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Assessment of Antibiotic Resistant Organism Transmission between Rooms of Hospitalized Patients, Healthcare Professionals, and the Hospital Environment Utilizing Surrogate Markers and Selective Bacterial Cultures

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Abstract

Objective: To assess potential transmission of antibiotic resistant organisms (AROs) using surrogate markers and bacterial cultures.

Design: pilot study.

Setting: 1,260-bed tertiary-care academic medical center.

Participants: 25 patients (17 on contact precautions for AROs) and 77 healthcare professionals (HCPs).

Methods: Fluorescent powder (FP) and MS2 bacteriophage were applied in patient rooms. HCP visits to each room were observed for 2–4 hours; hand hygiene (HH) compliance was recorded. Surfaces in and outside the room and HCP skin/clothing were assessed for fluorescence and swabs were collected for MS2 detection by PCR and selective bacterial cultures.

Results: Transfer of FP was observed for 20 (80%) rooms and 26 (34%) HCPs. Transfer of MS2 was detected for 10 (40%) rooms and 15 (19%) HCPs. Bacterial cultures were positive for one room and 8 (10%) HCPs. Interactions with patients on contact precautions resulted in fewer FP detections than interactions with patients not on precautions ($p<.001$); MS2 detections did not

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differ by patient isolation status. FP detections did not differ by type of HCP, but MS2 was recovered more frequently from physicians vs. nurses (p=0.03). HH compliance was better among HCPs caring for patients on contact precautions vs. HCPs caring for patients not on precautions (p=0.003), among nurses vs. other non-physician HCPs at room entry (p=0.002), and among nurses vs. physicians at room exit (p=0.03). HCPs who performed HH prior to assessment had fewer fluorescence detections (p=0.008).

Conclusions: Contact precautions were associated with greater HCP HH compliance and reduced detection of FP and MS2.

Introduction

Antibiotic resistant organisms (AROs) present a major infection control threat for patients in hospitals and increase the risk of serious healthcare associated infections. Hospital environmental surfaces can become contaminated with AROs and may contribute to ARO transmission, either directly or via the hands or clothing of healthcare professionals (HCPs).[1–5] Contact precautions (gowns and gloves) have been an essential component of infection prevention practices to limit transmission of AROs.[6] However, there has been debate about whether contact precautions are effective in reducing ARO transmission.[7–9]

It is difficult to study the relationship between environmental contamination, HCP cross-contamination, and ARO transmission. Previous studies have demonstrated that contaminated hospital surfaces can contribute to the spread of nosocomial infections.[10–12] Other studies have demonstrated ARO transfer from infected patients or contaminated surfaces to the hands and clothing of HCPs.[13–17] However, few studies have focused on the relationship between contaminated surfaces in patient rooms and the risk of HCP cross-contamination outside patient rooms.[18]

Additional studies that examine the associations between environmental surface contamination, HCP cross-contamination, and ARO transmission patterns, and the impact of contact isolation practices on these associations, are needed to better inform policies and procedures for the use of personal protective equipment (PPE) and to reduce ARO transmission and healthcare-associated infections (HAIs). Surrogate markers, such as fluorescent powder (FP) and MS2, a non-pathogenic bacteriophage, are unique tools to study ARO transmission and cross-contamination in hospitals.[19,20] FP and MS2 have been used to study HCP self-contamination while donning/doffing PPE,[17,21,22] and the effectiveness of hospital cleaning procedures.[23–25]

The aim of this prospective cohort study was to assess ARO transmission and cross-contamination patterns in real world hospital settings using two surrogate markers (FP and MS2 bacteriophage) and selective bacterial cultures.

Methods

This study was conducted in a general medicine ward, medical intensive care unit (ICU), and emergency department (ED) at a 1,260-bed tertiary care academic hospital in St. Louis, Missouri. Patients age ≥18 years hospitalized between 9/16/2015 and 2/9/2016 and HCPs

caring for enrolled patients were eligible for inclusion. The study protocol was reviewed and approved by the Washington University Human Research Protection Office. Written informed consent was obtained from all patients or a legally authorized representative. Participating HCPs provided verbal consent prior to study participation.

