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Original Article

Effectiveness of barrier precautions for prevention of patient-to-patient transfer of a viral DNA surrogate marker

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Abstract

Background: Gloves and gowns are used during patient care to reduce contamination of personnel and prevent pathogen transmission.

Objective: To determine whether the use of gowns adds a substantial benefit over gloves alone in preventing patient-to-patient transfer of a viral DNA surrogate marker.

Methods: In total, 30 source patients had 1 cauliflower mosaic virus surrogate marker applied to their skin and clothing and a second to their bed rail and bedside table. Personnel caring for the source patients were randomized to wear gloves, gloves plus cover gowns, or no barrier. Interactions with up to 7 subsequent patients were observed, and the percentages of transfer of the DNA markers were compared among the 3 groups.

Results: In comparison to the no-barrier group (57.8% transfer of 1 or both markers), there were significant reductions in transfer of the DNA markers in the gloves group (31.1% transfer; odds ratio [OR], 0.16; 95% confidence interval [CI], 0.02-0.73) and the gloves-plus-gown group (25.9% transfer; OR, 0.11; 95% CI, 0.01–0.51). The addition of a cover gown to gloves during the interaction with the source patient did not significantly reduce the transfer of the DNA marker ($P = .53$). During subsequent patient interactions, transfer of the DNA markers was significantly reduced if gloves plus gowns were worn and if hand hygiene was performed ($P < .05$).

Conclusions: Wearing gloves or gloves plus gowns reduced the frequency of patient-to-patient transfer of a viral DNA surrogate marker. The use of gloves plus gowns during interactions with the source patient did not reduce transfer in comparison to gloves alone.

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Barrier precautions such as gloves and cover gowns are often used during patient care to reduce contamination of personnel and to prevent transmission of healthcare-associated pathogens.[1] The use of gloves has been shown to reduce hand contamination with pathogens and to prevent *Clostridioides difficile* transmission.[2,3] Some studies have reported reductions in multidrug-resistant organism (MDRO) transmission with the use of gloves and gowns for all interactions with patients or environmental surfaces in patient rooms,[4,5] but others have suggested no benefit over use of gloves alone.[6] In a cluster-randomized trial, the use of gloves and gowns for all patient contact in intensive care units did not reduce the primary outcome of acquisition of methicillin-resistant *Staphylococcus aureus* (MRSA) or vancomycin-resistant *Enterococcus* (VRE).[7] However, the addition of cover gowns to gloves did significantly reduce MDRO contamination of the clothing of personnel.[8] Contaminated clothing could potentially serve as a source of pathogen transmission.[9–11] Thus, additional studies are needed to determine whether cover gowns provide a substantial benefit over gloves alone in preventing pathogen transmission.

Benign surrogate markers such as nonpathogenic viruses and viral DNA can be useful to study mechanisms of pathogen transmission and to evaluate control measures.[1,12–16] For example, in a neonatal intensive care unit, a cauliflower mosaic virus DNA marker inoculated onto a telephone was rapidly disseminated to surfaces throughout the unit and to the hands of personnel.[12] The viral DNA marker is similar to *C. difficile* spores in that it is not affected by alcohol hand sanitizer or quaternary ammonium disinfectants but is denatured by sodium hypochlorite and is reduced by mechanical washing or wiping.[16] In simulations of patient care, we found that a cauliflower mosaic virus DNA marker disseminated to the environment in a manner similar to *C. difficile* spores, but it was more frequently detected on the skin and clothing of personnel after removal of personal protective equipment.[16] In the current study, we compared the effectiveness of different

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levels of barrier precautions in reducing patient-to-patient transfer of cauliflower mosaic virus DNA markers inoculated on the skin and clothing of patients and on environmental surfaces in the patient rooms. We hypothesized that the use of gloves would reduce transfer of pathogens and that the addition of a cover gown would further reduce transfer.

