


Original Article

Hand hygiene and the sequence of patient care

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Abstract

Objective: To determine whether the order in which healthcare workers perform patient care tasks affects hand hygiene compliance.

Design: For this retrospective analysis of data collected during the Strategies to Reduce Transmission of Antimicrobial Resistant Bacteria in Intensive Care Units (STAR*ICU) study, we linked consecutive tasks healthcare workers performed into care sequences and identified task transitions: 2 consecutive task sequences and the intervening hand hygiene opportunity. We compared hand hygiene compliance rates and used multiple logistic regression to determine the adjusted odds for healthcare workers (HCWs) transitioning in a direction that increased or decreased the risk to patients if healthcare workers did not perform hand hygiene before the task and for HCWs contaminating their hands.

Setting: The study was conducted in 17 adult surgical, medical, and medical-surgical intensive care units.

Participants: HCWs in the STAR*ICU study units.

Results: HCWs moved from cleaner to dirtier tasks during 5,303 transitions (34.7%) and from dirtier to cleaner tasks during 10,000 transitions (65.4%). Physicians (odds ratio [OR]: 1.50; $P < .0001$) and other HCWs (OR, 2.15; $P < .0001$) were more likely than nurses to move from dirtier to cleaner tasks. Glove use was associated with moving from dirtier to cleaner tasks (OR, 1.22; $P < .0001$). Hand hygiene compliance was lower when HCWs transitioned from dirtier to cleaner tasks than when they transitioned in the opposite direction (adjusted OR, 0.93; $P < .0001$).

Conclusions: HCWs did not organize patient care tasks in a manner that decreased risk to patients, and they were less likely to perform hand hygiene when transitioning from dirtier to cleaner tasks than the reverse. These practices could increase the risk of transmission or infection.

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Hand hygiene prevents healthcare-associated infections (HAIs), but reported hand hygiene compliance rates have not reached satisfactory levels despite intensive improvement efforts.^{1–3} HCW type, isolation precautions, use of personal protective equipment, and intervention programs can affect hand hygiene compliance.^{3,4} In addition, hand hygiene compliance may be affected significantly by the tasks that occur before or after hand hygiene opportunities.^{5–7} As hand hygiene opportunities occur during transitions between different patient care tasks, the transition type may affect the likelihood that HCWs perform hand hygiene at specific opportunities. However, we know little about how HCWs incorporate hand hygiene into their patient care processes.

The World Health Organization (WHO) “My 5 Moments for Hand Hygiene” program specifies that HCWs should perform hand hygiene before patient contact, before aseptic tasks, after

exposures to patients' bodily fluids, after contact with patients, and after contact with objects and surfaces in the patient care area.⁸ However, different patient care task types and the contacts involved in these tasks present substantially different risks to both HCWs and patients.^{9–12} Consequently, task transitions vary in their risk of transmitting pathogens to patients, their invasive devices, and their environment if HCWs do not perform hand hygiene. We could not find published studies that examined the order in which HCWs perform patient care tasks and their hand hygiene compliance at different transition types. This study aimed to fill this information gap.