Patient Enrollment

Two patients on contact precautions for vancomycin-resistant Enterococcus (VRE) or methicillin-resistant *Staphylococcus aureus* (MRSA) were enrolled for each patient not on contact precautions. At enrollment, each patient's room was scanned for fluorescence using a UV light. If fluorescence was detected, the area was wiped clean before surrogate marker application. For patients on contact precautions, flocked swab collection kits (ESwab, Copan Diagnostics, Murietta, CA) were used to collect swabs from each of the surfaces targeted for surrogate marker application and to collect a nasal, axilla, inguinal, and stool or rectal swab from each patient. Baseline patient and environmental samples were interrogated using selective bacterial culture.

Surrogate Marker Application

Four high-touch surfaces in the patient room were selected for surrogate marker application: the front of the patient's gown, the top of each bedrail, and the bedside table or computer mouse. Fluorescent powder (FP; 0.02g, Glo Germ, Moab, UT) was applied to each surface using a brush applicator. MS2 bacteriophage (MS2; 1:10 dilution of commercially-available stock solution in viral transport medium, $1.0x10^8$ PFU/mL per site,[17] ZeptoMetrix, Buffalo, NY) was applied using an atomizer (Teleflex, Morrisville, NC).

HCP Enrollment and Observations

Following surrogate marker application, trained study coordinators observed each patient room for 2–4 hours from the hallway. During this period, HCP hand hygiene (HH) compliance at room entry and exit, defined as the use of alcohol hand rub or soap and water, were recorded, and the first three surfaces that each HCP touched after exiting the room were flagged for later assessment. Three to four HCPs who entered the room during the observation period were recruited for study participation.

Sample Collection

After the first visit to the patient's room, participating HCPs had their hands, face/hair, and clothing scanned with a UV light to identify areas of fluorescence. For patients on contact precautions, UV scanning was done after the HCP removed PPE. HCPs were assessed only once, even if they visited the room multiple times. At the end of the observation period, the patient's room, the first three surfaces that each participating HCP had touched after exiting the room, and four additional locations on the study ward (medication cabinet, door handles, nurse's station, and elevator buttons) were scanned for fluorescence.

Areas that fluoresced were photographed and trained study coordinators collected surface samples using a viral transport collection kit (Quidel, San Diego, CA). Additional samples were collected from the four locations on the study ward and from each participating HCP's

hands/gloves, face (periorbital/nasal/oral areas), and sleeve/wrist. These samples were tested for the presence of MS2.

If the patient was on contact precautions, flocked swab collection kits were used to collect additional samples from each area where fluorescence was observed and from the four locations on the study ward. One pooled sample was also collected from each participating HCP's face, hands, and wrists. These swabs were submitted for selective bacterial culture.

After sample collection, the surfaces where the surrogate markers had been applied and any areas where fluorescence was observed were wiped clean to prevent further transmission of FP and MS2. Each patient room was used only once to further minimize the possibility of residual marker from a previous patient.

Bacterial Culture

Swabs collected to identify MS2 contamination had RNA extracted from the transport medium using the QIAamp viral RNA Mini Kit (Qiagen, Germantown, MD). Real-time reverse transcriptase PCR was used to detect MS2 bacteriophage using the Cepheid Smart Cycler (Cepheid, Sunnyvale, CA).

