



Short report

Improving healthcare worker adherence to the use of transmission-based precautions through application of human factors design: a prospective multi-centre study

V.R. Williams^a, J.A. Leis^{a,b}, P. Trbovich^{c,d}, T. Agnihotri^a, W. Lee^e, B. Joseph^e, L. Glen^e, M. Avanes^a, F. Jinnah^a, N. Salt^a, J.E. Powis^{e,*}

^a Infection Prevention and Control, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

^b Department of Medicine and Centre for Quality Improvement and Patient Safety, University of Toronto, Toronto, Ontario, Canada

^c Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada

^d Research and Innovation, North York General Hospital, Toronto, Ontario, Canada

^e Infection Prevention and Control, Michael Garron Hospital, Toronto, Ontario, Canada

ARTICLE INFO

Article history:

Received 5 February 2019

Accepted 23 March 2019

Available online 30 March 2019

Keywords:

Human factors

Transmission-based precautions

Personal protective equipment



SUMMARY

A key component of transmission-based precautions (TBPs) is the use of personal protective equipment (PPE) but healthcare worker (HCW) adherence remains suboptimal. A human factors-based intervention was implemented to improve adherence to TBPs including (i) improved signage, (ii) standardized placement of signage, (iii) introduction of a mask with integrated face shield, and (iv) improvement in PPE availability. Donning of the correct PPE by HCWs improved significantly (79.7 vs 56.4%; $P < 0.001$). This approach may be more effective than education alone, but further study is required to determine sustainability and subsequent impact on transmission of healthcare-associated infections.

© 2019 The Authors. Published by Elsevier Ltd on behalf of The Healthcare Infection Society. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Transmission-based precautions (TBPs) are recommended when standard precautions are insufficient to interrupt the transmission of an infectious agent. The key component of TBPs is the use of personal protective equipment (PPE) [1].

Despite evidence demonstrating the value of TBPs, healthcare worker (HCW) adherence to the use of PPE remains suboptimal and has been implicated in the transmission of healthcare-associated infections [2–4]. Infection prevention and control (IPAC) programmes have attempted to address poor adherence through extraneous interventions such as education and enhanced auditing; however, these improvement strategies have not been associated with durable change [5–7]. By contrast, no studies have looked to address the intrinsic deficiencies in the system design of TBPs from a human factors perspective.

* Corresponding author. Address: Michael Garron Hospital, 825 Coxwell Ave., Toronto, ON, Canada M4C3E7. Tel.: +1 416 469-6252.

E-mail address: Jeff.Powis@tehn.ca (J.E. Powis).

Human factors principles dictate that improving the system design will improve the probability of HCWs performing the correct behaviour [8]. The objective of this study was to apply a human factors-based improvement strategy to improve HCW adherence to the use of PPE.

Methods

Study design, setting, and study population

A prospective before–after study was performed at two healthcare facilities in Toronto, Ontario, Canada. Sunnybrook Health Sciences Centre (Facility A) is a tertiary care academic centre with 1325 beds. Michael Garron Hospital (Facility B) is a 415-bed community teaching hospital. Emergency departments (EDs) and all inpatient units, with the exception of neonatal units, were eligible for inclusion.

Intervention development

To identify system design factors that promoted HCW non-adherence to the use of TBPs, usability assessments were completed by pairing observers with expertise in human factors principles with high-users of TBPs. Assessments evaluated individual HCWs to better understand their interaction with signage and PPE. System barriers were then grouped according to Systems Engineering Initiative for Patient Safety (SEIPS) work system themes: (1) tools/technology (e.g. ease of understanding existing TBP signage and usability challenges with goggles used for eye protection), (2) environment (e.g. variable signage placement), and (3) organization (e.g. availability of PPE equipment in the ward clean utility room).

The intervention was designed to address these identified system barriers including: (1) improved signage for TBPs, (2) standardized signage placement, (3) introduction of a mask with integrated face shield instead of goggles, and (4) improvement in availability of required PPE in unit clean utility rooms. Prototypes of improved TBP signage were designed separately at each facility in accordance with recognized usability principles (heuristics) [9]. Examples of the pre-existing and redesigned signage are included in the Supplementary Appendix. Placement was standardized and dedicated attachment mechanisms were installed in the preferred standardized location identified for each room type. Goggles for eye protection were replaced with a mask with integrated face shield. Each facility co-ordinated with central stores to ensure availability of correct PPE in the clean utility room on the unit. No formal education programme was associated with the implementation of the intervention.

