Impact of Ring Wearing on Hand Contamination and Comparison of Hand Hygiene Agents in a Hospital

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We determined risk factors for hand contamination and compared the efficacy of 3 randomly allocated hand hygiene agents in a group of surgical intensive care unit nurses. We cultured samples of one of the subjects’ hands before and samples of the other hand after hand hygiene was performed. Ring wearing was associated with 10-fold higher median skin organism counts; contamination with *Staphylococcus aureus*, gram-negative bacilli, or *Candida* species; and a stepwise increased risk of contamination with any transient organism as the number of rings worn increased (odds ratio [OR] for 1 ring worn, 2.6; OR for >1 ring worn, 4.6). Compared with use of plain soap and water, hand contamination with any transient organism was significantly less likely after use of an alcohol-based hand rub (OR, 0.3; 95% confidence interval [CI], 0.1–0.8) but not after use of a medicated hand wipe (OR, 0.9; 95% CI, 0.5–1.6). Ring wearing increased the frequency of hand contamination with potential nosocomial pathogens. Use of an alcohol-based hand rub resulted in significantly less frequent hand contamination.

There has been a recent increase in episodes of hospital-acquired infection by antimicrobial-resistant organisms [1]. These infections may result in substantial morbidity and higher health care costs [2, 3]. Health care workers’ hands frequently are contaminated with potential pathogens [4], which likely increases the risk of antimicrobial-resistant organism transmission. To minimize this risk, we need to better understand the factors that promote hand carriage of antimicrobial-resistant organisms and to identify methods to improve adherence to hand washing recommendations [5, 6].

Despite evidence and expert opinion that hand hygiene reduces transmission of potential pathogens or antimicrobial-resistant organisms [7–10], sustained improvements in adherence to hand hygiene recommendations and proper hand washing technique among health care workers are uncommon [11], even after educational efforts [12]. Lack of adherence to hand hygiene recommendations for soap and water use has resulted in recommendations to use sinkless alternatives, in particular, alcohol-based hand rubs [13]. Recently, the Healthcare Infection Control Practices Advisory Committee of the Centers for Disease Control and Prevention (Atlanta, GA) released new hand hygiene guidelines that promote increased use of alcohol-based hand rubs [14]. Alcohol preparations have been shown to be effective in many laboratory studies that used artificial hand contamination [15–17] and in a
few randomized clinical studies [18–22]; however, these clinical trials either did not evaluate ethyl alcohol preparations commonly marketed to US hospitals or did not differentiate common skin commensals (e.g., coagulase-negative staphylococci) from transient organisms. Investigators from a recently conducted study that evaluated the efficacy of several alcohol preparations for reducing hand contamination concluded that ethyl alcohol gels should contain at least 80% ethanol; however, in that study, volunteers’ hands were artificially contaminated in the laboratory with a single bacterial strain [23].

We evaluated the efficacy of the following 3 hand hygiene methods in a group of on-duty registered nurses in a surgical intensive care unit (ICU): use of an alcohol-based hand rub (formulated with 62% ethyl alcohol); use of a medicated hand wipe, which people may be more likely to use [24]; and hand washing with plain soap and water. We also assessed potential risk factors for hand carriage of several potential nosocomial pathogens.

PATIENTS AND METHODS

Hand Sampling Method

All nurses who participated in patient care during the day shift at Rush Presbyterian Saint Luke’s Medical Center’s (Chicago, IL) 27-bed surgical ICU from 21 November 2000 through 5 March 2001 were eligible for enrollment. After obtaining informed consent, we performed cultures of convenience samples of nurses’ hands during their routine work hours, always after a patient care episode. The hands of each nurse were sampled and cultured no more than once per day. A sealed envelope was opened that randomly determined the first hand to be sampled and the method of hand hygiene to be used (figure 1). The first hand was sampled by means of a modified “glove juice” method [25], rinsed, and dried. Then the nurse performed hand hygiene by one of the following methods: hands were lathered for 30 s with 2.0 mL of unmedicated soap, rinsed, and then dried with paper towels; 2.0 mL of a 62% ethyl alcohol-based gel was applied to the hands, and hands were washed with plain soap and water. We also assessed potential risk factors for hand carriage of several potential nosocomial pathogens.

