ORIGINAL RESEARCH

Frontline staff understanding of carbapenemase-producing *Enterobacterales* infection prevention and control measures – A cross-sectional survey conducted in Ontario, Canada

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ABSTRACT

Background: The Community of Practice (CoP) group, comprising members from Trillium Health Partners (THP), Halton Healthcare (HH) and William Osler Health System (WOHS) executed an education needs assessment survey. The objective of this survey was to evaluate the knowledge and understanding of carbapenemase-producing *Enterobacterales* (CPE) best practices amongst frontline staff across three organizations.

Methods: A quantitative, cross-sectional survey consisting of 10 questions was developed and distributed across the three organizations. Responses were independently reviewed by each site, and data from all sites were aggregated. The combined data were subsequently examined, charted and graphed in Microsoft Excel. The results were displayed both by hospital site and in a combined format.

Results: A total of 514 frontline staff completed the survey across all sites. While 86% of respondents were familiar with the term CPE, only 30% felt confident in explaining what CPE is. Furthermore, only 67% of respondents identified the appropriate isolation measures for CPE-positive patients, and 61% recognized the appropriate measures for CPE-exposed patients. Additionally, 57% were unable to identify the correct disposal process for liquid waste. Although 81% of respondents understood the severity of CPE infections, only 57% agreed that CPE-positive patients require ongoing additional precautions. Finally, only 25% could correctly identify when to collect CPE screening swabs for newly admitted patients per hospital policy.

Conclusions: The survey responses revealed consistent gaps in CPE knowledge and education across all three organizations. Although respondents demonstrated some understanding of CPE infections, including the ability to identify the organism and recognize its potential negative patient outcomes, significant knowledge deficiencies were evident. Across all sites, there was low confidence in managing CPE-positive patients and implementing appropriate additional precautions. Moreover, respondents exhibited a lack of comprehension regarding organizational policies and practices related to hand hygiene sink usage, liquid waste disposal, and screening of new admissions. These findings highlight the need for targeted educational interventions to address these deficiencies and enhance CPE management practices across the organizations.

KEYWORDS
Education, carbapenemase-producing *Enterobacterales*, integration, survey, community of practice

INTRODUCTION

The emergence of carbapenemase-producing *Enterobacterales* (CPE) represents a significant global health threat due to their ability to render carbapenems, one of the most potent classes of antibiotics ineffective (Logan & Weinstein, 2017). *Enterobacterales*, a large order of Gram-negative bacteria includes common pathogens such as *Escherichia coli* and *Klebsiella pneumoniae*. These organisms are commonly associated with a range of infections from uncomplicated cystitis to bacteremia with sepsis and are a leading cause of healthcare-associated infections (Oliveira *et al.*, 2023). The production of carbapenemase enzymes by these pathogens confers resistance not only to carbapenems, but often to multiple other classes of antibiotics, severely limiting treatment options and complicating clinical management (Logan & Weinstein, 2017).

Conflicts of interest: The authors declare that there is no conflict of interest to report for this article.

https://doi.org/10.36584/cjic.2024.003.01.144.152

The spread of CPE is facilitated by the horizontal transfer of genes encoding carbapenemases, such as *Klebsiella pneumoniae* carbapenemase (KPC), Verona integron-encoded MBL (VIM), New Delhi metallo-β-lactamase (NDM), Oxacillinase-48 like carbapenemase (OXA-48), and Imipenemase (IMP) (Otávio *et al.*, 2019; Peters *et al.*, 2023). These genes are often carried on plasmids, which can easily move between different bacterial species (Yang *et al.*, 2024). This genetic mobility has enabled the rapid global dissemination of CPE, posing a substantial challenge to public health systems and hospital infection control programs worldwide as strategies are developed to prevent and contain the spread of these organisms (Wang *et al.*, 2021). Yigit *et al.* (2001) highlighted the appearance of CPE in the USA, with a KPC-1 first identified in North Carolina in 2001. Subsequently, the first CPE cases in Canada were isolated in Ontario in 2008 (Goldfarb *et al.*, 2009; Pillai *et al.*, 2009).

High morbidity and mortality rates are associated with CPE infections due to limited treatment options, prolonged hospital stays and high healthcare costs (Hovan *et al.*, 2021). Moreover, the detection of CPE requires advanced laboratory techniques and robust surveillance systems to effectively monitor and manage their spread (Lupo *et al.*, 2013; Tamma & Simner, 2018). Notably, an increase in CPE infections and colonizations has been observed, emphasizing the urgency of local and global containment efforts (Public Health Ontario, 2023).

Despite these alarming trends, little is known about the overall understanding and awareness of CPE among frontline staff working in acute care hospitals within Peel region. The aim of the study was to better ascertain the overall understanding of CPE and CPE-related infection prevention strategies among frontline staff providing direct patient care using a quantitative survey with the intention of using the obtained results to develop targeted educational interventions.