Methods

Study design

The study protocol was approved by the Institutional Review Board of the Louis Stokes Cleveland VA Medical Center. The study was conducted during an 8-month period from April 20, 2019, through November 20, 2019. A convenience sample of 30 patients on medical-surgical wards in the hospital were enrolled as source patients (ie, source patients for potential dissemination of the viral DNA surrogate marker). Potential source patients were excluded if they were on contact precautions or if their anticipated length of stay was <1 day. One cauliflower mosaic virus DNA marker was applied to the skin (chest, abdomen, and forearm) and clothing (front of shirt over the chest and abdomen). A second cauliflower mosaic virus DNA marker was applied to the bed rail and bedside table in the source patients' room. Then 1 μg of each DNA marker was applied in 100 μL sterile water and allowed to air dry for at least 10 minutes before the first patient care interaction was observed. After the DNA markers were applied, research personnel were stationed on the ward in view of the room to identify personnel who would interact with the source patient.

For each source patient, up to 4 healthcare personnel providing care were randomized to wear gloves, gloves plus cover gowns, or no protective equipment during their interaction with the source patient. The personnel donned and doffed the gloves and gowns with their usual technique with no instruction. Each interaction between the personnel and the source patient was observed by research personnel, and sites and types of contact between personnel and the source patient were recorded (eg, hand or clothing contact with patient or environment, use of stethoscope).

After the personnel provided care for the source patient, they were followed by research personnel during their interactions with up to 7 subsequent patients. For subsequent patients, personnel were told to follow their usual practices for wearing protective equipment. The interactions with these patients were observed to identify sites associated with personnel that contacted the patients or their environment (eg, hands, clothing, stethoscopes, other devices) and to identify sites associated with patients that were contacted (eg, bed rail, bedside table, patient skin or clothing). Personnel were assessed for the performance of hand hygiene using alcohol hand sanitizer or soap and water. After each observed interaction, separate premoistened culture swabs (Becton Dickinson, Cockeysville, MD) were used to sample environmental (bed rail and bedside table) and skin and clothing sites (chest, abdomen, arm, and hand). If additional sites were observed to be contacted by personnel, they were included in the sample collection. After personnel completed participation in patient care interactions, a single culture swab was used to sample their hands and clothing (ie, anterior surface of white coat or scrubs over the chest and abdomen). To ensure that false-positive PCR results were not obtained during processing, 1 negative control swab (ie, no contact with a patient or environment) was included for each of the personnel participating in the study.

Cauliflower mosaic virus DNA marker generation and detection

The cauliflower mosaic virus DNA markers were synthesized and prepared as previously described.[16] The marker applied to the skin and clothing contained 222 base pairs of DNA, including all 210 nucleotides of the cauliflower mosaic virus 35S promoter region with the addition of GAATTC terminal sequences on each end.[16] The marker applied to the bed rail and bedside table contained 155 base-pairs of DNA, including all 140 nucleotides of the Glycine max transgenic cauliflower mosaic virus 35S promoter region with the addition of GAATTC terminal sequences on each end. The markers were detected by polymerase-chain reaction (PCR) as previously described.[16] The PCR primers for the marker applied to the skin and clothing have been previously reported.[16] For detection of the DNA marker applied to the environment, the forward primer was GTCTTCTTTTTCCACGATGCTCCTCG TGGG and the reverse primer was TGAAGATAGTGGAAAA GGAAGGTGGCTCCT.

Data analysis

The primary outcome was the percentage of transfer of 1 or both DNA markers from the source patient to subsequent patients during patient care interactions. Secondary outcomes included the percentages of contamination of the clothing and hands of personnel after completion of the patient care interactions that were assessed.

We used χ^2 tests to compare the frequencies of transfer of each of the DNA markers for each type of barrier precaution. Based on previous studies, we anticipated a contamination frequency of ~50% in the absence of barrier precautions.[16] Based on an estimated 3 patient-care interactions per barrier precaution group, we calculated 85% power to detect a 40% reduction with gloves plus gowns versus no barrier and 75% power to detect a 40% reduction for the comparison of each barrier type versus no barrier. Additional logistic regression analysis adjusted for the order of interaction with patients (1–7), performance of hand hygiene, and use of gloves and gown for subsequent patients who were on contact precautions. Data were analyzed using R version 3.5.0 software (R Foundation for Statistical Computing, Vienna, Austria).