Microbiological Methods

Laboratory personnel were blinded to all hand characteristics, the hand hygiene method used, and the hand (i.e., first or second) that was sampled for culture. Glove juice bags were prepared by aseptically transferring 75 mL of autoclaved sampling solution [4] into sterile sample bags. The nurse’s hand was immersed in the bag, and the palm and each finger were massaged through the bag for 30 s. After sampling, the sampling solution was filtered through a 2.5-µm prefilter and a 0.45-µm final filter. The prefilter was discarded, and the final filter was placed in a sterile petri dish. The filter was moistened with 2 mL of PBS (pH, 7.2), and the retained organisms were resuspended by means of a sterile loop.

Aliquots of 0.2 mL of resuspended organisms were inoculated onto 5 different media to detect target organisms and to determine the number of colony-forming units (cfu). To identify methicillin-resistant and meticillin-susceptible Staphylococcus aureus and methicillin-resistant coagulase-negative staphylococci, ChromAgar Staph aureus agar (ChromAgar), with or without oxacillin (4 µg/mL), was inoculated and incubated at 35°C for 48 h. Colonies suggestive of S. aureus were inoculated onto tryptic soy agar with 5% sheep blood (REMEL) and incubated at 35°C for 24 h. The presence of S. aureus was confirmed by latex agglutination testing (BACTi Staph; REMEL). To identify gram-negative bacilli, MacConkey agar (BBL) was inoculated and colonies were identified using API 20 E and/or API 20NE strips (bioMérieux). Spot indole testing was performed on putative Escherichia coli isolates. To identify vancomycin-resistant enterococci, Enterococcus agal (REMEL) with vancomycin (6 µg/mL) was inoculated and incubated at 35°C for 48 h. Isolates were subcultured on tryptic soy agar with 5% sheep blood for 24 h at 35°C and were tested with l- pyrogulutamic acid–β-naphthylamide (REMEL). To identify yeast, ChromAgar Candida (ChromAgar) was inoculated and incubated for 48 h at 35°C. Cultures that did not yield yeast
Species-level identification was performed using standard methods. “Transient organisms” were defined as those present on <50% of all nurses’ hands—that is, all organisms except methicillin-resistant coagulase-negative staphylococci.

**Statistical Methods**

**Evaluation of risk factors for hand contamination.** Because there were hand-specific risk factors (e.g., presence of rings or cuts on the hand), we included each hand sampled (n = 564) as a separate observation. The outcome variable was hand contamination, and we evaluated data for each hand hygiene method for inclusion in the final model. To evaluate whether an increased number of rings was more strongly associated with hand contamination, we constructed separate models that categorized ring wearing into 2 categories (i.e., presence or absence of a ring) and into 3 categories (i.e., no ring, 1 ring, or >1 ring).

**Evaluation of hand hygiene method efficacy.** To evaluate the efficacy of the hand hygiene agents, we constructed logistic regression models. The outcome variable was contamination of the second hand cultured (i.e., the cleansed hand); contamination of the first hand cultured (i.e., the uncleansed hand) was evaluated as an explanatory variable.

**Common to both analyses.** Data were collected on a standardized form and entered into a database (Access 2000; Microsoft). Categorical variables were compared using either Fisher’s exact test or the \( \chi^2 \) test. ORs and 95% CIs were calculated. Continuous variables were compared by the Wilcoxon rank sum test. Mantel-Haenszel summary ORs and 95% CIs were calculated for stratified analyses.