METHODS

Study setting

Responding to the provincial and regional increase in CPE cases, three hospital organizations, Trillium Health Partners (THP), Halton Healthcare (HH), and William Osler Health System (WOHS) convened a CPE educational focus task group through a collaborative Community of Practice (CoP). THP comprises Credit Valley Hospital, Mississauga Hospital, Queensway Health Centre, and several units at the Humber River Reactivation Care Centre, as well as a number of outpatient and community services, and serves the diverse populations of Mississauga, West Toronto, and surrounding areas. THP inpatient units include 1,457 beds and are staffed by over 11,000 employees. WOHS serves a population of over 1.3 million people within the areas of Brampton, North Etobicoke, and Caledon, as well as neighbouring areas. WOHS is comprised of Etobicoke General Hospital, Brampton Civic Hospital, Peel Memorial Centre for Integrated Health and Wellness, and several satellite sites, totalling 918 inpatient beds and over 6,900 staff members. HH encompasses three community hospitals in Milton, Oakville, and Halton Hills, which together offer a total of 674 inpatient beds serviced by over 5,000 staff members.

Prior to development of the study design, a literature search was performed to better understand CPE transmission trends in acute care facilities, correlations between sink colonization and CPE transmission, previous recommendations and studies for CPE infection control measures, and past studies on staff engagement in infection control practices and policies.

Study design

A quantitative cross-sectional survey was developed by the taskforce based on feedback and conversations with frontline staff and infection control professionals (ICPs) from all three infection prevention and control (IPAC) teams. ICPs from all three organizations tested and reviewed the surveys before they were finalized and approved. Once approved, surveys were distributed to frontline staff across the three organizations. The survey was designed to address areas identified as gaps in staff understanding and practices, with an emphasis on anonymity, ease of completion, and questions relevant to all three organizations. The survey specifically targeted frontline staff who provide direct patient care, as they are the most likely to encounter CPE-positive patients or environments colonized with CPE. Staff from all three organizations were included due to the increasing prevalence of CPE within the community and the possibility of encountering a CPE-positive patient in any inpatient or outpatient care setting. The content of this survey received approval from the respective hospital IPAC managers and directors.

The survey included a total of 10 questions (Table 1). The initial two questions aimed to collect general demographic information to verify that the sample collected was representative of the targeted population. The other eight questions assessed respondents' understanding of CPE and awareness of their hospital's CPE policy.

Sample size, inclusion and exclusion criteria

An adequate sample size was calculated using Andrew Fisher's formula based on an estimated staff population of 23,000 across all three organizations. The formula determined that a minimum sample size of 378 was required to adequately represent the population, with a 95% confidence level and a standard deviation of 0.5.

The targeted population included frontline staff who provide direct care to patients. Registered nurses (RNs), registered practical nurses (RPNs), and personal support workers (PSWs) were specifically targeted. However, responses were also accepted from other disciplines that have direct physical contact with patients in both inpatient and outpatient settings, including physical and occupational therapists, physicians, and nursing students. Responses given by staff members whose roles do not require them to come into direct contact with patients were excluded from final results.

Surveys were delivered and completed via paper forms or electronically using Microsoft Forms. ICPs actively disseminated the surveys to frontline staff during huddles, meetings, and rounds on clinical units, emphasizing the importance of collecting a large and diverse sample. Staff were encouraged to share the survey with colleagues within their units and to submit

completed surveys to an email address monitored by the THP IPAC team. The project and survey were also promoted at THP's annual IPAC Champions Day to representatives from inpatient and outpatient units, encouraging both their participation and sharing of the survey with colleagues to increase responses.

Data analysis

All survey results were compiled in a central Microsoft Excel database, which was shared among team members from all three hospitals for comparison and analysis. Analysis was performed with categorical data using frequencies and percentages. Not all respondents provided an answer for each survey question. Analysis was completed based only on valid responses to survey questions. Analysis focused on compiled answers and results from across all three organizations and their respective disciplines. Responses were categorized according to answers given as well as correct and incorrect responses. Survey questions and possible responses are outlined in Table 1, with correct responses indicated for each question.