Swabs associated with patients on contact precautions were cultured for VRE, MRSA, and methicillin susceptible *Staphylococcus aureus* (MSSA). Swabs were plated to CHROMID VRE chromogenic medium (bioMérieux, Marcy-l'Étiole, France) to select for VRE, Spectra MRSA chromogenic agar (Remel, Lenexa, KS) to select for MRSA, and 5% sheep's blood agar (Hardy Diagnostics, Santa Maria, CA) to recover MSSA. All swabs were also inoculated to 6.5% NaCl broth (Hardy Diagnostics) as an enrichment method to recover VRE, MRSA, and MSSA, if these did not grow on the primary plated media. When growth was observed, four colonies of each type of organism were subcultured and identified using matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF MS) using the VITEK MS.[26–28] After bacterial identification was confirmed, phenotypic antimicrobial susceptibly testing and repetitive sequence-based PCR (repPCR) was performed. Staphylococcal cassette chromosome *mec* (SCC*mec*) typing was performed on all *S. aureus* isolates.[29,30]

Statistical Analysis

Patterns in the location and type of surrogate marker detections were evaluated qualitatively. Odds ratios with 95% confidence intervals and chi-square/Fisher exact tests were used to characterize associations between predictor and outcome variables. Predictor variables included patient contact isolation status and type of HCP. Outcome variables included FP, MS2, and VRE, MRSA, or MSSA detections in patient rooms, on HCPs, and/or on surfaces touched by HCPs. HCP use of HH at room entry and exit were assessed as both predictor and outcome variables. Two measures of HCP HH compliance were examined: HH at the first room visit by participating HCPs, and HH over all room visits by all HCPs. The first measure was used to determine the association between HH and surrogate marker detections, while the second provided a more complete picture of overall HH practices. All analyses were performed using IBM SPSS Statistics, Version 24.0. (IBM Corp., Armonk, NY).

Results

Twenty-five patients were enrolled: ten in the medicine ward, ten in the ICU, and five in the ED. Seventeen patients (68%) were on contact precautions for VRE (12), MRSA (4), or VRE and MRSA (1). Seventy-seven HCPs participated in the study; half (40, 52%) were nurses (35), nurse practitioners (3), or student nurses (2). Other participating HCPs included physicians (16, 21%), patient care technicians (9, 12%), respiratory therapists (4, 5%), radiology technicians (2, 3%), dieticians (2, 3%), one pharmacist (1%), a pharmacy student, an infection preventionist, and a unit secretary.

Fluorescent Powder Detections

In 20 patient rooms (80%), fluorescence was detected on at least one site outside the areas where FP had been applied, most commonly on the computer keyboard (n=15), counter (n=7), or door handle (n=5). In three cases, fluorescence was also detected in the study ward, at the nurses' station (n=2) or on the medication cabinet (n=1). Twenty-six HCPs (34%) had fluorescence detected on their body/hands/clothing (n=23) and/or on a surface they touched after exiting the patient's room (n=10). Examples of FP detections are shown in Figure 1.

HCPs caring for patients on contact precautions had significantly fewer FP detections, on themselves and/or on the surfaces they touched, than HCPs caring for patients not on precautions (19% vs. 70%, $p<0.001$; Table 1). There was no significant difference in rates of FP detection among different types of HCPs (Table 2).

MS2 Detections

MS2 was detected inside nine patient rooms (36%), most commonly on the computer (n=4), and outside one room, on a medication cabinet. Fifteen HCPs (19%) had MS2 detections, either on their body or clothing (n=10), and/or on surfaces touched after exiting a patient room (n=6), most commonly the door handle (n=3). One HCP had MS2 identified on two sites on the body/clothing and one HCP had MS2 identified on two touched surfaces.

In general, MS2 was recovered less frequently on HCPs and/or surfaces touched by HCPs caring for patients on contact precautions versus HCPs caring for patients not on precautions, but these differences did not achieve statistical significance (Table 1). MS2 was more often detected on physicians than nurses (40% vs. 27%, $p=0.02$; Table 2).

Bacterial Culture Results

Twelve of the patients on contact precautions (71%) had baseline swabs that were positive for the ARO for which the patient was placed on contact precautions. Two patients, one on precautions for MRSA and one for VRE, had swabs positive for both MRSA and VRE. One patient on precautions for VRE had baseline swabs positive for MSSA.