Methods

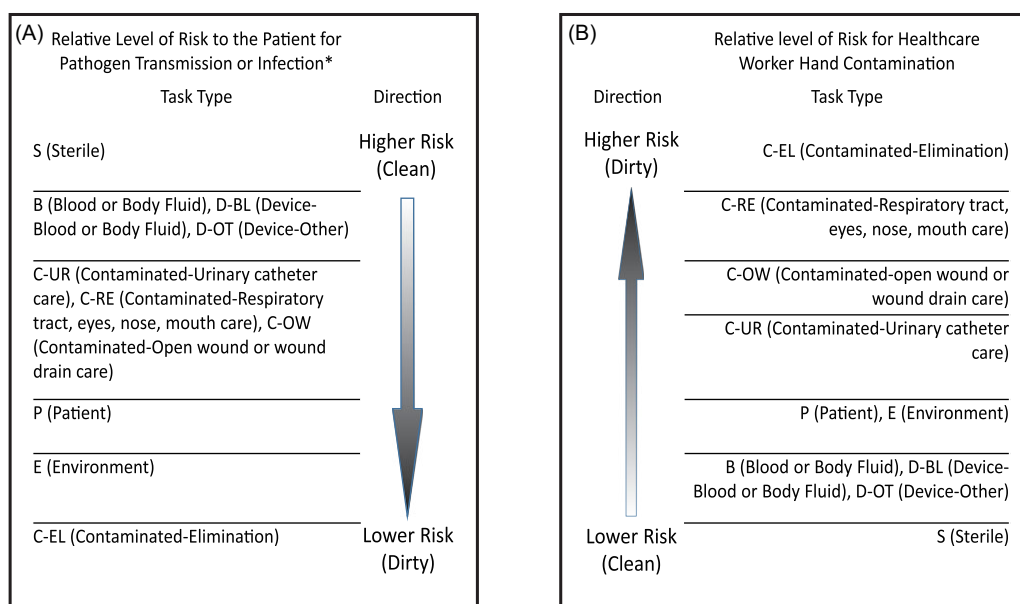
Patient care sequences and task transitions

We conducted a secondary analysis of data from the Strategies to Reduce Transmission of Antimicrobial Resistant Bacteria in Intensive Care Units (STAR*ICU) study using the data from the baseline period and the control arm to assess hand hygiene practices during routine ICU care and not during an intervention.¹³ During that study, which was conducted from April 2005 to

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*Risk of pathogen transmission if healthcare workers did not do hand hygiene before task

Fig. 1. Scales for assessing patient risk and healthcare worker hand contamination risk. (A) Risk to patients if healthcare workers do not perform hand hygiene before doing the task. (B) Risk of healthcare worker hand contamination while performing the task.

August 2006, observers recorded all tasks HCWs performed (Table 1), and they recorded whether the HCWs performed hand hygiene at each opportunity. The observers assigned HCWs an identifier specific to an observation session and linked all contacts (Appendix in Supplementary Material online) the HCWs made during that session to their identifiers. Because HCWs were assigned new identifiers each time they were observed, we were unable to follow individual HCWs across different observation sessions.

For the STAR*ICU study, tasks were defined as the group of contacts occurring between 2 consecutive hand hygiene opportunities, and tasks were classified by the contact in a group of contacts with the greatest risk of either contaminating HCW hands or transmitting pathogens to patients. For the current study, we defined patient care sequences as the series of alternating tasks and hand hygiene opportunities performed by a HCW while in a patient care area. If the HCW exited and re-entered the patient care area, the tasks performed after re-entry and the associated hand hygiene opportunities comprised a new patient care sequence.

After identifying complete patient care sequences, we identified the task transitions that occurred during individual HCW patient care sequences. Task transitions included 2 sequential tasks separated by a hand hygiene opportunity. For example, a patient care sequence with 5 patient care tasks had 6 transitions. During the STAR*ICU study, the research assistants could not observe HCW activities before they entered patients' rooms and after they exited the rooms. Thus, we excluded the transitions when HCWs entered or exited a patient care area from the analyses.

Risk of transmitting pathogens patients and risk of HCWs contaminating their hands

After a discussion with infection preventionists, we ranked tasks by both the risk to the patient if the HCW did not perform hand hygiene and the risk of HCW hand contamination (Fig. 1A). Compared with other tasks, clean tasks posed a higher risk to

patients if HCWs did not perform hand hygiene before performing the task and had a lower risk of HCW hand contamination. Dirty tasks had a higher risk of HCW hand contamination but a lower risk for the patient if HCWs did not perform hand hygiene before the task (Fig. 1B). The task classification could vary by the task transition. For example, tasks during which the HCW touched the environment would have a relatively lower risk of contaminating the HCW's hands compared with a contamination-elimination task (Appendix 1 in the Supplementary Material online) and a relatively higher risk of contaminating HCW's hands compared with a sterile task. Similarly, a device-blood task would have a relatively higher risk of transmitting pathogens to the patient compared with a task involving contact only with patient's intact skin but a relatively lower risk of transmitting pathogens to the patient compared with a sterile task.