Table 1: CPE survey questions and possible responses

Section 1 Questions	Possible Responses
1. What is your role?	• Registered Nurse (RN) • Registered Practical Nurse (RPN) • Personal Support Worker (PSW) • Other (includes all disciplines/roles not listed above)
2. Which location do you work out of primarily?	Locations listed on survey form varied according to organization
Section 2 Questions	**Possible Responses**
1. What does CPE stand for?	• Common Pathogenic *E. coli* • Carbapenemase-Producing *Enterobacteriaceae* (correct response) • Centralized pathogen eradication • Carbapenem-resistant *Escherichia*
2. On a scale of 1 to 5, how confident would you feel explaining what CPE is to a patient or visitor?	1 - Very unconfident 2 - Somewhat unconfident 3 - Neutral 4 - Somewhat confident (correct response) 5 - Very confident (correct response)
3. Which of the following additional precautions would be required for a patient who has tested positive for CPE on a rectal screening swab?	• Contact Precautions (correct response) • Contact Plus Precautions • Droplet/Contact Precautions • Droplet Contact Plus Precautions • Airborne Precautions • Routine practices only; no additional precautions would be required
4. Which of the following additional precautions would be required for a patient who is identified as a roommate of a CPE positive patient?	• Contact Precautions (correct response) • Contact Plus Precautions • Droplet/Contact Precautions • Droplet Contact Plus Precautions • Airborne Precautions • Routine practices only; no additional precautions would be required
5. Which of the following options could be used to dispose of used bathwater and/or IV fluids?	• Hand hygiene sink • Patient toilet (correct response) • Sink in soiled utility room • None of the above • Other (correct response)[1]
6. CPE infections are mild and easily treatable with antibiotics.	• True • False (correct response)
7. Patients who are colonized or infected with CPE are considered CPE+ indefinitely and cannot be cleared of their CPE infection status.	• True (correct response) • False
8. In which of the following situations would a CPE screening swab be required for a newly admitted patient?	• Patient has had recent hospitalization (within the last 12 months) outside of Canada (correct response)[2] • Patient is actively undergoing hemodialysis (correct response)[2] • Patient is a direct transfer from another healthcare facility (correct response)[2] • Patient had a known contact with a CPE positive roommate in 2019 but was never swabbed for CPE (correct response)[2] • None of the above

[1] Responses under "Other" for Question 5 were evaluated on a case-by-case basis and deemed correct or incorrect based on each response.

[2] Responses to Question 8 were evaluated based on the admission screening policy of the hospital from which the survey was received.

The first question in the second section of the survey asked respondents to identify the full name of CPE from a list of options. To avoid confusion, the term "carbapenemase-producing *enterobacteriaceae*" was provided as the correct answer.

The second question in Section 2 asked respondents to assess their confidence level in explaining CPE to a patient or visitor. This question aimed to gather empirical data on staff's perceived understanding of CPE and their confidence in providing education to patients and visitors.

The third and fourth questions in Section 2 asked respondents to identify the correct precautions for a CPE-positive and CPE-exposed patient from a list of possible additional precautions. These options included Contact Plus precautions, used at THP for patients positive for *Clostridium difficile*, indicating enhanced cleaning and disinfection measures for isolated patients. Also included were Droplet Contact Plus precautions, used for patients known or suspected to be positive for COVID-19, which consist of Droplet Contact measures and an N95 respirator instead of a surgical mask. HH and WOHS do not use these additional precautions. For both questions, Contact Precautions were the desired responses, as patients with CPE and their exposed roommates both require these precautions in a private room. Exposed roommates would have three sets of post-exposure swabs collected, with the last swab collected 21 days after the last date of exposure, after which precautions may be discontinued.

The fifth question asked respondents to identify the correct disposal method for liquid waste. Disposal of liquid waste had previously been identified at all three organizations as a practice issue. This has led to CPE colonization of sink drains due to the improper disposal of patient body fluids into hand hygiene sinks. For this question, the correct response was "patient toilet". Responses categorized under "other" in which respondents answered "toilet" or "soiled utility room hopper" were also accepted. Responses given under "other" that did not include these answers were not considered correct.

The sixth and seventh questions were true or false. Respondents were asked to identify whether statements regarding the severity and patient impact of CPE colonization and infection were true or false. These questions were included to better understand whether staff are aware of the impact a CPE infection or colonization may have on a hospitalized patient. For question eight, the correct response was "false". For question nine, the correct response was "true".

Finally, the last question of Section 2 asked respondents to identify scenarios that would prompt the collection of CPE screening swabs for newly admitted inpatients from a list of options. Because the three organizations have different CPE screening criteria, correct responses varied by organization. For THP respondents, all responses needed to be selected for a response to be considered correct. For HH respondents, responses that included all options except direct transfers from another healthcare facility as requiring CPE screening swabs were marked correct. For WOHS respondents, responses identifying patients hospitalized outside of Canada in the last 12 months and patients with known contact with a CPE-positive patient as requiring CPE screening swabs were marked as correct.

RESULTS

Survey response collection

Between November 2, 2023, and January 29, 2024, more than 600 surveys were distributed across all sites within the three organizations. Of the surveys returned, 514 results were completed appropriately and fit for analysis, as a large number were distributed electronically and disseminated to inpatient units. An exact response rate could not be calculated due to the unknown number of staff informed about the electronic survey through huddles, meetings, and word of mouth. A total of 218 completed surveys were collected from THP staff, 96 from HH staff, and 200 from WOHS staff. All results were anonymous, apart from tracking the location and roles of respondents to ensure a diverse sample population. Primary work location was tracked only for results received from THP and HH staff. Demographic information is displayed in Table 2.