Seven patients on contact precautions (41%) had one or more room surfaces with a positive baseline bacterial culture (Table 3). For six, the organism identified was the organism that triggered contact precautions; two patients had surfaces that were also positive for MSSA. The remaining patient, who was on precautions for VRE but had a baseline swab positive for MSSA, had baseline room surface swabs that were also positive for MSSA.

Among the swabs collected from surfaces where fluorescence was observed, only two had a positive bacterial culture (Table 3). One, from the foot of a bed, was positive for VRE. The other, from an elevator button, was positive for MSSA. Both were associated with the same patient, who had a baseline swab positive for VRE.

Of the 54 HCPs who cared for a patient on contact precautions, 8 (15%) had a positive pooled swab; all of which were positive for MSSA (Table 3). These HCP had cared for four different patients, none of whom had a baseline swab positive for MSSA, but one of whom had a baseline room surface positive for MSSA.

Only two (4%) HCPs who cared for a patient on contact precautions had a touched surface with a positive bacterial culture (Table 3). The first, a blood glucose monitor, was positive for VRE, although the HCP was positive for MSSA and MRSA was identified in the patient's room. The second, a door handle, was positive for MSSA and was touched by a HCP who was also positive for MSSA, although VRE was identified in the patient's room.

Among samples that were positive for VRE, 6 strain types were identified by repPCR. The most common, type C, was associated with 8 patients, three of whom were also positive for type B. Two patients had VRE type C identified in both patient and room surface samples. Another patient had multiple VRE types (A, D, E, F) identified in patient and room surface samples.

Among samples that were positive for *S. aureus*, 9 strain types were identified by repPCR (3 among MRSA samples and 8 among MSSA samples). Four strain types were identified by SCC*mec* typing. Four of the five patients who were positive for MRSA and two of the three patients with room surfaces positive for MRSA had the same strain typing (repPCR B, SCC*mec* IV*).* Among eight HCPs who were positive for MSSA, seven had the same SCC*mec* type (III). Three of these samples were repPCR type F, the others had diverse repPCR typing.

HCP Hand Hygiene Observations

Both measures of HCP HH compliance yielded similar estimates. HH compliance was lower at room entry than at room exit. Only 18% of HCPs performed HH at room entry (14/77 first visits by participating HCPs and 54/298 total HCP visits), while 52% performed HH at room exit (40/77 first visits and 54/290 total visits).

HCP HH compliance at room entry did not differ by patient isolation status (Table 4). However, compliance at room exit was better among HCPs caring for patients on contact precautions versus HCPs caring for patients not on precautions (61% vs. 30% first room visits, $p=0.02$ and 58% vs. 37% all room visits; $p<0.01$). No differences in HH compliance at first room visit were observed for nurses versus physicians or other HCPs (Table 5). However, when considering all room visits, nurses were more likely than other non-physician HCPs to perform HH at room entry (25% vs. 8%, $p<0.01$) and more likely than physicians to perform HH at room exit (59% vs. 43%; $p=0.03$).

The association between HCP HH and surrogate marker detections is shown in Table 6. Although few associations were observed between either HH measure and surrogate marker

detections, HCPs who performed HH immediately after the first room exit and before being swabbed were less likely than HCPs who did not perform HH at room exit to have fluorescence detected (20% vs. 49%; p=0.008).

Discussion

In this study, transfer of both FP and MS2 was observed both inside and outside patient rooms, on participating HCPs, and on surfaces touched by HCPs after exiting patient rooms. Transfer of FP occurred more frequently than transfer of MS2; positive bacterial cultures were even less frequent.