For all models, risk factors with a \( P \) value of <.2, as identified by univariate analysis, were evaluated by stepwise logistic regression. We constructed separate logistic regression models for each organism category, including the transient organism cat-
category. To control for the fact that the hands of most nurses were sampled more than once and, therefore, that all sampling episodes were not independent observations, we evaluated variables in both final logistic regression models using the generalized estimating equation. All analyses were performed by SAS for Windows, version 8.0 (SAS Institute), or Epi Info, version 6.04 (Centers for Disease Control and Prevention) [27].

RESULTS

Participant characteristics. We sampled the hands of 66 nurses for a total of 282 sampling episodes (figure 1). Of the 564 hands sampled, 222 (39%) had poor skin condition (i.e., a skin score of 4 or 5), 186 (33%) had a skin score of 1 or 2, and 56 (10%) had poor skin condition on the basis of the number of rings worn (OR for 1 ring, 4.6 [95% CI, 1.4–14.6]). Furthermore, there was a greater frequency of cuts on hands with rings, despite the method of hand hygiene used; hands with rings were 1.6-fold more likely to be contaminated after hand washing with plain soap and water and 2.3-fold more likely to be contaminated after use of the alcohol-based hand rub.

Hand contamination. The frequency of hand contamination varied by organism category and by hand hygiene status (table 2). The gram-negative bacilli included Acinetobacter species (n = 19), Enterobacter species (n = 13), Pseudomonas species (n = 12), Klebsiella species (n = 10), Stenotrophomonas maltophilia (n = 8), E. coli (n = 7), Serratia marcescens (n = 4), Proteus mirabilis (n = 1), Ochrobactrum anthropi (n = 1), and Erwinia species (n = 1). The majority of yeast isolates were Candida parapsilosis (n = 46), followed by Candida glabrata (n = 6), Candida albicans (n = 3), and Candida tropicalis (n = 2). Only 3 of the 63 S. aureus isolates were methicillin resistant, and all were recovered from an uncleansed hand.

Among uncleansed hands (i.e., the first hand cultured), the degree of hand contamination for each organism category, as measured by median cfu (interquartile range [IQR]), was greatest for methicillin-resistant coagulase-negative staphylococci (median, 970 cfu; IQR, 80–6500 cfu), followed by gram-negative bacilli (median, 60 cfu; IQR, 20–1270 cfu), S. aureus (median, 50 cfu; IQR, 30–175 cfu), Candida species (median, 30 cfu; IQR, 10–110 cfu), and vancomycin-resistant enterococci (median, 15 cfu; IQR, 10–40 cfu).

Risk factor determination. By multivariable analysis, ring wearing was found to be a risk factor for hand contamination for each organism category except that of methicillin-resistant coagulase-negative staphylococci (table 3), and there was a stepwise increase in the risk of hand contamination by any transient organism on the basis of the number of rings worn (OR for 1 ring, 2.6 [95% CI, 1.4–4.6]; OR for >1 ring, 4.6 [95% CI, 1.7–12]). In addition, the degree of hand contamination was significantly higher when a ring was worn, compared with the degree when a ring was not worn, for gram-negative bacilli (median, 565 vs. 40 cfu; P = .05) and Candida species (median, 120 vs. 10 cfu; P < .001). Furthermore, there was a greater frequency of contamination with any transient organism on hands with rings, despite the method of hand hygiene used; hands with rings were 1.6-fold more likely to be contaminated after hand washing with plain soap and water and 2.3-fold more likely to be contaminated after use of the alcohol-based hand rub.

