Original Article

Prospective, Controlled, Cross-Over Trial of Alcohol-Based Hand Gel in Critical Care Units

Mark E. Rupp, MD; Teresa Fitzgerald, RN; Susan Puumala, MS; James R. Anderson, PhD; Rita Craig, RN; Peter C. Iwen, PhD; Dawn Jourdan, RN; Janet Keuchel, RN; Nedra Marion, RN; Delayne Peterson, PA; Lee Sholtz, RN; Valerie Smith, RN

Background. There are limited data from prospective studies to indicate whether improvement in hand hygiene associated with the use of alcohol-based hand hygiene products results in improved patient outcomes.

Design. A 2-year, prospective, controlled, cross-over trial of alcohol-based hand gel.

Setting. The study was conducted in 2 medical-surgical ICUs for adults, each with 12 beds, from August 2001 to September 2003 at a university-associated, tertiary care teaching hospital.

Methods. An alcohol-based hand gel was provided in one critical care unit and not provided in the other. After 1 year, the assignment was reversed. The hand hygiene adherence rate and the incidence of nosocomial infection were monitored. Samples for culture were obtained from nurses' hands every 2 months.

Results. During 17,994 minutes of observation, which included 3,678 opportunities for hand hygiene, adherence rates improved dramatically after the introduction of hand gel, increasing from 37% to 68% in one unit and from 38% to 69% in the other unit \((P<.001)\). Improvement was observed among all groups of healthcare workers. Hand hygiene rates were better at higher workloads when hand gel was available in the unit \((P = .02)\). No substantial change in the rates of device-associated infection, infection due to multidrug-resistant pathogens, or infection due to Clostridium difficile was observed. Culture of samples from the hands of nursing staff revealed that an increased number of microbes and an increased number of microbe species was associated with longer fingernails (ie, more than 2 mm long), the wearing of rings, and/or lack of access to hand gel.

Conclusions. The introduction of alcohol-based gel resulted in a significant and sustained improvement in the rate of hand hygiene adherence. Fingernail length greater than 2 mm, wearing rings, and lack of access to hand gel were associated with increased microbial carriage on the hands. This improvement in the hand hygiene adherence rate was not associated with detectable changes in the incidence of healthcare-associated infection.

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Nosocomial infections pose a major challenge to the healthcare system and result in significant mortality, morbidity, and economic burden. Intensive care unit (ICU) patients are at great risk of acquiring nosocomial infections because of breaches in host defense (eg, as a result of trauma, invasive medical devices, and/or corticosteroid therapy) and because the ICU environment favors selection for drug resistant pathogens as result of widespread use of broad-spectrum antimicrobials. It is generally accepted that appropriate hand hygiene is an effective means for reducing the risk of transmission of nosocomial pathogens. Unfortunately, healthcare workers' adherence to hand hygiene recommendations is often poor. Use of alcohol-based, waterless hand hygiene preparations has been promoted as a quick, effective, and easy means to achieve hand disinfection. However, the pathogenesis of nosocomial infections is a complex process, and there are few data from prospective studies to indicate whether an improvement in hand hygiene associated with the use of alcohol-based hand hygiene products results in improved patient outcomes. We conducted a trial to determine whether the introduction of an alcohol-based gel for hand hygiene was associated with improvement in adherence to hand hygiene recommendations and to determine what impact this intervention had on rates of nosocomial infection.
and on the number and type of microbes found on healthcare workers' hands.

**Methods**

**Setting**

The study was conducted at Nebraska Medical Center (Omaha, Nebraska) in 2 medical-surgical ICUs for adults, each with 12 beds, from August 1, 2001, to September 30, 2003, at a university-associated, tertiary care teaching hospital. This study was approved by the facility's institutional review board.