Compilation of survey responses

Survey results were compiled into a central database using Microsoft Excel, and organized by hospital for tracking purposes. Once an adequate sample size had been obtained,

Table 2: Demographic information of survey respondents

Respondent role	Number of responses	% of total responses
Registered Nurse (RN)	332	64.6%
Registered Practical Nurse (RPN)	83	16.2%
Personal Support Worker (PSW)	12	2.3%
Other[1]	84	16.3%
No valid response	3	0.6%
Respondent primary work location	**Number of responses**	**% of total responses**
Credit Valley Hospital (Trillium Health Partners)	112	21.8%
Mississauga Hospital (Trillium Health Partners)	88	17.1%
Queensway Health Centre (Trillium Health Partners)	8	1.6%
Humber River Reactivation Care Centre (Trillium Health Partners)	10	2.0%
Georgetown Hospital (Halton Healthcare)	18	3.5%
Milton District Hospital (Halton Healthcare)	28	5.5%
Oakville Trafalgar Memorial Hospital (Halton Healthcare)	45	8.8%
Tri-Site, No Primary Location (Halton Healthcare)	5	1.0%
William Osler Health System (location not specified)	200	38.9%

[1] "Other" disciplines that responded to the survey included: Registered Dietician, Student Nurse, Physical Therapist/Occupational Therapist and Therapist Assistant, Physician, and Physiotherapist.

results from each organization were compiled into an overall results section for standardization. However, reviewing the survey results from each organization revealed similar outcomes across all three hospitals for all questions. Table 3 displays the number of responses received for each survey question, along with the percentage of overall respondents who gave that response. For several questions, some respondents using paper forms provided multiple responses, despite the question requesting only one. Additionally, some questions were left blank. Blank or illegible responses were recorded as "no valid response". This scenario occurred only with responses on paper forms, as the electronic form did not allow multiple responses for single-answer questions, or permit submission without completing all fields. In cases where multiple responses were received for a question requiring only one, the response was counted as incorrect.

Table 3: Survey responses by question

Question	Possible responses	Number of responses	Percent of total responses	Number (percent) of correct responses	Percent of incorrect responses
1. What does CPE stand for?	Common pathogenic *E. coli*	27	5.3%	440 (85.6%)	14.4%
	Carbapenemase-producing *Enterobacteriaceae*	440	85.6%		
	Centralized Pathogen Eradication	6	1.2%		
	Carbapenem-Resistant *Escherichia*	39	7.6%		
	No valid response	2	0.4%		
2. On a scale of 1 to 5, how confident would you feel explaining what CPE is to a patient or visitor?	1 - Very Unconfident	93	18.1%	149 (29.7%)	70.3%
	2 - Somewhat Unconfident	107	20.8%		
	3 - Neutral	153	29.8%		
	4 - Somewhat Confident	105	20.4%		
	5 - Very Confident	44	8.6%		
	No valid response	12	2.3%		
3. Which of the following additional precautions would be required for a patient who has tested positive for CPE on a rectal screening swab?	Contact Precautions[1]	355	69.1%	355 (69.1%)	30.9%
	Contact Plus Precautions[2]	86	16.7%		
	Droplet/Contact Precaution3	54	10.5%		
	Droplet Contact Plus Precaution[4]	11	2.1%		
	Airborne Precautions[5]	8	1.6%		
	Routine practices only; no additional precautions would be required	8	1.6%		
	No valid response	4	0.8%		
4. Which of the following additional precautions would be required for a patient who is identified as a roommate of a CPE positive patient?	Contact Precautions[1]	321	62.5%	321 (62.5%)	37.5%
	Contact Plus Precautions[2]	74	14.4%		
	Droplet/Contact Precautions[3]	50	9.7%		
	Droplet Contact Plus Precautions[4]	9	1.8%		
	Airborne Precautions[5]	10	1.9%		
	Routine practices only; no additional precautions would be required	55	10.7%		
	No valid response	3	0.6%		
5. Which of the following options could be used to dispose of used bathwater and/or IV fluids?	Hand hygiene sink	45	8.8%	255 (49.6%)	50.4%
	Patient toilet	255	49.6%		
	Sink in soiled utility room	247	48.1%		
	None of the above	54	10.5%		
	Other	27	5.3%		
	No valid response	8	1.6%		

Table 3 (cont'd): Survey responses by question

Question	Possible responses	Number of responses	Percent of total responses	Number (percent) of correct responses	Percent of incorrect responses
6. CPE infections are mild and easily treatable with antibiotics.	True:	96	18.7%	415 (80.7%)	19.3%
	False:	415	80.7%		
	No valid response	3	0.6%		
7. Patients who are colonized or infected with CPE are considered CPE+ indefinitely and cannot be cleared of their CPE infection status.	True:	295	57.4%	295 (57.4%)	42.6%
	False:	211	41.1%		
	No valid response	8	1.6%		
8. In which of the following situations would a CPE screening swab be required for a newly admitted patient?	Patient has had recent hospitalization (within the last 12 months) outside of Canada	349	67.9%	388 (75.5%)	24.5%
	Patient is actively undergoing hemodialysis	139	27.0%		
	Patient is a direct transfer from another healthcare facility	223	43.4%		
	Patient had a known contact with a CPE-positive roommate in 2019 but was never swabbed for CPE	388	75.5%		
	None of the above	14	2.7%		
	No valid response	11	2.1%		