Although few studies have utilized both FP and MS2 as surrogate markers, some have also reported higher rates of FP compared to MS2 detections.[17,31] Others reported similar detection rates,[19,32] or more frequent MS2 detections.[21] This lack of agreement may indicate that neither marker performs significantly better than the other or may be related to differences in the means of detection (visual versus swabs). However, the two markers are thought to model different types of contamination: FP may model gross bacterial contamination, while MS2 may simulate viral contamination events.[21] Therefore, different detection rates may be reasonable. More data are needed to determine which surrogate markers are better models for ARO transmission.

In contrast to surrogate markers, bacterial culture may identify actual ARO transmission events. This study focused on two AROs that routinely trigger contact precautions, MRSA and VRE, as well as MSSA. While MSSA does not routinely trigger contact precautions, it is a clinically relevant pathogen that causes significant morbidity in hospitalized patients.[33,34] The greater frequency of surrogate marker detections as compared to ARO detections may suggest that FP and MS2 over-represent the likelihood of ARO transmission. Previous studies using MS2 to model the spread of *Clostridioides difficile* spores have also reported more frequent MS2 detections versus bacterial detections on HCP skin and clothing.[19,35] However, in our study, both surrogate markers were present in all of the patient rooms, while only seven rooms had surfaces that were positive for VRE, MRSA, or MSSA at baseline. Therefore, the lower rate of positive bacterial cultures is not unexpected.

In this study, both surrogate markers were identified less frequently among HCPs caring for patients on contact precautions versus HCPs caring for patients not on contact precautions, although the difference only achieved significance for FP. We also observed that HCPs caring for patients on contact precautions more frequently performed HH at room exit, and that HCPs who performed HH had fewer FP detections. Previous studies have also reported an association between contact precautions and HH compliance,[36,37] and between HH and fewer MS2 detections on the hands of HCP.[38,39] These findings suggest that both contact precautions and HH play an important role in preventing the spread of AROs and provide additional data to support the role of contact precautions in preventing ARO transmission.

While we found no significant differences in the rate of FP detections among different types of HCPs, MS2 was more frequently detected among physicians compared to nurses. This observation may also be related to HH, as nurses were more likely than physicians to

perform HH at room exit. As in prior studies,[40] observed HCP HH compliance was low. However, differences in HH compliance by HCP job category suggest that a role exists for interventions promoting HH amongst all HCPs.

A key strength of this study is the use of multiple surrogate markers and bacterial cultures, which helps to generate a more complete model of pathogen transmission. Other strengths include the real-world hospital setting and detailed HCP observations. This study was subject to a few limitations. The small sample size may have limited the statistical power to detect differences in surrogate marker detections. This study also only included patients on contact precautions for VRE and MRSA, and only tested for VRE, MRSA, and MSSA. Therefore, it is unclear how our findings would translate to other AROs, such as *C. difficile* and multi-drug resistant gram-negative bacteria. Finally, despite detailed HCP observations, it was not always possible to observe HH occurring inside patient rooms when the door was closed. Therefore, we may have under-estimated HCP HH compliance; however, internal, routine HH observations support overall less than ideal HH compliance among hospital staff.

Despite these limitations, this study demonstrated transfer of both FP and MS2 beyond the initial areas of contamination inside patient rooms. This suggests that both surrogate markers may be useful tools to study ARO transmission. Larger studies using surrogate markers to assess ARO transmission and HCP cross-contamination are warranted, especially those focusing on the impact of contact precautions on ARO transmission.