Hand hygiene compliance

The STAR*ICU observers recorded hand hygiene compliance before and after tasks. We assessed hand hygiene compliance after the first task and before the second task in a task pair. If the HCW was compliant for either opportunity, they were compliant for that transition. HCWs were compliant if they used an alcohol-based hand rub or they washed their hands with soap and water.

Other variables

We adjusted analyses for isolation precautions (yes or no), use of gloves (yes or no), and HCW type, which have been shown to affect hand hygiene compliance.^{4,14-16} To adjust for HCW baseline hand hygiene practices, we included HCW hand hygiene compliance at their prior opportunity, which we defined as the hand hygiene opportunity immediately before the first task of a transition. We also assessed whether these variables were significantly associated with transition types.

Table 1. Contact Examples and Task Types

Task Type	Contact Examples
Sterile	Performing a sterile procedure
Blood or bodily fluid	Performing a procedure with the potential for exposure to blood or a bodily fluid
Device, blood or bodily fluid	Accessing (opening, connecting, injecting) an intravascular or other device entering a sterile site and not in contact with a mucous membrane or nonintact skin
Device, other	
Patient	Touching the patient's skin or a closed wound
Environment	Touching items or surfaces in the environment
Contaminated, respiratory tract, eyes, nose, mouth care	Touching excretions or secretions, mucous membranes, nonintact skin or items in contact with these substances or surfaces
Contaminated, urinary catheter care	
Contaminated, open wound or wound drain care	
Contaminated, elimination	

Table 2. Odds Ratios of Moving from Dirtier Tasks to Cleaner Tasks Versus Moving from Cleaner Tasks to Dirtier Tasks

Variables	No.	Risk Scale Used: Pathogen Transmission			Risk Scale Used: Healthcare Worker Hand Contamination				
		OR ^a	95% CI	P Value	OR ^a	95% CI	P Value		
Healthcare worker category									
Nurse	8,647	Ref			Ref				
Physician	2,085	1.50	1.34	1.68	<.0001	1.46	1.30	1.63	<.0001
Other	2,791	2.15	1.88	2.45	<.0001	2.10	1.84	2.39	<.0001
Gloves worn									
No	23,960	Ref			Ref				
Yes	18,389	1.22	1.14	1.31	<.0001	0.98	0.91	1.05	.5076
Isolation precautions									
No	34,067	Ref			Ref				
Yes	8,262	0.86	0.79	0.94	<.0001	0.93	0.86	1.11	.1171

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

^aUnadjusted odds ratio.

Statistical analysis

We used the χ^2 test to determine the odds of specific transition types occurring, and we used logistic regression to determine the odds of specific transition types occurring given HCW type, glove use, and isolation precautions. We used 95% confidence intervals to compare hand hygiene compliance rates and the χ^2 test to determine the odds of HCWs performing hand hygiene given a transition type. We used logistic regression for transition with a random effect to determine the odds of HCWs performing hand hygiene given HCW type, ward type, isolation precautions, whether the HCW performed hand hygiene during the prior transition, and the position in the complete patient care sequence at which the current transition occurred. We used deidentified, publicly available data, and we conducted the study in accordance with ethical guidelines.

Results

Transition direction

We generated 13,523 patient care sequences and 42,349 transitions from the STAR*ICU hand hygiene data. After we removed the first

and last transitions, 15,303 transitions remained. When we sorted transitions by risk to patients, we found that HCWs moved from cleaner to dirtier tasks during 5,303 transitions (34.7%) and from dirtier to cleaner tasks during 10,000 transitions (65.4%; $P < .0001$). When we sorted transitions by the risk of HCW hand contamination, we found that HCWs moved from cleaner to dirtier tasks 5,203 transitions (34.0%) and from dirtier to cleaner tasks during 10,100 transitions (66.0%; $P < .0001$). Thus, the results were similar regardless of the scale used to define transitions.