Table 1. Comparison of data for the hands of surgical intensive care unit nurses randomly allocated to 1 of 3 hand hygiene methods.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Alcohol hand rub group</th>
<th>Medicated wipe group</th>
<th>Plain soap and water group</th>
<th>χ²</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of cuts on hand</td>
<td>(n = 91)</td>
<td>(n = 97)</td>
<td>(n = 94)</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>Wore gloves during the patient care episodeb</td>
<td>18 (20)</td>
<td>15 (15)</td>
<td>7 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of poor skin condition</td>
<td>40 (44)</td>
<td>32 (33)</td>
<td>39 (41)</td>
<td>.27</td>
<td></td>
</tr>
<tr>
<td>Presence of rings</td>
<td>22 (24)</td>
<td>28 (29)</td>
<td>19 (20)</td>
<td>.32</td>
<td></td>
</tr>
<tr>
<td>Self-reported hand wash &lt;15 min before hand samplingb</td>
<td>50 (55)</td>
<td>52 (54)</td>
<td>58 (62)</td>
<td>.44</td>
<td></td>
</tr>
<tr>
<td>Cared for &gt;2 patients before hand samplingb</td>
<td>10 (11)</td>
<td>9 (9)</td>
<td>6 (6)</td>
<td>.52</td>
<td></td>
</tr>
<tr>
<td>Touched the patient’s skin during the patient care episode before hand sampling</td>
<td>28 (31)</td>
<td>37 (38)</td>
<td>28 (30)</td>
<td>.76</td>
<td></td>
</tr>
<tr>
<td>Contamination by transient flora on first hand sampled</td>
<td>28 (31)</td>
<td>30 (31)</td>
<td>33 (35)</td>
<td>.77</td>
<td></td>
</tr>
<tr>
<td>Shift duration of &gt;4.0 h before hand sampling</td>
<td>53 (58)</td>
<td>56 (58)</td>
<td>53 (56)</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>Presence of long fingernails</td>
<td>26 (29)</td>
<td>27 (28)</td>
<td>25 (27)</td>
<td>.95</td>
<td></td>
</tr>
</tbody>
</table>

a Calculated for the comparison of all 3 groups (i.e., a χ² test for a 2 × 3 table was performed).
b Data were not recorded for 5 sampling episodes.
Table 2. Frequency of hand contamination among surgical intensive care unit nurses, by organism category and hand hygiene status.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Time at which hand sampling was performed, no. (%) of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before performance of hand hygiene</td>
</tr>
<tr>
<td></td>
<td>(n = 282)</td>
</tr>
<tr>
<td>MRCN staphylococci</td>
<td>201 (71)</td>
</tr>
<tr>
<td>Any gram-negative bacilli</td>
<td>29 (10)</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>36 (13)</td>
</tr>
<tr>
<td>Candida species</td>
<td>33 (12)</td>
</tr>
<tr>
<td>VR enterococci</td>
<td>6 (2)</td>
</tr>
<tr>
<td>Any transient organismb</td>
<td>91 (32)</td>
</tr>
</tbody>
</table>

NOTE. MRCN, methicillin-resistant coagulase-negative; VR, vancomycin resistant.

a Significantly fewer episodes of hand carriage compared with those before hand hygiene was performed (P < .05).
b Included all organisms except MRCN staphylococci.

We obtained detailed ring information (i.e., frequency of ring wearing and ring characteristics) for 464 (82%) of 564 hands sampled; rings were worn at home and removed at work in 102 (22%) of 464 hands sampled and were worn at both home and work in 111 (24%) of 464 hands sampled. Among nurses who wore rings versus those who did not, there was a similar frequency of observed glove use (22% vs. 22%; P = 1.0) and of self-reported hand hygiene within 15 min of study participation (61% vs. 52%; P = .18). When we compared data for nurses who wore rings only at home and for those who wore rings at both home and work with data for those who never wore rings, after adjusting for other hand characteristics, we found that wearing rings only at home was not a risk factor for contamination with any transient organism (OR, 0.7; 95% CI, 0.4–1.3) but that wearing rings at home and work was an independent risk factor (OR, 2.6; 95% CI, 1.6–4.3). Hand contamination was not associated with any ring characteristic. Other independent risk factors for hand contamination varied by organism category (table 3).