[1] Contact precautions are used for organisms primarily spread via direct and indirect contact, and include hand hygiene, gowns, and gloves.
[2] Contact Plus precautions include all precautions used for Contact precautions as well as performing all cleaning and disinfection with sodium hypochlorite (bleach).
[3] Droplet/Contact precautions are used for organisms primarily spread via large droplets, and include hand hygiene, gowns, gloves, and facial protection (mask and eye protection).
[4] Droplet Contact Plus precautions are used at THP for patients with COVID-19, and include all precautions used for Droplet/Contact precautions as well as requiring an N95 respirator in place of a medical or surgical mask.
[5] Airborne precautions are used for organisms primarily spread via small droplets, and include hand hygiene, patient placement in a negative pressure isolation room, and use of an N95 respirator.

Survey response analysis

Standardized analysis of survey results posed a challenge due to organizational differences in isolation protocols, screening practices, and liquid waste disposal procedures. To simplify the interpretation of results and enable comparison across all three hospitals, responses for each question were categorized as either correct or incorrect. Surveys with no valid response were excluded from both the numerator and denominator in calculations of correct and incorrect response numbers, as well as the overall percentage for that question. For Question #1, the correct response was "carbapenemase-producing *Enterobacteriaceae*". All other responses were classified as incorrect. For Question #2, responses indicating that the respondent was somewhat or very confident in explaining CPE to a patient or visitor were classified as correct, while all other responses were classified as incorrect. For both Questions #3 and #4, Contact Precautions was the correct response, all other responses, including those providing more than one possible type of additional precaution, were marked as incorrect. For Question #5, patient bathwater and IV fluids should be disposed of in the patient toilet or the hopper in the soiled utility room. Responses that did not include these options, or which included other options, were classified as incorrect. For Question #6, the correct response was False, and for Question #7, the correct response was True. For Question #8, the correct response varied by organization, as each hospital has different policies dictating when to collect CPE swabs from admitted inpatients, as previously described. Correct and incorrect responses were compiled for all three organizations and are represented graphically as percentages in Figure 1. Figures 2 to 4 provide percentages of correct and incorrect responses within the RN, RPN, and PSW roles. As the "other" category included various disciplines, a breakdown of correct and incorrect responses for those classified as "other" was not conducted.

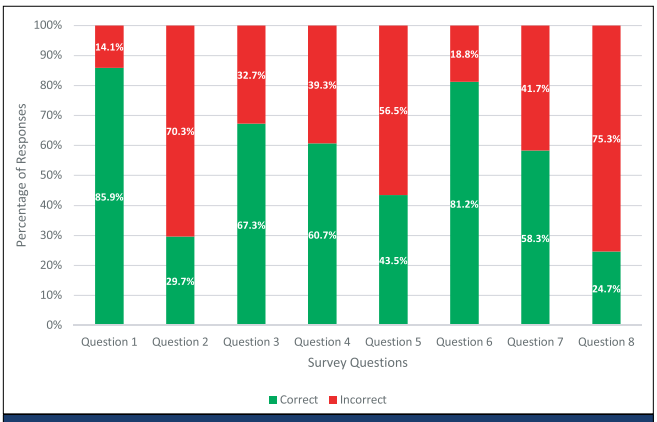

Figure 1: Overall percentage of correct and incorrect responses to survey questions.

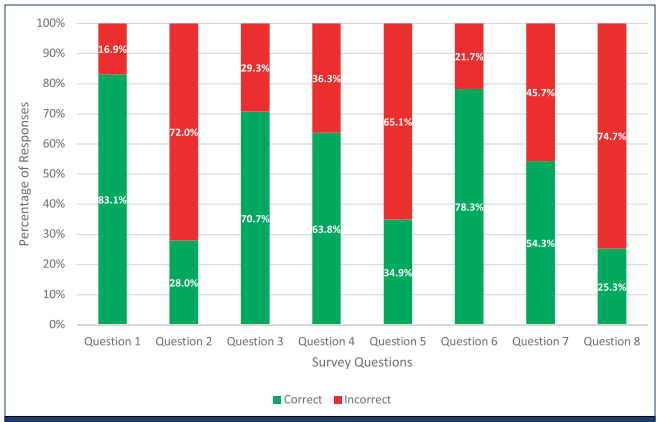

Figure 3: Percentage of correct and incorrect responses by RPNs.

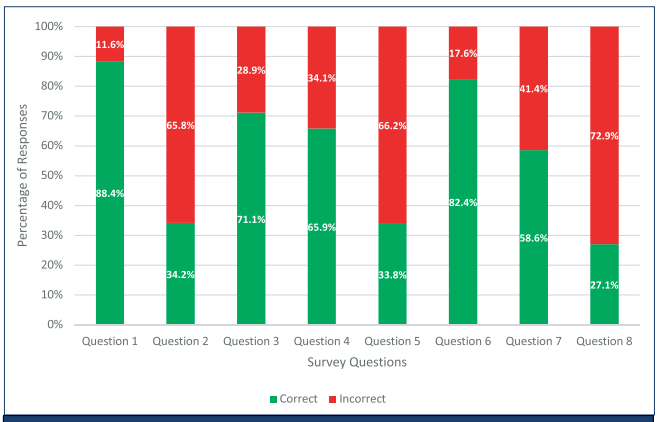

Figure 2: Percentage of correct and incorrect responses by RNs.