When we sorted the transitions by risk to patients if HCWs did not perform hand hygiene, we found that physicians and other HCWs were significantly more likely than nurses to move from dirtier to cleaner tasks (Table 2). Glove use was also significantly associated with transitions from dirtier to cleaner tasks. In contrast, HCWs were less likely to transition from dirtier to cleaner tasks when patients were in isolation precautions (Table 2). When we sorted the transitions by the risk of HCW hand contamination, we again found that physicians (Table 2) and other HCWs were significantly more likely to move from tasks with higher risk of hand contamination (dirtier) to tasks with lower risk of hand contamination (cleaner) than were nurses. However, neither glove use nor isolation precautions were associated with transition direction

Table 3. Adjusted Odds Ratios for Healthcare Workers Doing Hand Hygiene When Moving Between Tasks

Variables	Risk Scale Used: Pathogen Transmission			Risk Scale Used: Healthcare Worker Hand Contamination				
	aOR ^a	95% CI	P Value	aOR ^a	95% CI	P Value		
Position in Sequence ^b	0.98	0.97	0.99	<.0001	0.98	0.98	0.99	<.0001
Hand hygiene completed during the prior transition^c								
No	Ref				Ref			
Yes	1.20	1.17	1.22	<.0001	1.15	1.13	1.17	<.0001
Direction (risk to patient)								
Higher (ie, cleaner) to lower (ie, dirtier)	Ref				Ref			
Lower (ie, dirtier) to higher (ie, cleaner)	0.93	0.92	0.95	<.0001	0.96	0.94	0.97	<.0001
Healthcare worker type								
Nurses	Ref				Ref			
Physicians	0.87	0.82	0.92	<.0001	0.87	0.82	0.92	<.0001
Others	0.88	0.81	0.96	.0024	0.90	0.83	0.97	.0011
Gloves worn								
No	Ref				Ref			
Yes	1.20	1.17	1.22	.0001	1.19	1.17	1.21	<.0001
Isolation precautions								
No	Ref				Ref			
Yes	1.02	0.97	1.07	.3899	1.01	0.96	1.06	.2532

Note. aOR, adjusted odds ratio; CI, confidence interval.

^aAdjusted odds ratios.

^bLikelihood of healthcare workers performing hand hygiene as they moved to subsequent tasks during a patient care sequence;

^cWhether the healthcare worker performed hand hygiene in the transition before the current transition (eg, a sequence of 6 tasks will have 7 transitions, for transition 3, this variable would refer to the hand hygiene opportunity during transition 2, for transition 4, this variable would refer to the hand hygiene opportunity during transition 3, etc. The variable is null for the first transition in a sequence, as hand hygiene compliance at room entry is unknown).

when transitions were sorted by the risks of HCW hand contamination (Table 2).

Hand hygiene compliance during transitions

When we sorted transitions by the risk to patients if HCWs did not perform hand hygiene, hand hygiene compliance rate was 50.8% (95% CI, 49.5%–52.2%) when HCWs transitioned from dirtier to cleaner tasks and 42.7% (95% CI, 41.7%–43.7%) when they transitioned in the opposite direction. However, when we performed multivariable analysis to statistically adjust for position in the patient care sequence, hand hygiene at the prior opportunity, HCW type, glove use, and isolation precautions, we found that HCWs were less likely to perform hand hygiene when transitioning from dirtier to cleaner tasks compared with transitioning from cleaner to dirtier tasks (OR, 0.93; 95% CI, 0.92–0.95; $P < .0001$) (Table 3). A multivariable analysis conducted with the data sorted by the risk of HCW hand contamination yielded similar results (Table 3). Both multivariable models found that HCWs were less likely to perform hand hygiene as the number of tasks in a sequence increased (Table 3). HCWs were more likely to perform hand hygiene if they were wearing gloves or if they had performed hand hygiene during the prior transition, and nurses were significantly more likely than physicians or other HCWs to perform hand hygiene (Table 3).