Results

Of the 90 healthcare personnel observed during interactions with the 30 source patients, 25 (27.8%) were physicians, 22 (24.4%) were nurses, and 43 (47.8%) were ancillary medical staff (ie, nursing assistants, physical therapists). Figure 1 shows a flow diagram for the study. The total number of interactions observed with subsequent patients that included contact with the patient and/or environment was 254; 83 of these interactions (32.7%) involved personnel who had been randomized to no barrier during their interaction with the source patient, 90 (35.4%) involved personnel randomized to gloves only during interaction with the source patient, and 81 (31.9%) involved personnel randomized to gloves plus gowns during their interaction with the source patient. Of the 254 observed interactions, 200 (78.7%) involved contact with both the patient and the environment, 9 (3.5%) involved only contact with the patient, and 45 (17.7%) involved only contact with the environment. Hand hygiene was performed before 182 interactions (72%) and after 218 interactions (85.8%); 391 of 400 hand hygiene events (97.8%) involved hand sanitizer. Gloves were worn

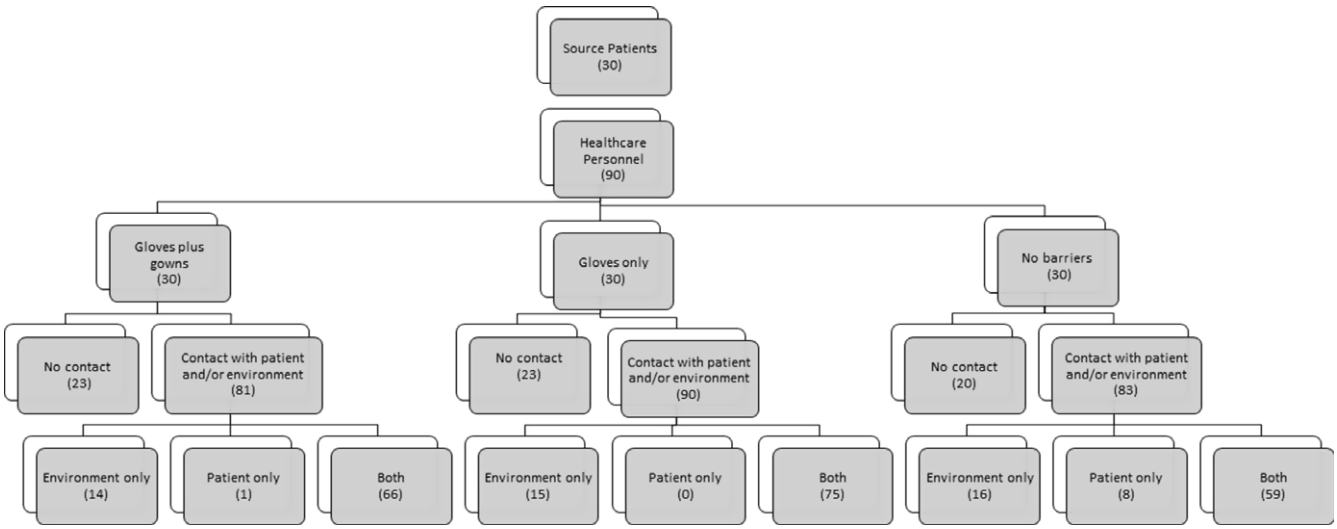

Fig. 1. Flow diagram for the study participants.