Outcome assessment

Audits were performed on rooms when a patient was under TBPs. Auditors were not previously known to HCWs and stood 1 m directly across from the entrance to the patient care area. Auditors visually assessed the appropriateness of signage, signage placement, and availability of PPE, and waited up to 10 min to directly observe an HCW entering the room. HCW adherence to recommended PPE

was evaluated based on the signage posted on entrance to the patient care area and HCWs were considered adherent if all PPE was used appropriately and non-adherent if any element was excluded. The same patients could not be audited again unless their location changed. More than one HCW could be observed during an observation period. Audits were performed only on weekdays during daytime shifts at standardized times for both baseline (July 11th to November 30th, 2017 at Facility A, May 16th to July 11th, 2017 at Facility B) and following the implementation of the intervention (December 12th, 2017 to March 13th, 2018 at Facility A, July 13th, to August 31st, 2017 at Facility B).

Statistical analysis

The primary outcome was the change in HCW adherence to recommended PPE between the baseline and intervention periods. Descriptive statistics were calculated and the χ^2 -test used to detect difference in proportions. $P < 0.05$ was considered statistically significant. Data were analysed using SPSS Statistics version 24 software (IBM, Markham, Ontario, Canada).

This study was deemed to be Quality Improvement within the mandate of the IPAC programme and therefore formal Research Ethics Board review was waived at both institutions.

Results

In total, 521 HCWs were audited for PPE adherence, including 238 at Facility A and 283 at Facility B. Donning correct PPE for the type of TBPs indicated on the signage improved during the intervention period at both facilities combined (79.7 vs 56.4%; $P < 0.001$) and individually at Facility A (79.6 vs 67.2%; $P = 0.004$) and Facility B (79.7 vs 46.2%; $P < 0.001$) (Figure 1). Adherence improved on all units with the exception of the EDs (45.9 vs 56.9%; $P = 0.4$). HCW adherence with PPE improved during the intervention period when care was being provided for patients in droplet precautions (65.2 vs 26.8%; $P < 0.001$) but not contact precautions (91.5 vs 84.8%; $P = 0.1$). At baseline, the most commonly missed item of PPE was eye protection, which HCWs did not don as required prior to caring for 69.0% of patients in droplet precautions. During the intervention period, use of eye protection increased significantly and was missed by only 30.5% of HCWs when required ($P < 0.001$).

Room audits were completed on 747 rooms/patient care areas including 500 at Facility A and 247 at Facility B. At both facilities, signage audits occurred most frequently on medical units, when patients had been in TBPs for ≤ 24 h and when the type of TBPs was droplet or contact precautions (Table 1). Visibility of signage improved during the intervention as compared to baseline (95.4 vs 78.8%; $P < 0.001$), as did the use of the correct signage (95.6 vs 85.0%; $P < 0.001$). No improvement was measured in the availability of appropriate PPE at room entrance at the two facilities combined (86.6 vs 82.4%; $P = 0.08$) but an increase was observed at Facility B (83.0 vs 71.9%; $P = 0.005$). Among rooms requiring droplet precautions, the item of PPE most frequently unavailable at baseline was eye protection (40.8%), which decreased to 15.4% during the intervention ($P < 0.001$).

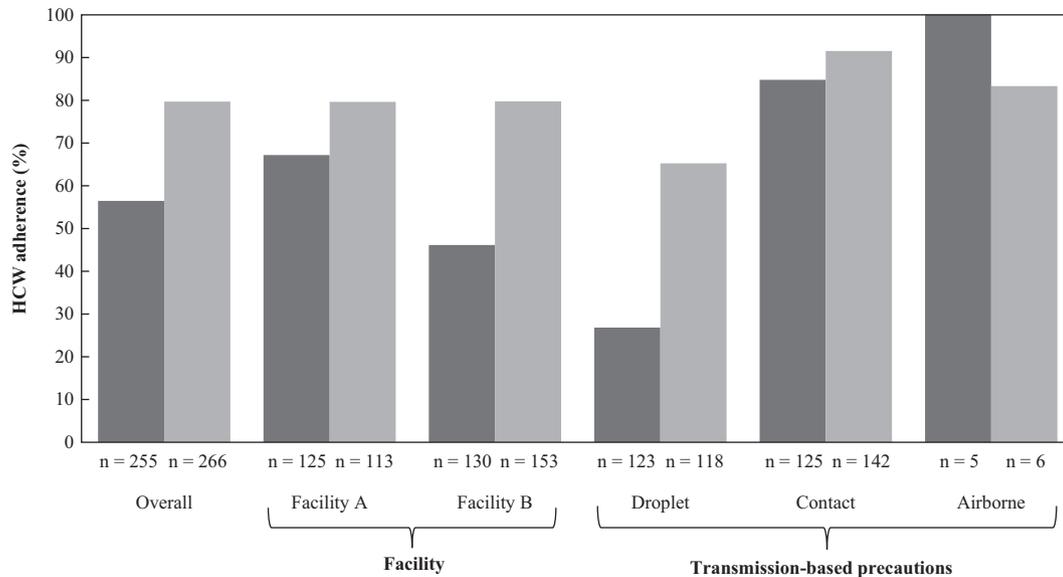


Figure 1. Healthcare worker compliance with donning personal protective equipment for transmission-based precautions at baseline (dark grey bars) and during the intervention period (light grey bars) by facility and type of transmission-based precautions. HCW, healthcare worker.