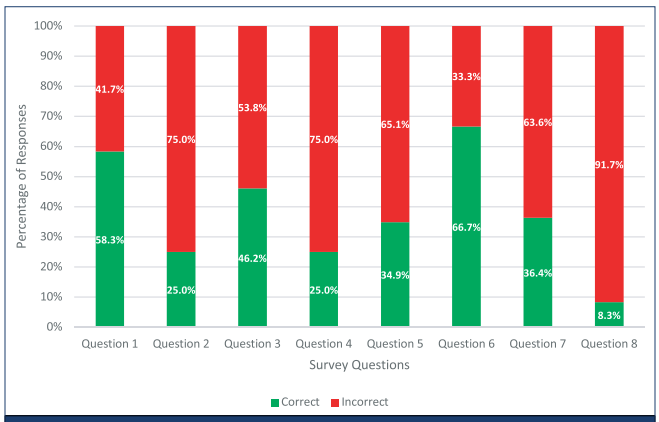

Figure 4: Percentage of correct and incorrect responses by PSWs.

DISCUSSION

A total of 514 frontline staff participated in the anonymous survey across all sites. The survey's anonymity encouraged candid responses, particularly concerning non-compliant or suboptimal practices. Prior to this survey, no formal CPE education was routinely provided, except during unit huddles that were part of infection control practices education. These huddles covered topics such as hand hygiene, the proper donning and doffing of personal protective equipment, the appropriate use of isolation rooms, waste disposal procedures, and environmental cleaning and disinfection practices. However, these huddles were not targeted specifically for CPE education.

The results of the CPE education survey clearly revealed a lack of understanding of CPE and best practices for its prevention and control among frontline staff providing direct care to patients. Although 86% of respondents were familiar with the term CPE, only 69% could accurately identify the appropriate isolation measures for CPE-positive patients, and 62% recognized the correct precautions for individuals exposed to CPE. While 81% of respondents understood the seriousness of a CPE infection and the limited treatment options available, only 57% agreed that CPE-positive patients require indefinite additional precautions. Furthermore, only 25% could accurately determine when to collect CPE screening swabs for newly admitted patients according to their hospital's policy. In contrast, Mathew *et al.* (2023) reported a higher level of CPE awareness among healthcare workers in an acute teaching hospital in Ireland, with 96.3% of respondents scoring above 50% on a similar knowledge survey and 52.3% scoring above 80%. This difference may be explained by the increased public awareness of CPE in Ireland following the declaration of CPE as a National Public Health Emergency in 2017 (Humphreys *et al.*, 2022). Studies by Thibodeau *et al.* (2014) and Di Gennaro *et al.* (2020) also demonstrated higher CPE knowledge scores compared to this study, although these studies primarily targeted physicians.

Only 30% of respondents felt confident in explaining CPE to patients and visitors. This lack of confidence may be attributable to workload factors such as time pressure, patient acuity, patient flow, and staffing, which aligns with findings from O'Connor *et al.* (2022). However, this result is concerning as frontline staff, particularly primary care nurses, are routinely the main point of contact and education for patients and visitors at the hospitals included in this study. They are also responsible for providing education on managing CPE and other infections after discharge. Care providers who lack confidence in their understanding of an organism or infection, regardless of their actual knowledge, may

be less willing to educate patients, visitors, or colleagues about it and necessary control measures. This reluctance could allow poor IPAC practices to persist without correction.

Finally, 57% of respondents were unable to correctly identify the proper disposal process for liquid waste. This finding aligns with Kearney *et al.* (2024), which reported that over 40% of nursing and medical staff in Irish hospitals reported improper waste disposal in clinical handwashing sinks. Similar behaviours have been documented in previous outbreak investigations, as noted by Leitner *et al.* (2015) and Parkes *et al.* (2018). This result is significant for CPE infection control practices, as CPE can colonize sink drains and is challenging to remove once a biofilm forms (Park *et al.*, 2020; Ganim *et al.*, 2020).

The findings of the current study were consistent across all three organizations, highlighting that this is not a "one-hospital problem". In response to these findings, educational materials will be developed and distributed to frontline staff across the three organizations. These will include in-person training sessions, infographics, posters, fact sheets, and Frequently Asked Questions documents, as well as updated patient and family educational handouts. In-person education will include formal evaluations through quizzes and surveys distributed to participating staff to ensure effectiveness and address knowledge gaps identified by this survey. A continued regional approach to this issue is essential for consistent practices and procedures. It will also ensure that policies aimed at preventing and controlling the spread of CPE are effectively implemented by frontline staff. This also presents an opportunity for broader education on IPAC best practices, emphasizing their role in preventing not only CPE but other infections as well, thereby improving overall patient care.

