Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Are health care workers protected? An observational study of selection and removal of personal protective equipment in Canadian acute care hospitals

Robyn Mitchell MHSc\textsuperscript{a,}*\textsuperscript{,} a, Virginia Roth MD\textsuperscript{b}, Denise Gravel MSc\textsuperscript{c}, George Astrakianakis PhD\textsuperscript{c}, Elizabeth Bryce MD\textsuperscript{d}, Sarah Forgie MD\textsuperscript{e}, Lynn Johnston MD\textsuperscript{f}, Geoffrey Taylor MD\textsuperscript{g}, Mary Vearncombe MD\textsuperscript{h}, and the Canadian Nosocomial Infection Surveillance Program

\textsuperscript{a}Public Health Agency of Canada, Ottawa, Ontario, Canada
\textsuperscript{b}The Ottawa Hospital, Ottawa, Ontario, Canada
\textsuperscript{c}University of British Columbia, Vancouver, British Columbia, Canada
\textsuperscript{d}Vancouver General Hospital, Vancouver, British Columbia, Canada
\textsuperscript{e}Stollery Children’s Hospital, Edmonton, Alberta, Canada
\textsuperscript{f}Queen Elizabeth II Health Sciences Centre, Halifax, Nova Scotia, Canada
\textsuperscript{g}University of Alberta Hospital, Edmonton, Alberta, Canada
\textsuperscript{h}Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

Key Words: Infection prevention and control Respiratory illness Hand hygiene

Background: The proper use of personal protective equipment (PPE) by health care workers (HCWs) is vital in preventing the spread of infection and has implications for HCW safety.

Methods: An observational study was performed in 11 hospitals participating in the Canadian Nosocomial Infection Surveillance Program between January 7 and March 30, 2011. Using a standardized data collection tool, observers recorded HCWs selecting and removing PPE and performing hand hygiene on entry into the rooms of febrile respiratory illness patients.

Results: The majority of HCWs put on gloves (88%, \(n = 390\)), gown (83%, \(n = 368\)), and mask (88%, \(n = 386\)). Only 37% (\(n = 163\)) were observed to have put on eye protection. Working in a pediatric unit was significantly associated with not wearing eye protection (7%), gown (70%), gloves (77%), or mask (79%). Half of the observed HCWs (54%, \(n = 206\)) removed their PPE in the correct sequence. Twenty-six percent performed hand hygiene after removing their gloves, 46% after removing their gown, and 57% after removing their mask and/or eye protection.

Conclusion: Overall adherence with appropriate PPE use in health care settings involving febrile respiratory illness patients was modest, particularly on pediatric units. Interventions to improve PPE use should be targeted toward the use of recommended precautions (eg, eye protection), HCWs working in pediatric units, the correct sequence of PPE removal, and performing hand hygiene.
entering and leaving the rooms of patients with febrile respiratory illness (FRI). We therefore conducted an audit to observe the selection and removal of PPE, as well as to determine when hand hygiene is performed by HCWs upon entry and exit into the rooms of FRI patients in Canadian hospitals.

METHODS

An observational study was conducted in 11 tertiary, acute care hospitals participating in the Canadian Nosocomial Infection Surveillance Program (CNISP) between January and March 2011. All hospital personnel (eg, nurses, physicians, housekeeping, laboratory technicians, respiratory therapists, and others) who entered the room of a patient with FRI were eligible for inclusion and are referred to generally as HCWs. FRI was defined as a patient with a fever >38°C and with a new or worsening cough or shortness of breath. Visitors and volunteers were excluded from this study. All hospital inpatient or Emergency Department (ED) units that cared for FRI patients were included; outpatient ambulatory care units other than ED were excluded.