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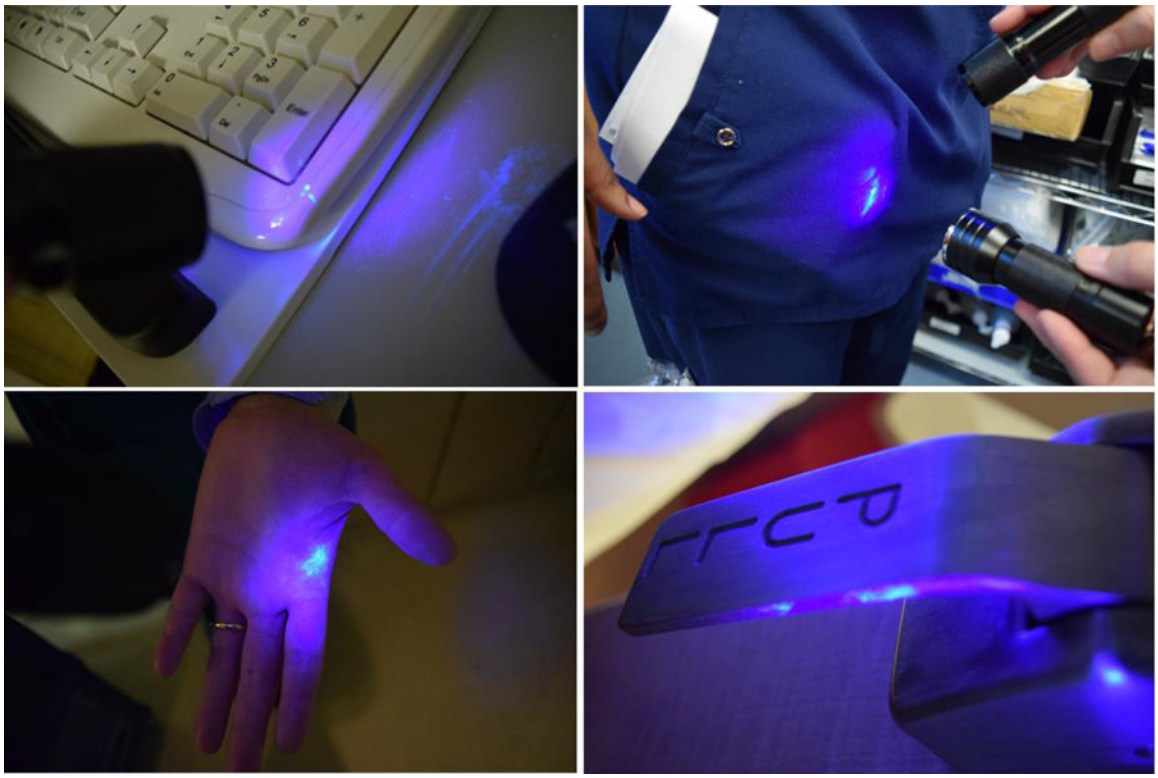

Figure 1.
Examples of fluorescent powder detections observed in this study

Table 1.

Fluorescent powder and MS2 detections on participating healthcare professionals (HCPs) and surfaces touched by participating HCPs after exiting the patient's room, by patient isolation status.

Type of detection	All HCPs N=77 (%)	HCPs caring for Patient on Contact Precautions N=54 (%)	HCPs caring for Patient not on Precautions N=23 (%)	OR (95% CI)	p[a]
Fluorescent Powder[b]	26 (34)	10 (19)	16 (70)	0.10 (0.03 – 0.31)	<0.001
HCP[c]	23 (30)	9 (17)	14 (61)	0.13 (0.04 – 0.39)	<0.001
Touched surface[d]	10 (13)	3 (6)	7 (30)	0.13 (0.03 – 0.58)	0.006
MS2[e]	15 (19)	8 (15)	7 (30)	0.40 (0.12 – 1.27)	0.13
HCP[c]	10 (13)	4 (7)	6 (26)	0.23 (0.06 – 0.90)	0.06
Touched surface[d]	6 (8)	4 (7)	2 (9)	0.84 (0.14 – 4.94)	1.00

Abbreviations: HCP, healthcare professionals

[a] Fisher's exact test was used for comparisons due to small cell sizes.

[b] Defined as the visualization of fluorescence when the HCP/surface was scanned with a handheld UV light.

[c] Includes HCP hands, sleeves/wrist, gloves, face, and clothing.