Discussion

The order in which HCWs perform patient care tasks could affect the risk to patients if HCWs do not perform hand hygiene at appropriate points. Some investigators have assessed the effect

of task type on the likelihood that HCWs would perform hand hygiene before or after patient care tasks.^{5,7,17} King et al¹⁷ reported that HCWs were more likely to perform hand hygiene after tasks, such as toileting, which they perceived to have a high risk of hand contamination. Raboud et al⁵ found that contacts with patients' bodily fluids, skin, or environmental/equipment surfaces were most strongly associated with hand hygiene compliance when HCWs left patient rooms. Harbarth et al⁶ found that HCWs in a pediatric intensive care unit were most likely to perform hand hygiene before contact with bodily fluids, before contact with wounds, and after handling bodily fluids and they were significantly less likely to perform hand hygiene if their patient care was interrupted. However, none of these groups assessed the order in which HCWs performed tasks and whether the task order affected hand hygiene compliance.

Other investigators have shown that the risk of HCWs' hands, gloves, or gowns becoming contaminated varies with the patient care tasks performed. Morgan et al¹¹ found a significant association between manipulation of wound dressings or artificial airways and multidrug-resistant *Acinetobacter baumannii* contamination of HCWs' gloves or gowns. Hayden et al¹⁸ found that HCWs were nearly as likely to contaminate their hands or gloves with vancomycin-resistant enterococci after touching either a colonized patient or the patient's environment.¹⁸ Pessoa-Silva et al⁹ found that HCWs who wore gloves had higher colony-forming unit (CFU) counts in hand cultures after diaper changes, respiratory care, skin contact, and contact with secretions than after contact with equipment. When HCWs did not wear gloves, their hand cultures had even higher CFU counts.⁹ None of these investigators

assessed whether the task order affected hand, glove, or gown contamination.

The Institute for Healthcare Improvement recommended monitoring compliance with hand hygiene at each opportunity during an episode of care.¹⁹ However, several studies by Eveillard *et al*^{20–22} are the only previously published studies that evaluated hand hygiene during sequences of care. They found that HCWs were significantly more likely to perform hand hygiene for extra-series opportunities (ie, before or after single contacts or before the first contact or after the last contact in a series of successive contacts) than they were for the opportunities during a series of contacts.^{20,21} Compliance in intensive care units (ICUs) was ~30% for each intraseries opportunity, but on non-ICU wards, it increased from 13.8% between the first and second contact to 35.7% after the fourth contact. Moreover, very few HCWs performed hand hygiene at all opportunities.^{20,22}

Like Eveillard *et al*, we aimed to identify how HCWs integrated hand hygiene into their patient care sequences. In addition, we evaluated the direction of care—cleaner tasks to dirtier tasks or dirtier tasks to cleaner tasks—and whether the direction of care was associated with hand hygiene compliance. We found that HCWs were more likely to transition between tasks in a manner posing more overall risk to patients regardless of whether we used the risk to the patient scale or the risk of HCW hand contamination scale. We were not surprised by this result because the ‘cleanliness’ concept was distinct from the scales. Although the 2 risk profiles had inverted risk profiles (Fig. 1), sterile tasks were always the cleanest tasks and contamination-elimination tasks were always the dirtiest.

In addition, HCWs were less likely to perform hand hygiene when they transitioned in a manner posing more risk to patients compared with when they transitioned in a manner posing less risk to patients. This finding is particularly disconcerting because such behavior could increase the likelihood that HCWs will transmit pathogens from dirty body sites to clean body sites, to invasive devices, to surfaces in the patient care area, or to other patients.

HCWs may have good reasons for performing dirtier tasks before cleaner tasks. For example, HCWs may intentionally “batch” dirtier tasks together and cleaner tasks together to be more efficient. They may choose to perform the dirtier tasks first to “get them out of the way” before they perform their other tasks. In addition, HCWs who enter a patient’s room intending to perform clean or sterile tasks may deviate from their care plans if they discover the patient was incontinent of stool. The study by Harbarth *et al*⁶ suggests that such deviations might decrease the likelihood that the HCWs would perform hand hygiene during the transition from cleaning up the stool (a contaminating task) to the planned clean or sterile task. Moreover, HCWs may not recognize that transitioning from cleaner tasks to dirtier tasks may both decrease the risk of contaminating vulnerable patient sites, such as invasive devices and surgical wounds and decrease their workload by reducing the number of hand hygiene opportunities.