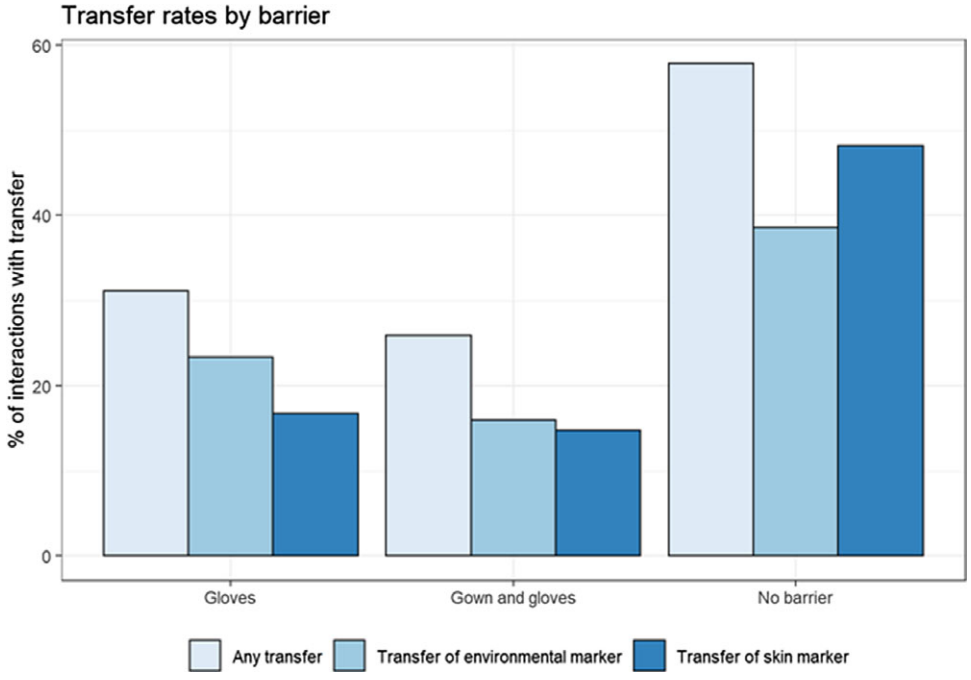

Fig. 2. Transfer of the DNA markers from the source patients to subsequent patients, stratified by the type of barrier precautions.

during 61 interactions (24.0%,) and gloves plus gowns were worn during 74 interactions (29.1%) with patients who were in contact precautions. Stethoscopes were used during only 13 interactions (5.1%) and were never cleaned after use.

Figure 2 shows the overall percentage of transfer of the DNA markers from the source patients to subsequent patients, stratified by the type of barrier precautions. Table 1 provides odds ratios (ORs) and 95% confidence intervals (CIs) for the transfer of 1 or both markers for the 3 groups. In comparison to the no-barrier group (57.8% transfer), transfer of 1 or both markers occurred significantly less often in the gloves group (31.1%; OR, 0.15; $P = .007$) and the gloves-plus-gown group (25.9%; OR, 0.10; $P = .002$). There was no significant difference in the percentage of transfer in the gloves group versus the gloves-plus-gown group. In an additional model adjusting for hand hygiene before interactions, order of interaction with subsequent patients, and use of gloves and gowns for subsequent patients, significant reductions in DNA marker transmission were present when hand hygiene was performed and when glove and gowns were worn for subsequent patient interactions.

Figure 3 shows the percentages of transfer of the patient and DNA markers, stratified by the site of recovery of the markers from the subsequent patients. The frequency of recovery of the markers from environmental surfaces and patients were similar. For each of the 4 transfer types shown, the percentage of transfer was significantly higher in the no-barrier group in comparison to the gloves and gloves plus gown groups ($P < .05$). Figure 4 shows the percentages of transfer of markers stratified by the order of interaction with subsequent patients. There were no trends regarding marker transfer and the order of the interaction.