[d] Environmental surfaces touched by HCPs after leaving the patient room.

[e] Defined as the detection of MS2 on a swab collected from the HCP/surface via real-time reverse transcriptase PCR.

Table 2.

Fluorescent powder and MS2 detections on participating healthcare professionals (HCP) and/or surfaces touched by participating HCP by type.

Type of detection	Surrogate marker detected	Surrogate marker not detected	OR (95% CI)	p
Fluorescent Powder	**N=26 (%)**	**N=51 (%)**		
Nurse[a] (n=40)	13 (50)	26 (51)	Reference	
Physician (n=16)	3 (12)	13 (26)	0.48 (0.12 – 1.98)	0.31
Other[b] (n=21)	10 (39)	12 (24)	1.89 (0.64 – 5.57)	0.25
MS2	**N=15 (%)**	**N=62 (%)**		
Nurse[a] (n=40)	4 (27)	35 (57)	Reference	
Physician (n=16)	6 (40)	10 (16)	5.40 (1.27 – 22.93)	0.02
Other[b] (n=21)	5 (33)	17 (27)	2.57 (0.67 – 11.88)	0.16

Abbreviations: HCP, healthcare professional

[a.] Includes nurse practitioners and student nurses.

[b.] Includes patient care technicians, respiratory therapists, radiology techs, dieticians, pharmacist, pharmacy student, infection prevention technician, and unit secretary.

Table 3.

Microbiologic culture results for the patients on contact precautions and the healthcare professionals (HCP) who cared for these patients

Samples	All Positive	VRE	MRSA	MSSA
Samples from patients (n=17)				
Baseline patient swabs[a]	13[b]	9[c]	5[d]	1[e]
Baseline room surface swabs	7[f]	3[g]	3[h]	3[i]
Surface swabs from areas where fluorescence was observed inside patient rooms	1	1[j]	0	0
Surface swabs from areas where fluorescence was observed outside patient rooms	1	0	0	1[k]
Samples from HCPs (n=54)				
Pooled swab from face, hands, and wrist	8	0	0	8[l]
Swabs collected from surfaces touched by participating HCP after leaving patient rooms	2	1[m]	0	1[n]

Abbreviations: VRE, vancomycin-resistant *Enterococcus*; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*; NA, not applicable; HCP, healthcare professional.

Note: MSSA is not an indication for contact precautions.

a. Included nasal, axilla, inguinal skin, and stool or rectal swabs.

b. For 12 patients, the identified organism matched the reason for contact precautions; two patients had swabs that were positive for both VRE and MRSA. One patient had swabs that were positive for only MSSA.

c. Repetitive sequence-based PCR (repPCR) results were variable: samples from one patient were type B, samples from 4 patients were type C, samples from 2 patients were types B and C, samples from 1 patient were types A, B and C, and samples from 1 patient were types A, D, E, and F.

d. Samples from 4 patients were repetitive sequence-based PCR (repPCR) type B and staphylococcal cassette chromosome *mec* (SCC*mec*) type IV. Samples from one patient were repPCR types E and G, SCC*mec* type III.

e. Samples were repPCR types C and B, SCC*mec* type III.

f. For 6 patients, the identified organism matched the reason for contact precautions; one patient had baseline room surface swabs that were positive for both MRSA and MSSA and one patient had swabs that were positive for both VRE and MSSA. One patient had baseline room surface swabs that were positive for only MSSA.

g. Baseline room surface samples from two patient rooms were all repPCR type C, samples from the third room were repPCR types D and F.

h. Samples from 2 rooms were repPCR type B, SCC*mec* type IV. Samples from one room were repPCR types E and G, SCC*mec* type III.

i. Samples from the first room were repPCR type B, SCC*mec* type III. Samples from the second room were repPCR type E, SCC*mec* type I. Samples from the third room repPCR types B and D, SCC*mec* type III.

j. Samples were repPCR types D and E.