Discussion

Our study demonstrates the impact of applying human factors design principles to improve HCW adherence to the use of PPE. The baseline performance of HCWs was within the range reported in the literature but after intervention improved to nearly 80%, exceeding the highest compliance measured elsewhere [2,3].

Poor HCW adherence to the use of TBPs is universal and linked to the transmission of healthcare-associated infection, yet there are surprisingly few studies evaluating improvement strategies. LeClair *et al.* reported on the use of audit and feedback to HCWs regarding their use of TBPs, but this intervention was resource intensive and not sustainable [5]. Hon *et al.* measured an improvement in testing scores for PPE donning and doffing scenarios when new hospital staff

Table 1

Characteristics of rooms audited for transmission-based precautions signage and healthcare worker compliance with personal protective equipment by facility and time period

Characteristic	Facility A (N = 500)		Facility B (N = 247)		Total (N = 747)	
	Baseline	Intervention	Baseline	Intervention	Baseline	Intervention
	(N = 197)	(N = 303)	(N = 224)	(N = 223)	(N = 421)	(N = 526)
Type of unit						
Emergency department	40 (20.3)	60 (19.8)	30 (13.4)	25 (11.2)	70 (16.6)	85 (16.2)
Intensive care unit	23 (11.7)	27 (8.9)	18 (8.0)	21 (9.4)	41 (9.7)	48 (9.1)
LTC/CCC	0	6 (2.0)	6 (2.7)	10 (4.5)	6 (1.4)	16 (3.0)
Maternal	1 (0.51)	13 (4.3)	—	—	1 (0.2)	13 (2.5)
Medical	95 (48.2)	104 (34.3)	143 (63.8)	146 (65.5)	238 (56.5)	250 (47.5)
Paediatric	—	—	7 (3.1)	9 (4.0)	7 (1.7)	9 (1.7)
Rehabilitation	18 (9.1)	29 (9.6)	6 (2.7)	3 (1.3)	24 (5.7)	32 (6.1)
Surgical	20 (10.2)	63 (20.8)	14 (6.3)	9 (4.0)	34 (8.1)	72 (13.7)
Type of transmission-based precautions						
Airborne	3 (1.5)	5 (1.7)	11 (4.9)	12 (5.4)	14 (3.3)	17 (3.2)
Droplet	97 (49.2)	195 (64.4)	96 (42.9)	77 (34.5)	193 (45.8)	272 (51.7)
Contact	95 (48.2)	103 (34.0)	117 (52.2)	134 (60.1)	212 (50.4)	237 (45.1)
Airborne/droplet/contact	2 (1.0)	0	—	—	2 (0.5)	0
Duration of transmission-based precautions						
≤24 h	193 (98.0)	223 (73.6)	164 (73.2)	141 (63.2)	357 (84.8)	364 (69.2)
>24 h	4 (2.0)	71 (23.4)	60 (26.8)	82 (36.8)	64 (15.2)	153 (29.1)

LTC, long-term care; CCC, complex continuing care. Values in parentheses are percentages.

completed an online learning course during orientation, but they did not investigate whether this improvement translated into improved practice during patient care [6]. Larsen *et al.* assessed the impact of an electronic monitoring system and demonstrated small, yet significant, improvements in the posting of correct signage for TBPs and adherence to appropriate PPE usage, but the system had substantial implementation costs [7]. With the exception of the study by Larson *et al.*, the above improvement strategies were dependent on education and reminders to healthcare providers without addressing underlying deficiencies in the system design that promoted poor HCW adherence.

Through usability assessments we identified several system design deficiencies that could be corrected in order to drive improved HCW adherence to PPE. HCWs reported that eye protection in the form of goggles was frequently unavailable at room entrance, was difficult to fit over personal eyewear, and often fogged during wear. Due to the poor usability of goggles, we and others have demonstrated that goggles are the most common element of PPE omitted by HCWs [3]. We improved the use of eye protection by integrating this element of PPE with a mask, which was rarely missed by HCWs at baseline (15.3%). Another consistent deficiency that we observed during our usability testing is that HCWs frequently missed donning PPE when the signage was not visible. Ensuring signage was located in a standardized location was a simple change that improved the odds of HCWs seeing the appropriate signage and subsequently donning PPE.

