ORIGINAL ARTICLE

Measurement of Patient Hand Hygiene in Multiorgan Transplant Units Using a Novel Technology: An Observational Study

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OBJECTIVE. Healthcare worker hand hygiene is known to prevent healthcare-associated infections, but there are few data on patient hand hygiene despite the fact that nosocomial pathogens may be acquired by patients via their own unclean hands. The purpose of this study was to measure patient hand hygiene behavior in the hospital after visiting a bathroom, before eating, and on entering and leaving their rooms.

DESIGN. Cross-sectional study.

SETTING. Acute care teaching hospital in Canada.

PATIENTS. Convenience sample of 279 adult patients admitted to 3 multiorgan transplant units between July 2012 and March 2013.

METHODS. Patient use of alcohol-based hand rub and soap dispensers was measured using an ultrasound-based real-time location system during visits to bathrooms, mealtimes, kitchen visits, and on entering and leaving their rooms.

RESULTS. Overall, patients performed hand hygiene during 29.7% of bathroom visits, 39.1% of mealtimes, 3.3% of kitchen visits, 2.9% of room entries, and 6.7% of room exits.

CONCLUSIONS. Patients appear to perform hand hygiene infrequently, which may contribute to transmission of pathogens from the hospital environment via indirect contact or fecal-oral routes.

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Healthcare worker (HCW) hand hygiene is commonly advocated as one of the most important strategies to prevent healthcare-associated infections (HAIs). Although it is well established that HCWs may transmit pathogens to patients via unclean hands,[1] nosocomial pathogens may also be acquired by patients via their own hands.[2] However, there has been comparatively little emphasis on patient hand hygiene as a way to potentially reduce HAIs.

Measurement of hand hygiene is an important component of hand hygiene improvement strategies, but there are few data on hand hygiene behavior in hospitalized patients. One study used the World Health Organization (WHO) method of direct observation and found that patient hand hygiene compliance was 56% among 75 opportunities.[3] Another study, in which junior doctors covertly observed patients, reported a compliance rate of 73% during 471 mealtimes.[4] These studies were limited by the use of direct observation, which can measure only a small sample of hand hygiene opportunities and is known to be subject to bias.[5] Electronic hand hygiene monitoring technology, such as real-time location systems (RTLSs), offers a novel approach to assessing patient hand hygiene.

Given that patients' hands may be contaminated by organisms in the hospital environment, there are 4 moments when hand hygiene may be indicated to reduce their risk of HAIs: after using the bathroom, before eating, and when entering and leaving their rooms.[6] The objective of this study was to characterize patient hand hygiene behavior during these 4 moments in an acute care hospital using a novel RTLS.

METHODS

Settings and Participants

An RTLS was installed in 3 multiorgan transplant units of an acute care teaching hospital in southern Ontario as part of a larger research study. The system used small transponders attached to hospital bracelets that emitted ultrasound "pings" at regular intervals, which were picked up by a network of several hundred wireless receivers throughout the units and processed to track the movement and location of patients.

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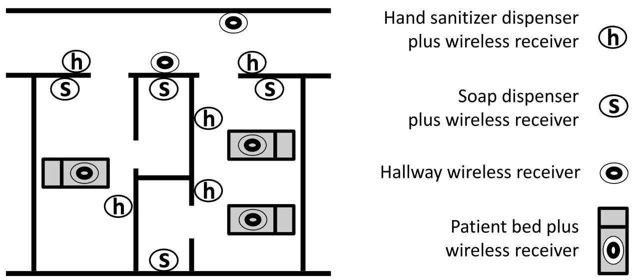

FIGURE 1. Typical patient room layout with the location of dispensers and real-time location system components.

Transponders affixed to all soap and alcohol-based hand rub (ABHR) dispensers emitted ultrasound pings whenever they were used, and the RTLS recorded a hand hygiene event. The system could detect if a person wearing a transponder was immediately in front of the dispenser when it was used, and it linked the hand hygiene event to that transponder. The layout of a typical patient room with the location of dispensers and RTLS components is shown in Figure 1.