The Public Health Agency of Canada’s Infection Control Research Working Group adapted the audit form from an observational tool used to assess an online infection control course in British Columbia. The audit form was piloted by 6 CNISP participating hospitals from February 9 to April 10, 2010. Observers collected data on the selection and removal of PPE. Hand hygiene following the removal of gloves, gown and mask, and/or eye protection was also observed. Trained observers included infection control professionals or students who were provided with instructions on how to complete the audit form and how to best observe HCWs. Whereas staff on care units were not informed in advance of the audit, no attempt was made to disguise the purpose of the observations. Patient rooms in which the HCWs PPE selection and removal could not be observed were excluded (eg, an anteroom without a window). Signs were posted outside of patient rooms describing additional precautions and what PPE were required. The Public Health Agency of Canada’s guidelines Prevention and Control of Influenza During a Pandemic for all Healthcare Settings (Annexe F) was used to determine PPE requirements for an FRI patient. Instructions for the correct procedure to remove PPE were provided on the audit form and were further defined, when necessary, according to the facility’s infection prevention and control policy. The correct sequence of PPE removal was defined in the following order: gloves, gown, eye protection, and then mask.

A mask was defined as either an N95 respirator or surgical (procedure) mask. Eye protection was defined as either a face shield/mask combination or goggles. Eyeglasses were not considered to be eye protection. Observers were asked to identify the occupation of the observed HCW to the best of their ability, without asking the HCW. If they did not know the occupation, they selected the “don’t know” response. A nurse was defined as a nursing assistant, nursing aid, or registered nurse. Allied health professional included respiratory therapists, occupational therapists, laboratory technicians and x-ray technicians. A student was defined as an intern, a resident, or a health care profession student.

Because the study was observational and did not involve any alteration in patient care, informed consent from the patient and HCW were not required. Because auditing of infection prevention and control practices is part of routine infection prevention and control activities institutional ethics review board approval was not sought. The data collected were confidential; no personal identifying information was collected. Proportions were calculated to describe the study population and for each PPE item and hand hygiene moment by occupation and clinical area. Logistic regression was performed to identify associations between PPE use, clinical areas, and occupations. Odds ratios were reported; 95% confidence intervals and P values reflect a 2-tailed α level of .05. Missing data and unable to assess responses were removed from all calculations. Statistical analysis was performed using Stata version 11 (StataCorp, College Station, TX).

RESULTS

There were 442 observations collected from 11 CNISP participating hospitals across 6 provinces. Thirty-four percent of the observations were collected from hospitals in Ontario (n=149), 30% (n=131) from Alberta, 9% (n=41) from Manitoba, 9% (n=41) from Nova Scotia, 9% (n=40) from Québec, and 9% (n=40) from British Columbia. Of the 434 observations for which occupation was reported, 53% (n=228) were nurses, 13% (n=57) were students, 12% (n=53) were physicians, 10% (n=42) were allied health professionals, and 4% (n=19) were housekeeping staff. Forty-five percent of the observations were collected on a medical unit (n=200), 27% (n=121) on a pediatric unit, 16% (n=70) on an intensive care unit (ICU), and 6% (n=27) in an ED.

PPE selection

Thirty-four percent of HCWs (n=149) put on all PPE (gloves, gown, mask, and eye protection). The majority of HCWs put on gloves (88%, n=390), gown (83%, n=368), and mask (88%, n=386). Only 37% (n=163) were observed to have put on eye protection. Of those HCWs who put on a mask, 71% (n=274) put on a surgical mask; 18% (n=70) put on an N95 respirator; and, in 11% (n=42), the type of mask worn was not specified. Allied health professionals and students were significantly more likely to put on gloves than physicians, and students were also more likely to put on a mask than physicians (Table 1). HCWs working in a pediatric unit were significantly less likely to put on all PPE as compared with HCWs working in an ICU, an ED, or a medical unit (Table 2).

PPE removal

Of those HCWs who put on PPE, the majority correctly removed their gloves (87%, n=313), gown (82%, n=282), mask (72%, n=264), and eye protection (74%, n=110). Nurses, allied health professionals, and students were significantly more likely to correctly remove their masks than physicians (Table 1). HCWs working in an ICU were significantly more likely to correctly remove their masks than those working in a pediatric unit (Table 2).

Half of the observed HCWs (54%, n=206) removed their PPE in the correct sequence. Nurses and housekeeping staff were significantly more likely to remove PPE in the correct sequence compared with physicians (Table 1). HCWs working in a pediatric unit were significantly less likely to remove PPE in the correct sequence as compared with those working in an ICU, an ED, or a medical unit (Table 2).