**Design**

This study was a prospective, controlled, cross-over trial involving 2 similar, structurally identical, adult medical-surgical ICUs. The baseline rates of hand hygiene adherence and nosocomial infection were established over a 6-month period prior to the introduction of alcohol-based hand gel into either ICU. Next, an educational program regarding hand hygiene was conducted in both units, which consisted of face-to-face meetings with nursing staff (and mandatory videotaped viewing for the night shift), a questionnaire with handouts, and posting of reminder signs. Dispensers for alcohol-based hand gel were then installed in unit B, inside and outside of each patient care room and in other conspicuous and convenient locations, and the hand gel was made available in unit B. After 12 months of observation, hand hygiene gel was no longer available in unit B, and it was now introduced in unit A. The same number of hand gel dispensers were installed in unit A, in the same locations as in unit B.

**Hand Hygiene Products**

Purell (Gojo Industries), containing 62% ethyl alcohol and 0.3% triclosan, was provided as the hand hygiene gel and used in accordance with the manufacturer's recommendations. Provon Antimicrobial Lotion Soap (Gojo Industries), with 0.3% chloroxylenol, was available as the standard soap-and-water hand hygiene option throughout the study.

**Hand Hygiene Adherence**

Surveillance to determine adherence to hand hygiene was conducted unobtrusively every 60 days by 10 trained individuals (6 infection control professionals and 4 specially trained assistants). All observers had regular duties in the ICU, and it was not apparent to healthcare workers when surveillance team members were performing hand hygiene observation. Appropriate opportunities for hand hygiene were identified on the basis of published guidelines. The adequacy of hand hygiene (eg, the time spent on hand hygiene and/or surface coverage with the hygiene product) was not assessed. The location of observations was determined by randomization of ICU room numbers, and observations were performed in 20-minute increments over 2-week periods. To minimize interobserver variation observations were validated by comparing them with those of a standard observer. An experienced infection control professional served as the standard observer. Ninety percent of an observer's assessments had to agree with those of the standard observer before an observer was certified to participate in the study. Hand hygiene compliance data were periodically given to unit personnel at staff meetings and posted in each of the ICU break rooms every 2 months. Personnel were not identified on the report forms, and data were reported in composite by unit and by job category (ie, nursing staff, physicians, and allied health professionals).

**Surveillance for Device Use and Nosocomial Infection**

Centers for Disease Control and Prevention (CDC) National Nosocomial Infection Surveillance (NNIS) system definitions and methods were used to define device use and the incidence of nosocomial infections. Infections were defined as device associated (ie, central venous catheter–related bacteremia, urinary catheter–associated urinary tract infection, and ventilator-associated pneumonia) and/or as caused by multidrug-resistant organisms (ie, methicillin-resistant *Staphylococcus aureus* [MRSA] and vancomycin-resistant enterococci [VRE]). Because triclosan can serve as a substrate for multidrug efflux pumps in bacteria, the rate of nosocomial infection due to *Pseudomonas aeruginosa* (a prototypical organism possessing a multidrug efflux pump) was monitored. Because alcohols have poor activity against bacterial spores, the rate of *Clostridium difficile*–associated diarrhea (CDAD) was monitored.

**Microbiologic Cultures**

Every 60 days, we performed quantitative cultures of samples from the dominant hand of ICU nursing staff members by use of a modified "glove juice" method. Informed consent was obtained from nursing staff, and a signed consent form was obtained at the time the first samples were collected. Informed consent was verbally confirmed at the time of each subsequent culture. Culture sampling was performed at announced times. Briefly, the dominant hand was placed in a sterile plastic bag containing 50 mL of a sampling buffer (sodium chloride, 5 g/L; bactotryptone, 20 g/L; KH₂PO₄, 1.5 g/L; Na₂HPO₄, 9 g/L) and the hand and nail beds were massaged through the bag for 60 seconds. The sampling buffer was then serially diluted and inoculated on sheep blood agar plates (Remel) and incubated at 37°C for 48 hours, followed by incubation at room temperature for 48 hours. Additionally, 0.1 mL of the undiluted sampling buffer was inoculated on MacConkey agar plates (Remel) to facilitate detection of gram-negative aerobic bacilli. Colonies that were visibly different were identified to the species level using standard lab-
Table 1. Comparison of Features of Patient Care in Intensive Care Unit (ICU) A and ICU B