After completion of the observed interactions, the frequency of contamination of personnel hands and clothing was higher in the

Table 1. Risk for Transfer of Viral DNA Surrogate Markers in Personnel Interacting With a Contaminated Source Patient While Wearing No Barrier, Gloves Alone, or Gloves Plus Gowns

Marker Transferred	Comparison Groups	OR	95% CI	*P* Value
Unadjusted model				
Any marker	Gloves versus no barrier	0.15	(0.03–0.54)	.007
	Gloves + gown versus no barrier	0.10	(0.01–0.36)	.002
	Gloves versus gloves + gown	1.56	(0.39–7.27)	.527
Environment	Gloves versus no barrier	0.25	(0.04–1.06)	.070
	Gloves + gown versus no barrier	0.14	(0.02–0.61)	.015
	Gloves versus gloves + gown	1.78	(0.37–10.05)	.466
Patient	Gloves versus no barrier	0.03	(0–0.22)	.008
	Gloves + gown versus no barrier	0.02	(0–0.17)	.005
	Gloves versus gloves + gown	1.41	(0.17–13.36)	.744
Model adjusted for hand hygiene, order of subsequent patient interactions, and use of gloves and gown for subsequent patient interactions				
Any marker	Gloves versus no barrier	0.16	(0.02–0.73)	.027
	Gloves + gown versus no barrier	0.11	(0.01–0.51)	.012
	Gloves + gown for subsequent interactions	0.30	(0.11–0.77)	.015
	Hand hygiene	0.27	(0.09–0.72)	.013
	Order of patient interactions	0.79	(0.59–1.03)	.095

Note. OR, odds ratio; CI, confidence interval.