Hand hygiene

Twenty-six percent of HCWs (n=99) performed hand hygiene after removing their gloves, 46% (n=163) after removing their gown, and 57% (n=212) after removing their mask and/or eye protection. Nine percent of HCWs (n=36) did not perform any hand hygiene. Difference in hand hygiene moments between clinical areas and occupations are shown in Table 3.

DISCUSSION

Findings from our audit suggest that, whereas the majority of HCWs put on gloves, mask, and gown upon entry into the room of
an FRI patient, few put on eye protection or removed their PPE in the correct sequence. HCWs working in pediatric units were less likely to use PPE when entering the room of an FRI patient. Furthermore, hand hygiene was infrequently performed after the removal of PPE. These findings indicate breaches in PPE use and hand hygiene that may provide opportunities for the transmission of respiratory infections to HCWs and thus should inform infection prevention and control education of HCWs.

Overall, PPE selection was unsatisfactory because only 76% of HCWs wore mask, gown, and gloves upon entry into the room of an FRI patient, and even fewer HCWs (34%) were observed to have used eye protection. There are several potential reasons why PPE selection was not 100%. Although we did not collect data on availability of PPE, it is possible that PPE was not readily available. In addition, risk perception has been known to influence the use of PPE. For example, HCWs working in pediatric units may feel less at risk of being infected and therefore less likely to wear PPE. Time pressures, perceived or real, may also in fluence the decision to wear PPE and may explain the poor adherence with PPE in EDs and among physicians.

Findings from the literature have shown that inconsistent or improper use of PPE has been significantly associated with respiratory infection among HCWs. Our study found that only half of HCWs were observed to remove their PPE in the correct sequence, thereby creating opportunities for self-contamination. Hand hygiene adherence was suboptimal. The literature describes possible methods to improve hand hygiene adherence such as increasing the number of private rooms and ensuring easy access to alcohol hand rub dispensers in and outside patient rooms. These are strategies that should be applied to improve hand hygiene performance after PPE removal.

Our study has several limitations. First, the Hawthorne effect is common in observational studies. This potential bias arises when...
were observed. Finally, our simulations because only HCWs in large, acute care, tertiary hospitals have arti-
despite the potential for overestimation of adherence. 1,3,7-9 in recommended infection prevention and control measures
observational studies have been very useful in demonstrating gaps
Second, our
the act of being observed in
fl
coordinates even more poorly in situations in which the HCW could
predict. Our sense is that PPE and hand hygiene would be per-
fi
altered the
whether the HCW was or was not observed, this could have
fl
correct sequence of PPE removal, and performing hand hygiene.

Logistic regression: Hand hygiene by clinical area and occupation

|                      | No. (%) | Odds ratio | 95% CI | P value |
|----------------------|---------|------------|--------|---------|
| HH after glove removal |         |            |        |         |
| Pediatric unit       | 28 (31) | 1          | Reference | |
| ICU                  | 12 (20) | 0.57       | 0.26-1.23 | .15     |
| Medical unit         | 52 (29) | 0.91       | 0.52-1.57 | .73     |
| Emergency department | 1 (4)   | 0.85       | 0.01-6.66 | .02     |
| HH after gown removal |         |            |        |         |
| Pediatric unit       | 52 (64) | 1          | Reference | |
| ICU                  | 22 (37) | 0.33       | 0.17-0.67 | .002    |
| Medical unit         | 77 (44) | 0.44       | 0.25-0.75 | .003    |
| Emergency department | 8 (31)  | 0.25       | 0.10-0.64 | .004    |

CI, Confidence interval; HH, hand hygiene.
*Includes respiratory therapists, occupational therapists, laboratory technicians, and x-ray technicians.

the act of being observed influences the behavior of the individual being observed. It is possible that the presence of an auditor may have artificially increased adherence with PPE use. Nonetheless, observational studies have been very useful in demonstrating gaps in recommended infection prevention and control measures despite the potential for overestimation of adherence. 1,3,7-9 Second, our findings may not be generalizable to all HCW populations because only HCWs in large, acute care, tertiary hospitals were observed. Finally, our findings included only those situations in which HCWs could be observed. If there was a systematic difference in the adherence to PPE and hand hygiene according to whether the HCW was or was not observed, this could have altered the findings of our study in a direction that is difficult to predict. Our sense is that PPE and hand hygiene would be performed even more poorly in situations in which the HCW could not be observed, and our findings actually represent a best case scenario.