A limitation of this study is its relatively narrow focus, primarily involving nursing staff while excluding other key healthcare workers, such as physicians. Expanding the participant pool to include a broader range of healthcare professionals would provide a more comprehensive view of CPE practices. Increasing the number of participants and incorporating more detailed questions on attitudes and practices could yield deeper insights into compliance and challenges. The study was limited to three hospitals in only two health regions within Ontario (Peel and Halton), potentially limiting the generalizability of these results to other regions. Expanding the geographical scope in future studies could provide a more comprehensive understanding of CPE knowledge and practices across healthcare settings and regions.

The CoP group formed by THP, HH and WOHS played a crucial role in addressing gaps in CPE education within all three organizations, sparking the educational needs assessment study. The collaboration and communication among the three organizations across various regions were instrumental in gathering relevant data from frontline staff and highlighting the universal need for enhanced education and resources for preventing and controlling CPE in Ontario hospitals. By sharing experiences and pooling resources, the CoP organizations amplified efforts to collect sufficient data and collaborated on developing new resources. This would have been challenging for any single organization to achieve alone. This collaboration and shared workload contributed immensely to the success of the project.

IPAC departments have recognized CPE for years, making it a consistent focus for many. However, despite this increased focus, the survey results clearly indicate that opportunities remain for enhancing frontline staff education on effective control of CPE. To combat the threat of CPE effectively, it is crucial to bridge the gaps between policy and practice highlighted by these survey results. Frontline staff must be well-educated on what CPE is, how it affects patients, and how to control it effectively in a healthcare setting using IPAC best practices.

REFERENCES

Di Gennaro, F., Marotta, C., Amicone, M., Bavaro, D. F., Bernaudo, F., Frisicale, E. M., et al. (2020). Italian young doctors' knowledge, attitudes, and practices on antibiotic use and resistance: A national cross-sectional survey. *Journal of Global Antimicrobial Resistance, 23*, 167-173. https://doi.org/10.1016/jgar.2020.08.022

Ganim, C., Mazher, M., & Breaker, E. (2020). Establishment of a Sink Gallery to Investigate Growth of Carbapenemase-Producing Klebsiella pneumoniae and Biofilms in P-Traps. *Infection Control & Hospital Epidemiology, 41*(S1), s219–s220. doi:10.1017/ice.2020.763

Goldfarb, D., Harvey, S. B., Jessamine, K., Jessamine, P., Toye, B., & Desjardins, M. (2009). Detection of plasmid-mediated KPC-producing *Klebsiella pneumoniae* in Ottawa, Canada: Evidence of intrahospital transmission. *Journal of Clinical Microbiology, 47*(6), 1920–1922. https://doi.org/10.1128/JCM.00098-09

Gupta, N., Limbago, B. M., Patel, J. B., & Kallen, A. J. (2011). Carbapenem-resistant Enterobacteriaceae: Epidemiology and prevention. *Clinical Infectious Diseases, 53*(1), 60-67. https://doi.org/10.1093/cid/cir202

Hoven, M., Narayanan, N., Cedarbaum, V., Bhowmick, T., & Kirn, T. (2021). Comparing mortality in patients with carbapenemase-producing carbapenem-resistant *Enterobacterales* and non-carbapenemase-producing carbapenem-resistant *Enterobacterales* bacteremia. *Diagnostic Microbiology and Infectious Disease, 101*(4), 115505. https://doi.org/10.1016/j.diagmicrobio.2021.115505

Humphreys, H., Cormican, M., Brennan, W., Burns, K., O'Donovan, D., Dalchan, T., Keane, S., & Sheahan, A. (2022). Reflections on a national public health emergency response to carbapenemase-producing *Enterobacterales* (CPE). *Epidemiology and infection, 150*, 1–19. Advance online publication. https://doi.org/10.1017/S0950268822000218

Ji, W. Y., Nam, J. H., Lee, K. J., & Yoo, J. S. (2024). Effect of temperature on carbapenemase-encoding plasmid transfer in *Klebsiella pneumoniae*. *Microorganisms, 12*(3), 454. https://doi.org/10.3390/microorganisms12030454

Kearney, A., Humphreys, H., & Fitzgerald-Hughes, D. (2024). Infection prevention and control policy implementation for CPE: A cross-sectional national survey of healthcare workers reveals knowledge gaps and suboptimal practices. *Journal of Hospital Infection, 145*, 148-154. https://dx.doi.org/10.1016/j.jhin.2023.12.007

Leitner, E., Zarfel, G., Luxner, J., Herzog, K., Pekard-Amenitsch, S., Hoenigl, M., et al. (2015). Contaminated handwashing sinks as the source of a clonal outbreak of KPC-2-producing Klebsiella oxytoca on a hematology ward. *Antimicrobial Agents and Chemotherapy, 59*(1), 714-716. https://doi.org/10.1128/AAC.04306-14