k. These samples were repPCR type A, SCC*mec* type I.

l. One HCP had samples that were repPCR type A, SCC*mec* type III; one had samples that were repPCR type B, SCC*mec* type III; one had samples that were repPCR type E, SCC*mec* type I; 3 had samples that were repPCR type F, SCC*mec* type III; one had samples that were repPCR types A, C, and D, SCC*mec* type III; and one had samples that were repPCR types E and D, SCC*mec* type III.

m. Samples were repPCR type C.

n. Two surfaces touched by the same HCP had samples that were positive for MSSA types H and A, SCC*mec* type III.

Table 4.

Healthcare professional observations where hand hygiene was performed, at first room entry/exit and all room entries/exits, by patient isolation status.

Observation	Patients on contact precautions	Patients not on contact precautions	OR (95% CI)	p[a]
First room visit by participating HCP	N=54 (%)	N=23 (%)		
Room entry	8 (15)	6 (26)	2.03 (0.61 – 6.71)	0.33
Room exit	33 (61)	7 (30)	0.28 (0.10 – 0.79)	0.02
All HCP room visits	N=221 (%)	N=77 (%)		
Room entry	38 (17)	16 (21)	1.26 (0.66 – 2.43)	0.50
Room exit[b]	124 (58)	28 (37)	0.44 (0.26 – 0.75)	0.003

[a] Fisher's exact test was used for comparisons due to small cell sizes.

[b] Eight room exit observations were missing because room exit could not be observed.

Table 5.

Healthcare professional hand hygiene observations, at first room entry/exit and all room entries/exits, by type of healthcare professional.

Observation	Hand hygiene performed N (%)	OR (95% CI)	p
First room visit by participating HCP			
Room entry (n=77)			
Nurse[a] n=40	7 (18)	Reference	
Physician n=16	5 (31)	0.47 (0.12 – 1.77)	0.26
Other[b] n=21	2 (10)	2.02 (0.38 – 10.70)	0.41
Room exit (n=77)			
Nurse[a] n=40	19 (48)	Reference	
Physician n=16	9 (56)	0.70 (0.22 – 2.26)	0.56
Other[b] n = 21	12 (57)	0.68 (0.23 – 1.97)	0.48
All HCP room visits			
Room entry (n=298)			
Nurse[a] n=150	38 (25)	Reference	
Physician n=71	10 (14)	2.07 (0.97 – 4.44)	0.06
Other[b] n=77	6 (8)	4.02 (1.62 – 9.98)	0.003
Room exit[C] (n=290)			
Nurse[a] n=147	87 (59)	Reference	
Physician n=68	29 (43)	1.95 (1.09 – 3.49)	0.03
Other[b] n=75	36 (48)	1.57 (0.90 – 2.75)	0.11

[a.] Includes student nurses and nurse practitioners.

[b.] Includes patient care technicians, respiratory therapists, radiology techs, dieticians, pharmacist, pharmacy student, infection prevention technician, and unit secretary.

[c.] Eight room exit observations were missing because room exit could not be observed.

Table 6.

Association between hand hygiene performance at room exit and detection of fluorescence and MS2 on healthcare professionals and on environmental surfaces touched by healthcare professionals.

Observation	Hand hygiene performed	Hand hygiene not performed	OR (95% CI)	p
First room exit by participating HCP	N=41 (%)	N=36 (%)		
Fluorescent powder detected	8 (20)	18 (49)	3.79 (1.38 – 10.38)	0.008
MS2 detected	8 (20)	7 (19)	0.93 (0.30 – 2.89)	0.91
All HCP room exits	N = 29 (%)	N = 48 (%)		
Fluorescent powder detected	7 (24)	19 (40)	2.06 (0.74 – 5.76)	0.17
MS2 detected	7 (24)	8 (17)	0.63 (0.20 – 1.97)	0.42

Abbreviations: HCW, healthcare professional.