The ultrasound transponders (Sonitor Technologies, Inc) used in the RTLS have been previously used in patient tracking systems,[7] and this installation of the RTLS demonstrated consistent measurement of hand hygiene event rates in another project.[8] Validation testing prior to the start of this study involved a series of simulated clinical scenarios with a clinician in both single and double patient room environments. For detection of hand hygiene opportunities for staff hand hygiene compliance, sensitivity was 81.1%, specificity was 94.4%, positive predictive value was 97.4%, and negative predictive value was 77.3%. For the correct attribution of hand hygiene dispensing events, sensitivity was 91.4%, specificity was 94.4%, positive predictive value was 98.5%, and negative predictive value was 77.3%. In additional test scenarios involving a single simulated patient, detection and correct attribution of dispensing events were both 100%.

All adult patients admitted to the study units from July 24, 2012, to March 2, 2013, were approached by study personnel, and patients who agreed to wear a transponder provided verbal consent. Patients were told that the purpose of the transponders was to identify instances of staff-patient contact to measure staff hand hygiene compliance but were not told that their own hand hygiene behavior could also be recorded. Patients did not receive any specific information about their own hand hygiene and were not educated on when they should perform hand hygiene. The overall study received approval from the institutional Research Ethics Board, and the requirement for full informed consent from patients was waived given that the hand hygiene data were deidentified and there was no significant risk involved. Furthermore, informing patients about the exact nature of the monitoring may have altered their hand hygiene behavior.

Measurement of Hand Hygiene Opportunities and Behavior

Bathroom visits were included as hand hygiene opportunities when the length of time in the bathroom was greater than 30 seconds but less than 12 minutes. This time period was chosen a priori to reflect the fact that short visits would not likely have involved activities that required hand hygiene and longer visits may represent showers that also would not require hand hygiene. Hand hygiene events were attributed to bathroom visits if patients used soap while inside the bathroom or ABHR within 30 seconds of leaving the bathroom.

For patient hand hygiene behavior before eating, mealtimes and kitchen visits were assessed. Mealtime opportunities included a 90-minute window 3 times per day for each patient during the times when meal trays were typically delivered in the units. Hand hygiene events were attributed to the meal if patients used soap or ABHR during each mealtime window. All patient visits to kitchens in the units were also included

TABLE 1. Patient Demographics

Variable	All patients	Females	Males
No. (%)	279	119 (42.7)	160 (57.3)
Age, mean (95% CI), years	52 (50–54)	51 (48–54)	53 (51–55)
Length of stay, days	19 (10–42)	21.9 (11.2–45)	16.4 (10–36.1)
No. of bathroom visits	31 (14–62)	38 (15–70)	29 (13–54)
No. of meals	15 (9–30)	13 (8.5–28.5)	16 (9–30)
No. of kitchen visits	6 (2–13)	7 (3–15)	4 (2–12)
No. of room entries and exits	20 (8–46)	18 (8–40)	22 (7.5–48)

NOTE. Data are median (interquartile range) per patient during the study period, unless otherwise indicated. CI, confidence interval.

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TABLE 2. Descriptive Statistics and Hand Hygiene Rates by Sex for Bathroom Visits

Variable	All patients	Females	Males
No.	222	96	126
No. of bathroom visits	12,649	6,428	6,221
Proportion of visits associated with hand hygiene, %	29.7	35.6[a]	23.6[a]
Proportion of soap use (vs ABHR), %	92.0	94.6[b]	87.9[b]

NOTE. ABHR, alcohol-based hand rub.
[a] $P < .001$.
[b] $P < .001$.

as hand hygiene opportunities, and any use of ABHR outside the kitchen before entry or any use of soap while inside the kitchen was attributed to that visit. For mealtimes and kitchen visits, it was not possible to determine whether the hand hygiene event occurred before or after eating.

All room entries and exits by patients into their rooms were counted as opportunities. Hand hygiene events were attributed to the entry or exit if patients used soap or ABHR inside the patient room, inside the bathroom, or in the hallway within 1 minute of entry or exit. Patient rooms were a mix of single and double occupancy. Patients with fewer than 2 entries or exits were excluded a priori because this may have represented either a malfunctioning tag or a nonmobile patient.