Our audit highlights gaps in PPE selection and removal that may increase the opportunity for transmission of respiratory infections and that represent educational opportunities in the health care setting. Few HCWs selected eye protection for patients with FRI. Working in a pediatric unit was associated with not wearing PPE when entering the room of an FRI patient. Only half of the HCWs removed their PPE in the correct sequence, and hand hygiene was not routinely performed after removal of PPE. Therefore, interventions to improve PPE use should be targeted toward the use of recommended precautions, HCWs working in pediatric units, the correct sequence of PPE removal, and performing hand hygiene.

Acknowledgment

The authors thank Krista Wilkinson, Ethan Hermer, and the infection control professionals in each participating hospital.

References

1. Weber DJ, Sickbert-Bennett EE, Brown VM, Kittrell JP, Adams TL. Compliance with isolation precautions at a University Hospital. Infect Control Hosp Epidemiol 2007;28:358-61.
2. Swaminathan A, Martin R, Gamon S, Aboltins C, Athan E, Braithg G, et al. Personal protective equipment and antiviral drug use during hospitalization for suspected avian or pandemic influenza. Emerg Infect Dis 2007;13:1541-7.
3. Gammon J, Morgan-Samuel H, Gould D. A review of the evidence of suboptimal compliance of healthcare practitioners to standard/universal infection control precautions. J Clin Nurs 2008;17:157-67.
4. Ackroyd M, Soych Z. Surgical nurses and compliance with personal protective equipment. J Hosp Infect 2007;66:346-51.
5. Dafoe NL, Neeham DM, Robinson L, Bilderbek A, Rand CS. The use of personal protective equipment for control of influenza among critical care clinicians: a survey study. Crit Care Med 2009;37:1210-6.
6. Visentin LM, Bondy SJ, Schwartz B, Morrison LJ. Use of protective equipment during infectious disease outbreak and nonoutbreak conditions: a survey of emergency medical technicians. CJEM 2009;11:44-56.
7. Alkumran D, Kim LE, Parks RL, L'Ecuyer PR, Mutha S, Jeffe DB, et al. Use of personal protective equipment and operating room behaviors in four surgical subspecialties: personal protective equipment and behaviors in surgery. Infect Control Hosp Epidemiol 1999;20:110-4.
8. Ait W, Huo P, Brassard P, Loe V. Compliance with methicillin-resistant Staphylococcus aureus precautions in a teaching hospital. Am J Infect Control 2002;30:430-3.
9. Maman FA, Ponzillo J. Compliance with routine use of gowns by healthcare workers (HCWs) and non-HCWs: an entry into the rooms of patients under contact precautions. Infect Control Hosp Epidemiol 2007;28:337-40.
10. Gamache B, Moore D, Copes R, Yassi A, Breye E. Protecting health care workers from SARS and other respiratory pathogens: a review of the infection control literature. Am J Infect Control 2005;33:114-21.
11. Loeb M, Dafoe NL, Mahoney J, John M, Sarabia A, Glaun V, et al. Surgical masks. J Clin Infect Dis 2007;481-7.
12. Swaminathan A, Martin R, Gamon S, Aboltins C, Athan E, Braithg G, et al. Personal protective equipment and antiviral drug use during hospitalization for suspected avian or pandemic influenza. Emerg Infect Dis 2007;13:1541-7.
13. Harriman K, Rosenberg J, Robinson S, Bernier B, Bentz R, Waller K, et al. Novel influenza A (H1N1) 2009 among patients with respiratory illness in acute care hospitals. Am J Infect Control 2009;37:250-5.
14. Conly JM. Personal protective equipment for preventing respiratory infections: what have we really learned? CMAJ 2008;176:263-4.
15. Setho WH, Tsang D, Yung RWH, Ching TY, Ng TK, Ho M, et al. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). Lancet 2003;361:1519-20.