Hand hygiene efficacy. By univariate analysis, we found that, compared with uncleansed hands, hands cleansed with alcohol-based hand rub were significantly less likely to be contaminated with methicillin-resistant coagulase-negative staphylococci, Candida species, or any transient organism (table 2).

Table 3. Results of multivariable analysis of the efficacy of 3 hand hygiene methods and of independent risk factors for hand carriage of potential pathogens, by organism category, in a group of surgical intensive care unit nurses.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yeast</th>
<th>Staphylococcus aureus</th>
<th>Gram-negative bacilli</th>
<th>Any transient organismb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of hand hygiene methods (n = 282)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plain soap and water</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Medicated hand wipeb</td>
<td>1.2</td>
<td>1.8 (0.5–5.9)</td>
<td>0.7 (0.2–2.3)</td>
<td>0.9 (0.5–1.6)</td>
</tr>
<tr>
<td>Alcohol hand rubb</td>
<td>0.4</td>
<td>0.9 (0.3–2.3)</td>
<td>0.2 (0.1–0.9)</td>
<td>0.3 (0.1–0.8)</td>
</tr>
<tr>
<td>Contamination of opposite hand</td>
<td>17.6</td>
<td>10 (3.3–31)</td>
<td>6.2 (1.8–22)</td>
<td>2.8 (1.8–8.0)</td>
</tr>
<tr>
<td>Presence of &gt;1 ring</td>
<td></td>
<td>2.6 (0.9–7.5)</td>
<td>2.0 (0.9–4.7)</td>
<td></td>
</tr>
<tr>
<td>Risk factors for hand contamination (n = 564)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring(s) present</td>
<td>2.8</td>
<td>2.1 (1.0–4.4)</td>
<td>2.9 (1.5–5.8)</td>
<td>3.0 (1.8–4.9)</td>
</tr>
<tr>
<td>Touched patient</td>
<td>2.8</td>
<td></td>
<td>1.6 (1.0–2.7)</td>
<td>1.5 (1.0–2.2)</td>
</tr>
<tr>
<td>Poor skin condition</td>
<td></td>
<td></td>
<td>0.4 (0.1–1.1)</td>
<td></td>
</tr>
<tr>
<td>Use of alcohol hand rub</td>
<td>0.3</td>
<td></td>
<td>0.3 (0.2–0.6)</td>
<td></td>
</tr>
</tbody>
</table>

a Included all organisms except methicillin-resistant coagulase-negative staphylococci.
b Results for medicated hand wipe use and alcohol-based hand rub use were compared with results for hand washing with plain soap and water.
After we adjusted for risk factors for hand contamination, we found that, compared with use of plain soap and water, use of the alcohol-based hand rub resulted in a significantly decreased frequency of hand contamination with gram-negative bacilli or with any transient organism and that there was a trend toward decreased contamination with yeast (table 3).

DISCUSSION

In a surgical ICU, we found that use of an alcohol-based hand rub resulted in significantly less frequent hand carriage of any transient organism, compared with results of hand washing with plain soap and water. In our analysis to determine risk factors for hand contamination, we found that the presence of rings on nurses’ hands resulted in an increased frequency of hand carriage of *S. aureus*, gram-negative bacilli, or *Candida* species and that, for any transient organism, there was a larger increase when several rings were worn.

Our study adds to information about hand contamination by (1) evaluating hands during routine work rather than after artificial hand contamination, which may misrepresent the degree and sites of hand contamination and usually evaluates only a single species of bacteria; (2) using a method that assessed risk factors unique to each hand; and (3) identifying organisms to the species level, rather than just quantifying the total cfu.

We evaluated 3 methods of hand cleansing in the routine work setting of an ICU. Our findings are consistent with those of other investigators who have documented the superior efficacy of alcohol-based preparations for disinfecting hands in the laboratory or clinical setting, and they add further evidence in support of the findings that, in the routine work setting, after controlling for characteristics that might affect hand contamination (e.g., wearing rings or having a poor skin condition), use of alcohol-based hand rubs resulted in a significantly decreased frequency of hand contamination [15, 17, 19, 21, 22, 28]. This benefit is complemented by the other known salutary effects of alcohol-based hand rubs (e.g., mitigation of skin damage during performance of hand hygiene and decreased time needed to perform hand hygiene) [14].