Data Analysis

Crude hand hygiene rates were calculated for each patient hand hygiene moment. The results were stratified by sex and by use of ABHR or soap and were compared using the Fisher exact test, with a 2-sided P value of .05 considered significant. Logistic regression was used to calculate odds ratios (ORs) for hand hygiene at each indicated opportunity for patient age group and sex, time of day (AM vs PM), and day of the week (weekday vs weekend). A generalized estimating equation model was used to adjust for clustering effects owing to repeated measures. For age group, the population was divided in half, which resulted in a cutoff of 55 years of age and older compared with less than 55 years of age. All ORs were adjusted for sex, age group, time of day, and day of the week. Unadjusted and adjusted ORs were calculated to check for confounding. Data analysis was conducted using SAS version 9.3 (SAS Institute).

TABLE 3. Multivariate Logistic Regression for Hand Hygiene during Bathroom Visits

	Odds ratio (95% confidence interval)	
Variable	Unadjusted	Adjusted
Sex (women vs men)	1.79 (1.06–3.03)	1.77 (1.64–1.91)
Time of day (after 12 PM)	1.33 (1.21–1.46)	1.31 (1.22–1.42)

Role of the Funding Source

This study was funded by grants from Canada Health Infoway and the Health Technology Exchange. The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all data in the study and had final responsibility for the decision to submit for publication.

RESULTS

Of the 1,132 patients admitted to the units during the study period, 279 (24.6%) agreed to wear transponders. Characteristics of the participating patients and the number of measured hand hygiene opportunities appear in Table 1.

There were 12,649 bathroom visits, and hand hygiene was associated with 29.7% of those visits. Women were more likely to perform hand hygiene than men (35.6% vs 23.6%; $P < .001$) and were more likely to use soap than men when they did (94.6% vs 87.9%; $P < .001$). Table 2 shows the descriptive statistics and hand hygiene rates for bathroom visits. The results of logistic regression for hand hygiene during bathroom visits are shown in Table 3. Hand hygiene was more likely among women (OR, 1.77 [95% confidence interval (CI), 1.64–1.91]) and after 12:00 PM (OR, 1.31 [95% CI, 1.22–1.42]). No variables were confounded.

There were 6,005 mealtimes included in the study, with a median of 15 meals per patient (interquartile range, 9–30). Table 4 shows the hand hygiene rates for mealtimes. Overall, hand hygiene occurred during 39.1% of mealtimes. Women used soap significantly more than men (23.4% vs 20.5%; $P = .007$), and men's use of ABHR trended higher than women's, although the difference was not significant. Hand hygiene rates were lowest at breakfast (32.2%) and highest at dinner (45.9%). Table 5 shows the logistic regression results for mealtime hand hygiene. Compared with breakfast, the adjusted ORs were 1.36 (95% CI, 1.20–1.55) for lunch and 1.79 (95% CI, 1.58–2.04) for dinner. There were no other significant predictors of mealtime hand hygiene, and no variables were confounded..

There were 1,122 visits by 92 patients to 2 kitchens in the study units. Of the patients who visited kitchens, 53 (57.6%) were male. Overall, hand hygiene occurred in association with

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TABLE 4. Descriptive Statistics and Hand Hygiene Rates by Sex for Mealtimes

Variable	All	Females	Males
No. (%)	247	108 (43.7)	139 (56.3)
No. of meals	6,005	2,581	3,424
All meal hand hygiene: soap + ABHR	39.1	39.8	38.7
All meal hand hygiene: soap only	21.8	23.4[a]	20.5[a]
All meal hand hygiene: ABHR only	23.3	22.4	24.1
Breakfast hand hygiene: soap + ABHR	32.2	33.6	31.1
Breakfast hand hygiene: soap only	16.5	19.4[b]	14.3[b]
Breakfast hand hygiene: ABHR only	20.0	19.3	20.5
Lunch hand hygiene: soap + ABHR	39.3	39.8	38.9
Lunch hand hygiene: soap only	21.0	23.1[c]	19.4[c]
Lunch hand hygiene: ABHR only	23.0	21.5	24.1
Dinner hand hygiene: soap + ABHR	45.9	45.9	46.0
Dinner hand hygiene: soap only	27.8	27.8	27.8
Dinner hand hygiene: ABHR only	27.0	26.3	27.5

NOTE. Data are %, unless otherwise indicated. ABHR, alcohol-based hand rub.
[a] $P < .007$.
[b] $P < .003$.
[c] $P = .05$.

3.3% of visits, with soap used in 0.8% and ABHR in 2.5%. Hand hygiene rates were 3.0% among females and 3.5% among males.