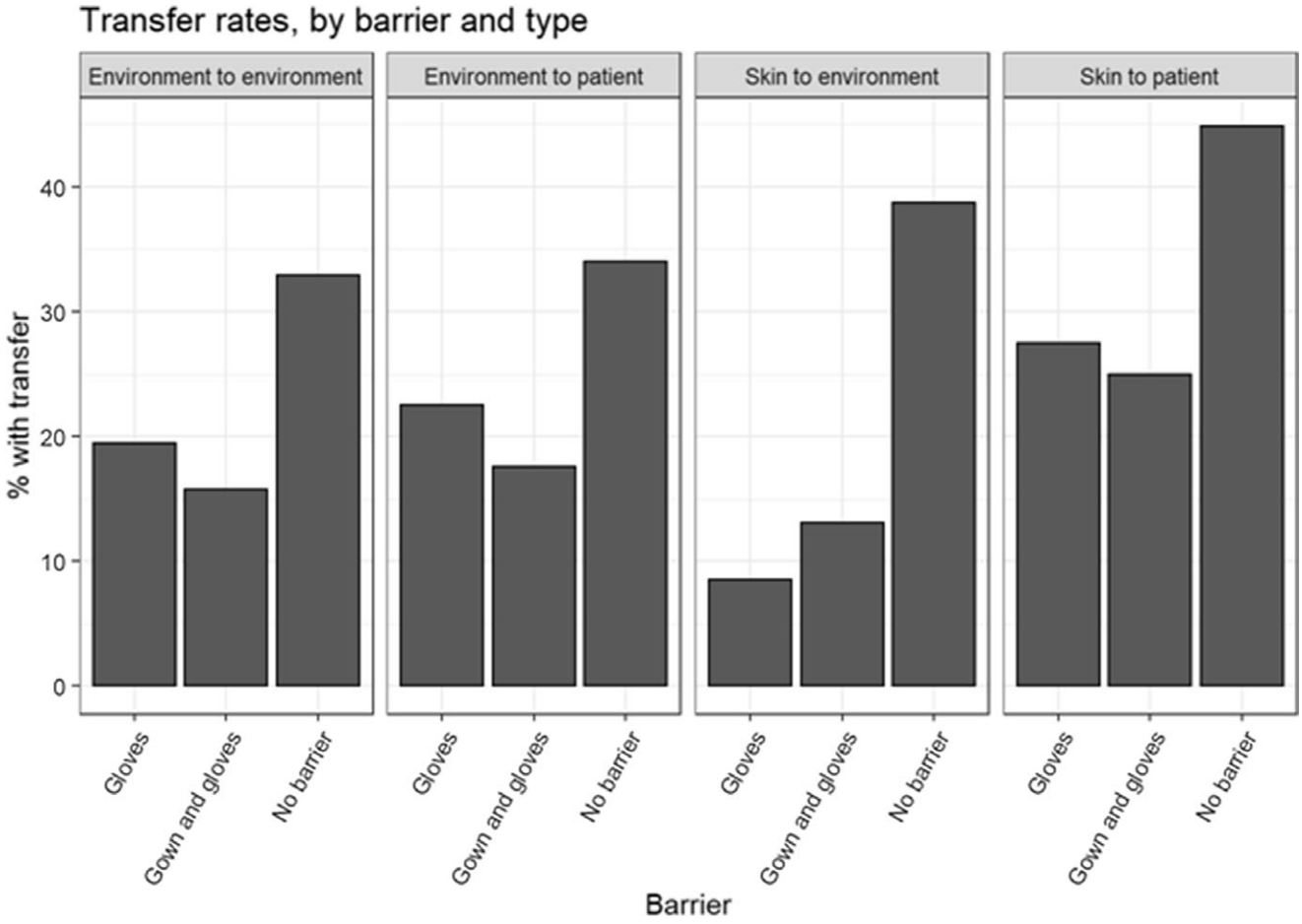

Fig. 3. Transfer of the patient and environment DNA markers, stratified by the site of recovery of the markers from the subsequent patients.