Logan, L. K., & Weinstein, R. A. (2017). The epidemiology of carbapenem-resistant Enterobacteriaceae: The impact and evolution of a global menace. *Journal of Infectious Diseases, 215*(Suppl_1), S28-S36. https://doi.org/10.1093/infdis/jiw282

Lupo, A., Papp-Wallace, K. M., Sendi, P., Bonomo, R. A., & Endimiani, A. (2013). Non-phenotypic tests to detect and characterize antibiotic resistance mechanisms in *Enterobacteriaceae*. *Diagnostic Microbiology and Infectious Disease, 77*(3), 179-194. https://doi.org/10.1016/j.diagmicrobio.2013.06.001

Mathew, S., et al. (2023). Knowledge, attitudes, and self-reported practices of healthcare professionals on Carbapenemase-Producing *Enterobacterales* (CPE): A cross-sectional study. *Infection Prevention in Practice, 5*(1). https://doi.org/10.1016/j.infpip.2022.100257

Min-Ge, W., Liu, Z., Liao, X. P., Ruan-Yang, S., Li, R., Liu, Y., et al. (2021). Retrospective data insight into the global distribution of carbapenemase-producing *Pseudomonas aeruginosa*. *Antibiotics, 10*(5), 548. https://doi.org/10.3390/antibiotics10050548

O'Connor, M., McNamara, C., & Doody, O. (2023). Healthcare workers' experiences of caring for patients colonized with carbapenemase-producing Enterobacterales (CPE) in an acute hospital setting: A qualitative descriptive study. *Infectious Diseases & Health, 28*, 186-194.

Oliveira, J., & Reygaert, W. C. (2023, August 8). Gram-negative bacteria. In StatPearls. Retrieved from: https://www.ncbi.nlm.nih.gov/books/NBK568595/

Ontario Agency for Health Protection and Promotion (Public Health Ontario). (2023). Surveillance report: Carbapenemase-producing *Enterobacteriaceae* in Ontario: 2022 annual summary. Toronto, ON: King's Printer for Ontario.

Otávio Hallal, F. R., de Lima-Morales, D., Barth, A. L., Paim, T. G., Mott, M. P., Riche, C. V. W., & Gales, C. A. (2019). Putative horizontal transfer of carbapenem resistance between Klebsiella pneumoniae and Kluyvera ascorbata during abdominal infection: A case report. *Infection Control & Hospital Epidemiology, 40*(4), 494-496. https://doi.org/10.1017/ice.2019.26

Park, S. C., Parikh, H., Vegesana, K., Stoesser, N., Barry, K. E., Kotay, S. M., Dudley, S., Peto, T. E. A., Crook, D. W., Walker, A. S., & Mathers, A. J. (2020). Risk Factors Associated with Carbapenemase-Producing Enterobacterales (CPE) Positivity in the Hospital Wastewater Environment. *Applied and Environmental Microbiology, 86*(24), e01715-20. https://doi.org/10.1128/AEM.01715-20

Parkes, L. O., & Hota, S. S. (2018). Sink-related outbreaks and mitigation strategies in healthcare facilities. *Current Infectious Disease Reports, 20*(10). https://doi.org/10.1007/s11908-018-0648-3

Peters, B. K., Reddy, N., Shungube, M., Girdhari, L., Baijnath, S., Mdanda, S., et al. (2023). In vitro and in vivo development of a β-lactam-metallo-β-lactamase inhibitor: Targeting carbapenem-resistant *Enterobacterales*. *ACS Infectious Diseases, 9*(3), 486-496. https://doi.org/10.1021/acsinfecdis.2c00485

Pillai, D. R., Melano, R., Rawte, P., Lo, S., Tijet, N., Fuksa, M., et al. (2009). Klebsiella pneumoniae carbapenemase, Canada. *Emerging Infectious Diseases, 15*(5), 827-829. https://doi.org/10.3201/eid1505.081536

Tamma, P. D., & Simner, P. J. (2018). Phenotypic detection of carbapenemase-producing organisms from clinical isolates. *Journal of Clinical Microbiology, 56*(11), e01140-18. https://doi.org/10.1128/JCM.01140-18

Thibodeau, E., Doron, S., Iacoviello, V., Schimmel, J., & Snydman, D. R. (2014). Carbapenem-resistant *Enterobacteriaceae*: Analyzing knowledge and practice in healthcare providers. *PeerJ, 2*, e405. https://doi.org/10.7717/peerj.405

Yigit, H., Queenan, A. M., Anderson, G. J., Domenech-Sanchez, A., Biddle, J. W., Steward, C. D., et al. (2001). Novel carbapenem-hydrolyzing beta-lactamase, KPC-1, from a carbapenem-resistant strain of Klebsiella pneumoniae. *Antimicrobial Agents and Chemotherapy, 45*(4), 1151-1161. https://doi.org/10.1128/AAC.45.4.1151-1161.2001