There were 5,786 room entries and 5,779 room exits by patients, with overall hand hygiene rates of 2.9% and 6.7%, respectively. The majority (88.7%) of hand hygiene events on room entry and exit involved ABHR rather than soap. Descriptive statistics and hand hygiene rates are shown in Table 6. Table 7 shows the logistic regression results for room entry and exit. Hand hygiene was more likely on room exit compared with entry (OR, 2.34 [95% CI, 1.94–2.81]), in the afternoon (OR, 1.72 [95% CI, 1.38–2.15]), and on weekdays (OR, 1.40 [95% CI, 1.13–1.73]). No variables were confounded.

DISCUSSION

This study found that hospital inpatients in multiorgan transplant units had low rates of hand hygiene during bathroom visits, mealtimes, kitchen visits, and room entry and exit. A search of the published literature (MEDLINE search with unrestricted dates) suggests that this is the largest observational study of patient hand hygiene behavior and the first to use an electronic monitoring system.

Although there has been relatively little emphasis to date on patient hand hygiene compared with HCW hand hygiene, there is a strong theoretical basis by which pathogens may be transmitted to patients from the environment via their own unclean hands. Organisms such as *Clostridium difficile* or norovirus, which are transmitted via the fecal-oral route, can survive on fomites and surfaces, contaminate patients' hands, and then be ingested, leading to infection.[2] Similarly, pathogens transmitted by indirect contact, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and respiratory viruses, could also be acquired by patients from the environment via their hands.

In addition to the theoretical considerations, there is some preliminary evidence that interventions to improve patient hand hygiene lead to reductions in infection rates. For example, one study demonstrated that compulsory disinfection of patients' hands 4 times per day significantly reduced the number of respiratory and gastrointestinal outbreaks and the number of affected patients in a psychiatric ward.[9] Another study found that asking patients to clean their hands twice daily on weekdays reduced the rate of nosocomial MRSA infections.[10] Although the existing studies in this area are subject to significant methodological limitations, patient hand hygiene is a promising area for future research given that HAI rates and associated costs remain high despite many years of infection prevention and control initiatives.[11]

Measurement of hand hygiene compliance is a recommended component of hand hygiene improvement initiatives,[1] and it is important to understand baseline patient hand hygiene behavior prior to embarking on quality improvement. There have been 2 previous studies of hand hygiene behavior among hospitalized patients. In one of the studies, auditors using the WHO method to directly observe HCWs, patients, and visitors in 2 wards in a teaching hospital over a 24-hour period.[3] The hand hygiene opportunities measured

TABLE 5. Multivariate Logistic Regression for Mealtime Hand Hygiene

	Odds ratio (95% confidence interval)[a]	
Meal	Unadjusted	Adjusted
Lunch vs breakfast	1.36 (1.20–1.55)	1.36 (1.20–1.55)
Dinner vs breakfast	1.79 (1.58–2.04)	1.79 (1.58–2.04)
Dinner vs lunch	1.31 (1.16–1.49)	1.31 (1.16–1.49)

[a] Mealtimes were not adjusted for time of day.

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table 6. Descriptive Statistics and Hand Hygiene Rates by Sex for Room Entries and Exits

Variable	All	Females	Males
No. (%)	279	119 (42.7)	160 (57.3)
No. of entries	5,786	2,633	3,153
No. of exits	5,779	2,613	3,166
Entry hand hygiene: soap + ABHR (all)	2.9[a]	2.7[b]	3.1[c]
Entry hand hygiene: soap only	0.2	0.1[d]	0.4[d]
Entry hand hygiene: ABHR only	2.8	2.7	2.8
Exit hand hygiene: soap + ABHR (all)	6.7[a]	6.6[b]	6.8[c]
Exit hand hygiene: soap only	0.9	0.7	1.0
Exit hand hygiene: ABHR only	5.9	5.9	5.8

note. Data are %, unless otherwise indicated. ABHR, alcohol-based hand rub.
[a] $P < .0001$.
[b] $P < .0001$.
[c] $P < .0001$.
[d] $P < .03$.

by the WHO method include before touching a patient, before clean/aseptic procedure, after body fluid exposure risk, after touching a patient, and after touching a patient environment.[1] Among patients there were 75 opportunities observed, and overall hand hygiene compliance was 56%.[3] Compliance ranged from 50% after touching a patient environment to 67% after exposure to their own body fluids. Although the opportunities are not the same as in our study, patient room exit is an example of an opportunity after touching a patient environment, and bathroom visits frequently involve body fluid exposure risk. However, the compliance rates seen in the earlier study are higher than the rates of 6.8% on room exit and 29.3% during bathroom visits that we found. Another study used junior doctors to covertly observe patients during 471 mealtimes and reported a compliance rate of 73% before meals.[4] Again, this is higher than the compliance rate of 39.1% during mealtimes and 3.3% on kitchen visits seen in our study.

