) were carbapenem-resistant.

Carbapenemase genes were only identified in 3 (0.8%) isolates; two isolates carried *bla*_{IMP-26} and one isolate carried *bla*_{GES-5}.

Wide genetic diversity was observed with 151 different STs identified. The most common STs were ST17 (4.6%), ST27 (4.6%), and high-risk clones ST235 (4.3%), ST244 (3.5%), ST253 (6.4%), and ST357 (2.7%). cgMLST clusters were identified amongst 34.9% of the high-risk clones, suggesting clonal dissemination.

Figure 4. Annual numbers of ertapenem-resistant Enterobacterales isolated in Canada from 2007 to 2023 stratified by the presence or absence of a carbapenemase gene (CPE or not CPE).

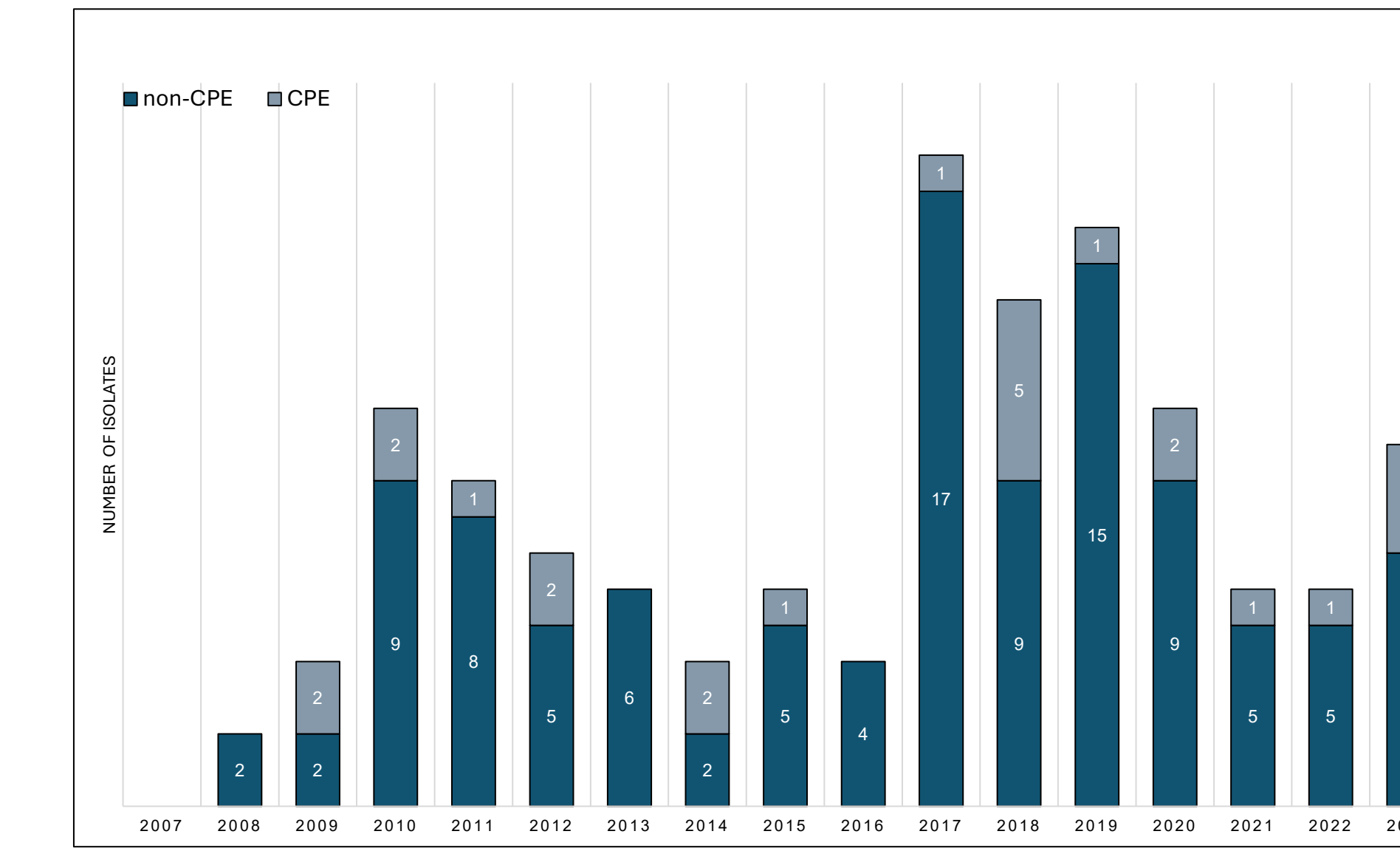
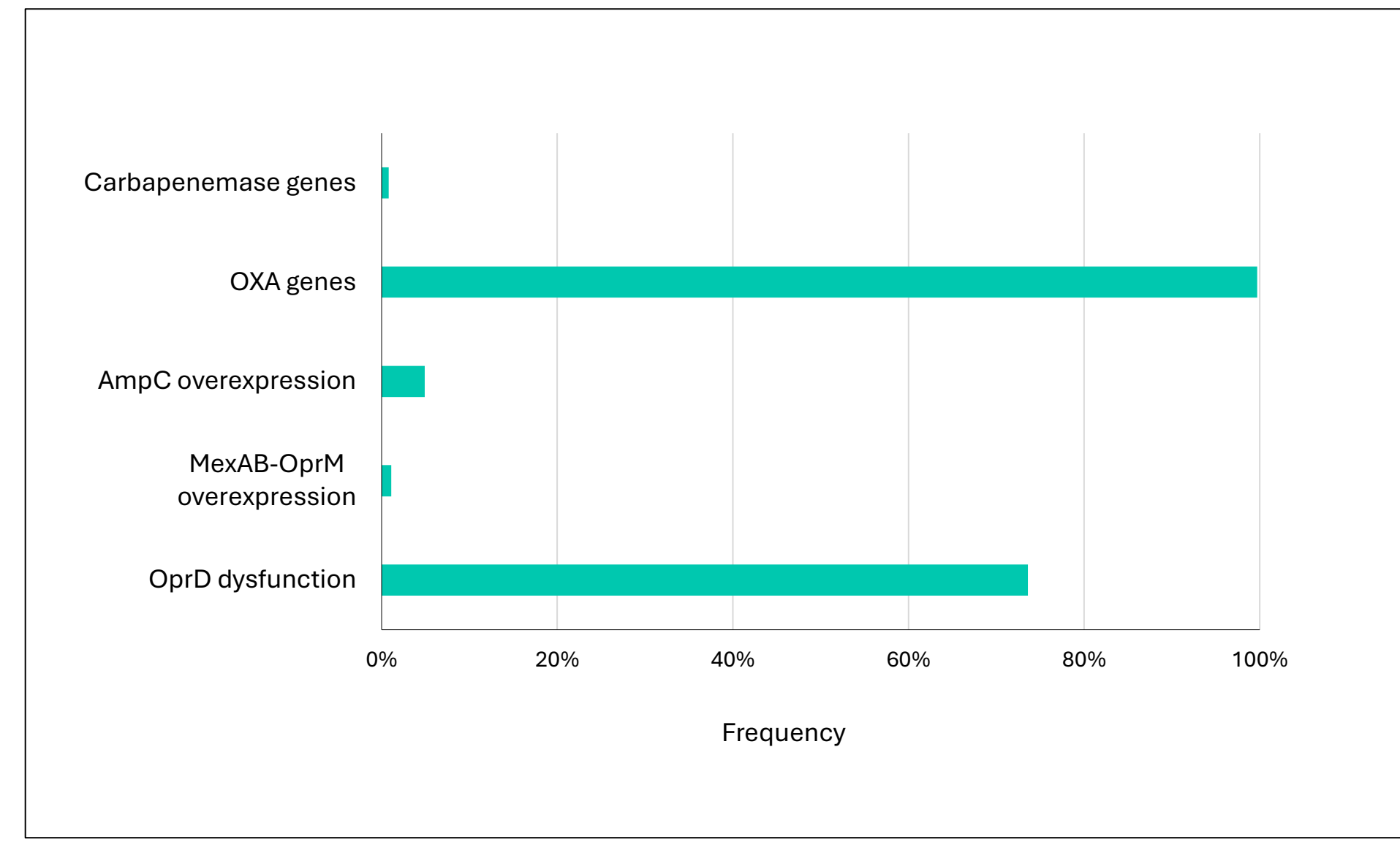


Figure 5. Distribution of possible mechanisms of resistance to carbapenems in 371 carbapenem-resistant *P. aeruginosa*.



Tables 2-5. Antimicrobial susceptibilities versus ESBL *E. coli* (Table 2), MRSA (Table 3), carbapenemase-producing ertapenem-resistant Enterobacterales (Table 4), and carbapenem-resistant *P. aeruginosa* (Table 5).