Use of the antimicrobial hand wipe was similar in efficacy to hand washing with plain soap and water. Although hand wipes impregnated with alcohol have been reported to be preferred by health care personnel [24, 29] and have been reported to increase the frequency of hand hygiene performance outside of a health care facility [30], current guidelines do not recommend hand wipes as a replacement for alcohol-based hand rubs or antimicrobial soap [14].

Several findings implicated rings as a major contributor to hand contamination: (1) contamination with any transient organism was twice as likely when rings were worn; (2) after hand hygiene, regardless of the method used, hand contamination with any transient organism was more likely among nurses who wore rings; (3) a dose-response effect was observed between ring wearing and the frequency of contamination (that is, wearing >1 ring resulted in a greater frequency of hand contamination than did wearing 1 ring); and (4) the degree of contamination with yeast species or gram-negative bacilli was significantly greater on the hands of nurses who wore rings.

When we compared data for hands on which rings were worn at home but were removed before work with data for hands that never had rings present, there was no increased frequency of hand carriage. This suggests that hand contamination was not due to dermatitis underneath the ring but, rather, was due to the pressure of the rings themselves. In our study, because methicillin-resistant coagulase-negative staphylococci were the most common organisms identified but were not associated with the presence of a ring, enumerating colony-forming units of bacteria (a common approach in hand hygiene studies), rather than identifying bacteria to the species level, may have obscured the role of rings as a risk factor for hand contamination. Other investigators have also reported that ring wearing increases the risk for hand contamination [31–33].

It is possible that nurses who wore rings were less likely to adhere to infection-control practices; however, we found that the frequency of glove use and the self-reported time since the most recent hand hygiene episode, which are markers for adherence to infection-control policies, were similar between nurses who wore a ring and those who did not wear rings.

It is not known whether ring removal would minimize the transmission of organisms from patient to patient. We do know that uncleaned hands of health care workers are an important factor in the acquisition of hospital-acquired infection [9, 34–37]. Given the strong association between ring wearing and hand contamination, removal of rings from health care workers’ hands should result in decreased frequency of hand carriage of several potential pathogens both before and after performance of hand hygiene.

There are several limitations to our study. Although we were able to compare the efficacy of the alcohol-based hand rub with that of 1 medicated product, the antimicrobial hand wipe, we did not include a medicated formulation of soap in this study. Currently, there are no national guidelines that require the use of medicated soaps in US hospitals, and we used the hand hygiene agent readily available in the study ICU. Also, we only evaluated nurses in an ICU; however, because the organisms we detected on nurses’ hands are problematic pathogens for patients regardless of the health care setting and are likely to be found on other health care workers’ hands, we believe our study is generalizable to other health care settings and to other categories of health care workers. It remains to be seen whether use of those alcohol preparations with greater efficacy in the
laboratory [23] results in an important reduction in hand carriage of potential pathogens in the clinical setting beyond the significant reduction that we observed with use of a 62% ethyl alcohol preparation. The overall frequency of glove use during patient care (22%) was lower than has been reported by other investigators (31%–55%) [38–40]; however, comparisons between studies are complicated by the type of patient-care activity [41].

In conclusion, use of an alcohol-based hand rub resulted in a significant decrease in the frequency of hand contamination among surgical ICU nurses. Also, there was a significantly increased frequency of hand carriage of potential pathogens among nurses who wore at least 1 ring, and hand carriage was highest among nurses who wore >1 ring. Ring removal during work and use of alcohol-based hand rubs should reduce the degree of hand carriage of potential pathogens among ICU personnel.

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References