Some of the variation in reported compliance rates may be due to the different measurement techniques; directly observed compliance is not defined in the same way as electronically measured hand hygiene. Furthermore, the previously published studies were significantly limited by the use of direct observation, which is known to be subject to numerous biases, including selection bias, observer bias, and the Hawthorne effect (behavior change due to awareness of being observed).[5] These biases tend to result in an overestimation of hand hygiene compliance rates. Electronic monitoring systems avoid the potential for bias by applying consistent algorithms for determining compliance, although there are questions about accuracy and how well compliance rates correlate with the well-established WHO 5 Moments.[12] Furthermore, direct observation can measure only a small sample of hand hygiene opportunities, in contrast to thousands of opportunities measured 24 hours a day over 222 days in this study.

table 7. Odds Ratios for Overall Hand Hygiene (Soap plus Alcohol-Based Hand Rub) for Room Entries and Exits

	Odds ratio (95% confidence interval)	
Variable	Unadjusted	Adjusted
Weekday vs weekend	1.40 (1.07–1.83)	1.40 (1.07–1.82)
Time of day (after 12 pm)	1.75 (1.32–2.31)	1.72 (1.30–2.27)
Direction (exit vs entry)	2.36 (1.84–3.04)	2.33 (1.82–2.99)

Our study has several limitations. First, it is impossible for the RTLS to determine what patients were doing while they were in the bathroom, during mealtimes, and on kitchen visits. Hand hygiene may not have been indicated during some bathroom visits—for example, if the patient did not use the toilet—and it is not possible to know whether the patient ate during mealtimes and kitchen visits or whether hygiene was performed before or after eating. This would result in an underestimation of hand hygiene rates. Second, some of the hand hygiene events may have been attributable to staff or patients who were not wearing RTLS tags but were located close to a tagged patient. For example, some of the hand hygiene events on room entry and exit may have been performed by untagged hospital porters who were transporting patients. This is particularly salient for meals, for which measurement was not triggered by patient movement but merely by being present in the room during the time window when meals were served. As a result, hand hygiene rates may be significantly overestimated. Third, it was not possible for the RTLS to accurately capture the hand hygiene behavior of nonmobile patients. For example, patients using bedpans or urinals would not be included in the measurement of bathroom hand hygiene. Additionally, tagged ABHR dispensers were not routinely available at patient bedsides, so hand hygiene performed by nonmobile patients during mealtimes could not be measured. However, of the 247 patients for whom mealtime data were available, 89.1% visited the bathroom during their admissions and were therefore ambulatory. Fourth, not all patients in the study units consented to wear RTLS tags, and it is not known whether the hand

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hygiene behavior of the tagged patients was representative of the population as a whole. Finally, this study took place in multiorgan transplant units, and generalizability to other settings is unknown. Because this patient population is immunocompromised, they may be more aware of infectious risks and have higher rates of hand hygiene than other hospital inpatients.

In conclusion, inpatients perform hand hygiene infrequently, which may contribute to transmission of pathogens from the hospital environment via indirect contact or the fecal-oral route. More research is needed to measure hand hygiene behavior in other patient populations and to determine whether improving patient hand hygiene leads to a reduction in HAIs. Patient hand hygiene is a largely unexplored area of infection prevention and control, but it may represent a promising approach to reducing HAIs.

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Potential conflicts of interest. C.D.F. reports receipt of personal fees from Infonaut, Inc (the manufacturer of the real-time location system used in this study) during the conduct of the study; receipt of personal fees from GOJO Industries (the supplier of the hand hygiene products used in this study) outside the submitted work; and having a patent pending (PCT/CA2009/001776, "Disease Mapping and Infection Control System and Method"). All other authors report no conflicts of interest relevant to this article. All authors submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and the conflicts that the editors consider relevant to this article are disclosed here.

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