Although these changes were associated with a significant improvement in the use of TBPs, there were barriers impeding the ability to achieve 100% adherence. Sign placement was not always standardized as intended due to the learning curve associated with this change in practice. Although the mask with integrated visor significantly improved adherence to eye protection, staff could continue to choose a mask without integrated face shield as the availability of ear-loop masks was required to be maintained on the units for alternative purposes such as patient cough containment, use by visitors, and for unvaccinated staff during influenza season. Whereas improvement in adherence to appropriate PPE for TBPs was recorded in the majority of inpatient units, a similar improvement was not achieved in the EDs, which may have been associated with the challenges specific to this area such as higher patient turnover, perceived time pressures, and suboptimal patient accommodations limiting appropriate options for posting signage [10]. Specifically, we noted that, among ED room assessments post intervention, signs were in the preferred location less than half the time.

Our study has several important limitations. Although we implemented these changes across multiple institutions and healthcare settings, approximately half of all observations occurred on medical units and many areas such as long-term care and paediatrics were underrepresented. Temporal changes may have been a factor in the observed results as the intervention period at Facility A occurred during influenza season and the improvement in HCW adherence was primarily in droplet precautions driven by using the mask with integrated face shield. Whereas improvement in the availability of required PPE in unit clean utility rooms was a key component of the intervention bundle, we did not include an intervention aimed at ensuring correct stocking of PPE at the room/patient care area. As a result, no improvement was measured in the

availability of appropriate PPE at room entrance and this is a possible area for future intervention.

Implementation of changes to the signage and equipment used for TBPs based on human factors principles improved HCW adherence with appropriate PPE. Several system deficiencies were identified and addressed with our intervention, the most significant of which was replacement of goggles for eye protection to a mask with integrated face shield. A human factors-based approach may be more effective than education alone; however, further study is required to determine the sustainability of our intervention and its impact on the transmission of healthcare-associated infections.

Acknowledgements

We would like to acknowledge the contributions of the Infection Preventionists at SB (S. Cobham, C. Corpus, M. Eng-Chong, C. Kerr, A. Linkenheld-Struk, L. Maze dit Mieusement, D. Pajak, P. Reason, K. Viridi) and MGH (A. O'Shaughnessy, A. Porstmouth, S. Sasikanthan) for their input during intervention development and subsequent implementation. Daily HCW and room audits were completed with the help of A. David and T. Law.

Conflict of interest statement

None declared.

Funding source

This work was supported by a Michael Garron Hospital Foundation Grant.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jhin.2019.03.014>.

References

- [1] Siegel JD, Rhinehart E, Jackson M, Chiarello L; Healthcare Infection Control Practices Advisory Committee. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. *Am J Infect Control* 2007;35(10 Suppl 2):S65–164.
- [2] Weber DJ, Sickbert-Bennett EE, Brown VM, Brooks RH, Kittrell IP, Featherstone BJ, et al. Compliance with isolation precautions at a university hospital. *Infect Control Hosp Epidemiol* 2007;28:358–61.
- [3] Mitchell R, Roth V, Gravel D, Astrakianakis G, Bryce E, Forgie S, et al. Are health care workers protected? An observational study of selection and removal of personal protective equipment in Canadian acute care hospitals. *Am J Infect Control* 2013;41:240–4.
- [4] Krein SL, Mayer J, Harrod M, Weston LE, Gregory L, Petersen L, et al. Identification and characterization of failures in infectious agent transmission precaution practices in hospitals: a qualitative study. *JAMA* 2018;178:1051–7.
- [5] Leclair JM, Freeman J, Sullivan BF, Crowley CM, Goldmann DA. Prevention of nosocomial respiratory syncytial virus infections through compliance with glove and gown isolation precautions. *N Engl J Med* 1987;317:329–34.
- [6] Hon CY, Gamage B, Bryce EA, LoChang J, Yassi A, Maultsaid D, et al. Personal protective equipment in health care: can online infection control courses transfer knowledge and improve proper selection and use? *Am J Infect Control* 2008;36:33–7.

- [7] Larson E, Behta M, Cohen B, Jia H, Furuya EY, Ross B, et al. Impact of electronic surveillance on isolation practices. *Infect Control Hosp Epidemiol* 2013;34:694–9.
- [8] Holden RJ, Carayon P, Gurses AP, Hoonakker P, Hundt AS, Ozok AA, et al. SEIPS 2.0: a human factors framework for studying and improving the work of healthcare professionals and patients. *Ergonomics* 2013;56:1669–86.
- [9] Zhang J, Johnson TR, Patel VL, Paige DL, Kubose T. Using usability heuristics to evaluate patient safety of medical devices. *J Biomed Inform* 2003;36:23–30.
- [10] Graff L, Stevens C, Spaite D, Foody J. Measuring and improving quality in emergency medicine. *Acad Emerg Med* 2002;9:1091–107.