Other investigators have shown that HCWs often “have positive intentions towards hand hygiene” even though their compliance is low.^{11,12,23} Previously published studies found that action planning can help improve compliance with behaviors for which intention and practice are incongruent.^{24–26} Results of a pilot study by Erasmus *et al*²³ suggest that nurses who develop action plans including hand hygiene in their patient care processes may significantly improve their hand hygiene compliance. Scheithauer *et al*²⁷ and Carter *et al*²⁸ also found that hand hygiene compliance improved significantly after action planning was introduced.

Future studies should assess whether HCWs who create action plans are more likely than those who do not to organize their work in a way that decreases the risk of pathogen transmission from dirty sites to clean sites and devices and to incorporate hand hygiene into their care sequences even when they are interrupted or encounter surprises that force them to deviate from their initial plans.

In this study, the likelihood HCWs would perform hand hygiene decreased as the number of tasks they performed during a single patient-care sequence increased. Hayden *et al*¹⁸ obtained hand cultures from HCWs caring for patients colonized or infected with vancomycin-resistant enterococci (VRE). They found that each contact increased the risk that HCWs would contaminate their hands with VRE by 10%. Taken together, these results suggest that HCWs are more likely to contaminate their hands but less likely to perform hand hygiene as the complexity of their task sequences increases, which could substantially increase the risk of transmission or infection.

Some investigators^{29–31} found that HCWs were less likely to perform hand hygiene if they wore gloves for a task while others found the reverse.^{32–34} Our result corroborates the results of the latter studies.^{32–34} We previously found that HCWs were more likely to perform hand hygiene after dirty tasks than after clean tasks.³⁵ Since HCWs are likely to wear gloves for tasks they consider to be dirty, our finding of high hand hygiene compliance with glove use may be related to a sense of disgust associated with dirty tasks.^{36,37}

Our study is the first to evaluate the direction of patient care and to assess the association of care direction and hand hygiene compliance. In addition, the STAR*ICU study involved multiple ICUs from different healthcare centers in different geographic locations. Thus, we evaluated thousands of care sequences and hand hygiene opportunities, which increased the generalizability of our results. However, our study had several limitations because we retrospectively analyzed data collected during the STAR*ICU study. First, research assistants aggregated contacts into task groups, which prevented us from performing analyses at the level of specific contacts. In addition, we removed the first and last transitions from each care sequence because we did not know what tasks HCWs performed immediately before they entered rooms and immediately after they exited rooms. Thus, we could not assess transitions between patients. Consequently, we studied task sequences, not contact sequences, which may have caused us to miscategorize some transitions, and our sensitivity may have decreased somewhat. We also could not follow individual HCWs across observation periods. Thus, we could not adjust for individual HCWs’ behaviors, such as their baseline hand hygiene compliance. Additionally, as the difference in risk of transitions was relative, we could not compare the difference in the risk levels posed by individual transitions and their influence on HCWs’ hand hygiene compliance. Lastly, due to the setting and the time when the STAR*ICU was conducted, our results may not accurately reflect practices outside of the ICU or current practices in ICUs.

In conclusion, HCWs observed during the STAR*ICU study were more likely to transition from dirtier to cleaner tasks than they were to transition from cleaner to dirtier tasks. Moreover, they were less likely to perform hand hygiene when they transitioned from dirtier to cleaner tasks than they were when they transitioned in the opposite direction, suggesting they could increase the risk of transmitting pathogens from dirtier body sites to cleaner or more vulnerable body sites, including invasive devices, and thereby inadvertently increase the risk of HAI. Interventions that include action

planning might help HCWs care for patients more efficiently, effectively, and safely while avoiding hand hygiene errors and decreasing the risk of HAI.

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