16. Wise ME, De Perio MD, Halpin J, Jiang M, Magill S, Black SR, et al. Transmission of Pandemic (H1N1) 2009 Influenza to Personnel in the United States. Clinical Infect Dis 2011;52(Suppl 1):S198-204.
17. Harriman K, Rosenberg J, Robinson S, Bernier B, Bentz R, Wailer K, et al. Novel influenza A (H1N1) 2009 infections among health-care personnel: United States, April-May 2009. MMWR 2009;58:541-5.
18. Eramus V, Daha Tj, Brug H, Robertson J, Bergh J, Behrendt MD, Vos MC, et al. Systematic review of studies on compliance with hand hygiene guidelines in hospital care. Infect Control Hosp Epidemiol 2010;31:283-94.
19. Chau JPC, Thompson DR, Twinn S, Lee DTF, Pang SWM. An evaluation of hand hygiene practice and glove use in Hong Kong. J Clin Nurs 2011;20:1319-28.
20. Scheithauer S, Oude-Aost J, Streiner D, Heftman H, Schwanz T, Waitschies B, et al. Hand hygiene in pediatric and neonatal intensive care unit patients: daily opportunities and indication- and profession-specific analyses of compliance. Am J Infect Control 2011;39:1-6.
21. Novoa AM, Pi-Sunyer T, Sama MA, Cortes E, Castells X. Evaluation of hand hygiene adherence in a tertiary hospital. Am J Infect Control 2007;35:676-82.
22. Loeb M, Dafoe NL, Mahoney J, John M, Sarabia A, Glaun V, et al. Surgical masks. J Clin Infect Dis 2007;481-7.
23. Hon CY, Gamage B, Bryce EA, LoChang J, Yassi A, Maultsaid D, et al. Hand hygiene in pediatric and neonatal intensive care unit patients: daily opportunities and indication- and profession-specific analyses of compliance. Am J Infect Control 2011;39:1-6.
24. Brien-Pallas L, McGeer A, Manno M, Holness DL. The influence of hospital safety climate and its relationship with safe work practices and workplace exposure incidents. Am J Infect Control 2000;28:211-21.
25. Public Health Agency of Canada. Prevention and control of influenza during a pandemic for all healthcare settings. Annex F. Available from: http://www.phac-aspc.gc.ca/cpsp-pcp/pand/impf/prin/index-eng.php. Accessed April 16, 2012.
26. Nichol K, Bigelow P, O'Brien-Pallas L, McGeer A, Mann M, Holmes DL. The individual, environmental, and organizational factors that influence nurses' use of facial protection to prevent occupational transmission of communicable respiratory illness in acute care hospitals. Am J Infect Control 2008;36:481-7.
27. Gershon RRM, Karkashian CD, Grosh JW, Murphy LR, Escamilla-Ceja A, Flanagan PA, et al. Hospital safety climate and its relationship with safe work practices and workplace exposure incidents. Am J Infect Control 2000;28:211-21.
25. Moore D, Gamage B, Bryce E, Copes R, Yassi A. Protecting health care workers from SARS and other respiratory pathogens: organizational and individual factors that affect adherence to infection control guidelines. Am J Infect Control 2005;33:88-96.

26. Virseda S, Restrepo MA, Arranz E, Magan-Tapia P, Fernandez-Ruiz M, de la Camara AG, et al. Seasonal and pandemic A (H1N1) 2009 influenza vaccination coverage and attitudes among health-care workers in a Spanish University Hospital. Vaccine 2010;28:4751-7.

27. Beam EL, Gibbs SG, Boulter BA, Beckerdtite ME, Smith PW. A method for evaluating health care worker’s personal protective equipment technique. Am J Infect Control 2011;39:415-20.

28. Mertz D, Johnstone J, Krueger P, Brazil K, Walter S, Loeb M. Adherence to hand hygiene and risk factors for poor adherence in 13 Ontario acute care hospitals. Am J Infect Control 2011;39:693-6.

29. Bischoff WE, Reynolds TM, Sessler CN, Edmond MB, Wenzel RP. Handwashing compliance by health care workers. Arch Intern Med 2000;160:1017-21.