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit A, study period</th>
<th>Unit B, study period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>No gel(^a)</td>
</tr>
<tr>
<td></td>
<td>4.1 ± 0.3</td>
<td>4.4 ± 0.4</td>
</tr>
<tr>
<td>Length of stay, mean ± SD, days</td>
<td>2.0 ± 0.07</td>
<td>2.1 ± 0.10</td>
</tr>
<tr>
<td>Acuity score, mean ± SD</td>
<td>0.557 ± 0.078</td>
<td>0.559 ± 0.114</td>
</tr>
<tr>
<td>CVC use ratio, mean ± SD</td>
<td>0.286 ± 0.023</td>
<td>0.41 ± 0.075</td>
</tr>
<tr>
<td>Ventilator use ratio, mean ± SD</td>
<td>0.517 ± 0.106</td>
<td>0.688 ± 0.047(^e)</td>
</tr>
</tbody>
</table>

**Note.** The use ratio was defined as the number of central venous catheter-days or ventilator-days per total number of patient-days for the unit. CVC, central venous catheter.

\(^a\) Period when alcohol-based hand gel was not available for hand hygiene.

\(^b\) Period when alcohol-based hand gel was available for hand hygiene.

\(^c\) Significant difference (\(P<.05\)) compared to baseline observation period for that unit.

A patient acuity scoring system, WinPFS (Quadra Med), was used to compare the complexity of care between ICUs and between time periods.

Statistical Analysis

Generalized estimating equations (GEEs) were used to analyze hand hygiene adherence rates over time and their relationship to job category and hand gel availability, appropriately accounting for the potential correlation among observations. Baseline infection rates were determined from historic data obtained through routine infection control surveillance for a 6-month period prior to the initiation of the study. For the analysis of the relationship between infection rates and hand hygiene, a Poisson regression model was used. Each type of infection was modeled separately. The set of analyses regarding microbes on healthcare workers' hands examined the number of organisms, the number of microbial species, and the carriage of gram-negative aerobic rods. Differences in the number of organisms and number of species relative to nail length, the wearing of at least 1 ring, and the availability of hand gel were examined using analysis of variance. Nail length was characterized as less than 1 mm, 1-2 mm, or greater than 2 mm. The number of organisms was transformed using a logarithmic transformation to satisfy model assumptions. Differences in the rate of carriage of gram-negative aerobic rods relative to nail length, the presence of at least 1 ring, and the availability of hand gel were examined using the \(\chi^2\) test. There was no linkage between the identity of the person whose hands were sampled and the microbial culture results, so all observations were treated as independent. A linear regression model was used to examine differences in device use (ie, central venous catheters, urinary catheters, and ventilators) based on unit and the availability of hand gel. All analyses were performed using the SAS System for Windows, version 9.1 (SAS Institute).

Results

ICU Comparisons

As summarized in Table 1, the patient mix was similar in units A and B with respect to acuity score and length of stay. In unit A, the use ratio for central venous catheters (ie, the number of catheter-days per total patient-days for the unit) and mechanical ventilator use ratio (ie, the number of ventilator-days per total patient-days for the unit) was significantly higher during the period when alcohol-based hand gel was in use. In unit B, the use ratio for central venous catheters was significantly higher during the study period when alcohol-based hand rub was not available.

![Figure 1](image-url) Rates of adherence to hand hygiene (in % of opportunities) for all healthcare workers. We observed 2,342 opportunities for hand hygiene for nurses, 824 opportunities for physicians, and 512 opportunities for allied health professionals. G, periods when alcohol-based hand gel was available in the unit. \(P<.001\) for comparison with other periods.
Hand Hygiene Adherence

A total of 17,994 minutes of observation were conducted over the course of the study, and 3,678 appropriate opportunities for hand hygiene (12.3 opportunities per hour) were recorded. The overall rate of adherence to hand hygiene recommendations was significantly affected by receipt of hand-hygiene education and the availability of the alcohol-based hand gel, as illustrated in Figure 1. The GEE modeling showed a significant increase in hand hygiene compliance during periods when the alcohol-based gel was available ($P < .001$). We observed 2,342 appropriate opportunities for hand hygiene for nursing staff, 824 opportunities for physicians, and 512 opportunities for allied health personnel. During the periods when alcohol-based gel was available, 81% of instances of hand hygiene were performed with the gel in unit A, and 68% of instances of hand hygiene were performed with the gel in unit B.