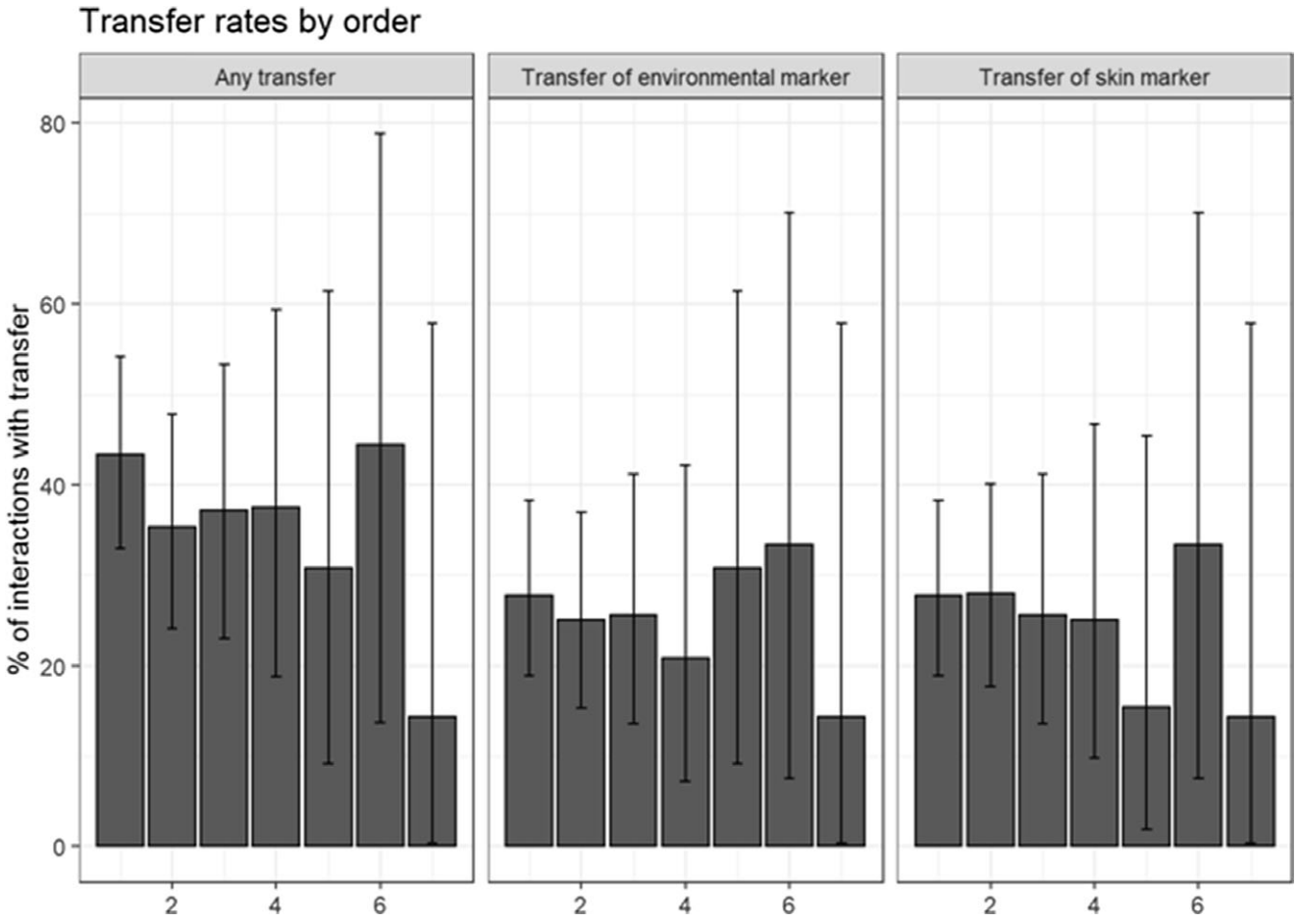

Fig. 4. Transfer of the patient and environment DNA markers, stratified by the order of interaction with subsequent patients.

no-barrier group (19 of 29 personnel assessed, 65.5%) than in the gloves group (14 of 27 personnel assessed, 51.9%) and the gloves-plus-gown group (13 of 27 personnel assessed, 48.1%), but the differences were not statistically significant ($P > .05$).

Discussion

In this study, wearing gloves or gloves plus gowns significantly reduced patient-to-patient transfer of viral DNA surrogate markers on medical-surgical wards. The frequency of transfer was similar for markers inoculated on environmental surfaces and on patient skin and clothing. The addition of gowns to gloves during interactions with the source patients did not significantly reduce transfer of the DNA markers. However, transfer was significantly reduced if gloves plus gowns were worn during subsequent patient interactions and if hand hygiene was performed. These findings have important implications for the use of barrier precautions in healthcare settings.

Our results are consistent with previous evidence that cover gowns may not add substantial benefit over gloves alone in preventing transmission of healthcare-associated pathogens.[6] However, previous studies have demonstrated that the addition of cover gowns may significantly reduce contamination of the clothing of personnel.[9] In the current study, we sampled clothing and hands as a composite and did not detect a significant reduction with the addition of gowns to gloves. Notably, contamination of the hands and clothing of personnel with the DNA markers occurred very frequently even in the gloves group and the gloves-plus-gown group (52% and 48%, respectively). Further studies are needed to determine the routes of contamination of hands and clothing despite the presence of barriers. Potential explanations might include contamination during removal of personal protective equipment[17] or through inadvertent breaks in technique that are common while wearing protective equipment.[18]

Our study has some limitations. The viral DNA surrogate marker provides a useful tool to study routes of pathogen transmission, but it has some limitations. As noted previously, DNA marker is similar to *C. difficile* spores in that it is not affected by alcohol hand sanitizer.[16] Thus, rates of transfer with the DNA marker are likely to be higher than rates of transfer of an alcohol-susceptible pathogen. A high concentration of the marker is used and therefore the frequencies of transfer and contamination may represent a worst-case scenario. Personnel participating in simulations were closely observed and this may have altered their usual infection control practices. The use of stethoscopes or portable equipment was uncommon in the study. Several studies have demonstrated the potential for transfer of pathogens by stethoscopes and other fomites.[14,15,19–21] Thus, our finding may underestimate the contribution of fomites to transmission.

In conclusion, wearing gloves or gloves plus gowns reduced transfer of a DNA marker in a clinical setting. The addition of gowns to gloves during interaction with the source patient did not reduce transfer in comparison to gloves alone. Future studies

are needed to evaluate the impact of barrier precautions on transfer of healthcare-associated pathogens in healthcare settings.

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