Relative rates of compliance among various job categories during the study periods is shown in Figure 2. At baseline in unit A, nurses exhibited greater adherence to hand hygiene recommendations than allied health personnel (47% vs 22% of opportunities; $P = .001$). After the education program, when hand gel was not available in the unit, nurses had a higher rate of adherence to hand hygiene than physicians (62% vs 40%; $P = .001$) and allied health personnel (62% vs 33%; $P = .001$). During the period when hand gel was available, physicians’ rate of adherence to hand hygiene dramatically improved to 82% of opportunities, which was significantly higher than the rates among nurses (66%; $P = .001$) and allied healthcare personnel (63%; $P = .002$). At baseline in unit B, there were no significant differences in the rate of hand hygiene adherence among nurses, physicians, and allied health personnel. During the period when hand gel was available, the rate of adherence among nurses (74% of opportunities) was significantly higher than that observed among physicians (67%; $P = .002$) and allied healthcare personnel (56%; $P < .001$). During the period after hand gel was no longer available in the unit, the rate of adherence to hand hygiene decreased precipitously among all groups of healthcare workers, although the rate for nurses (37% of opportunities) was higher than that for physicians (26%; $P < .001$) and allied health personnel (26%; $P = .03$).

The association between the rate of hand hygiene adherence and the activity index is shown in Figure 3. There was a significant association between the availability of the alcohol-based hand gel and adherence to hand hygiene recommendations when we controlled for activity index ($P = .02$).

Hand Hygiene and Nosocomial Infection

The rates of 3 types of specific device-associated infections were examined: central venous catheter–related bacteremia, urinary catheter–associated urinary tract infection, and ventilator-associated pneumonia. Rates for these infections are summarized in Table 2. Overall, infection rates were relatively low in both units, and a significant relationship between hand hygiene adherence rates and the occurrence of device-associated nosocomial infections was not observed.

Hand Hygiene and Infection Due to Multidrug-Resistant Organisms

A Poisson regression model was used to examine the association between the rate of infection due to multidrug-resistant organisms and the rate of hand hygiene adherence. The
rate of hospital-acquired infection due to MRSA and the rate of hospital-acquired infection due to VRE were analyzed. Surveillance cultures to detect asymptomatic colonization were not performed, and routine clinical cultures were used to identify infection due to MRSA or VRE. The infection rate in both study units was relatively low, and no significant relationship was observed between rates of hand hygiene adherence and rates of infection due to MRSA, VRE, or *C. difficile*. The rate of infection due to MRSA ranged from 1.67 to 2.77 infections per 1,000 patient-days, and for VRE the rate ranged from 0.35 to 1.36 infections per 1,000 patient-days. The rate of nosocomial infection due to *P. aeruginosa* was too low to allow for meaningful comparisons (there were 12 infections over the 2-year study period). In unit A, the baseline rate of CDAD was 1.67 infections per 1,000 patient-days. During the period when alcohol-based hand gel was not available, the rate was 1.39 infections per 1,000 patient-days. The rate further declined to 0.31 infections per 1,000 patient-days when the alcohol-based gel was introduced. In unit B, the opposite trend was noted. The baseline rate of CDAD was 0.67 infections per 1,000 patient-days; the rate increased to 2.52 infections per 1,000 patient-days when the

**Figure 3.** Relationship between activity index, the rate of hand hygiene adherence, and the availability of alcohol-based hand gel. A and C, rates of hand hygiene adherence in unit A during the 2 intervention periods; B and D, rates of adherence in unit B during the 2 intervention periods. *Filled triangle*, mean hand hygiene adherence rate (in % of opportunities) for a week of observation; *line*, regression line.

**Table 2.** Comparison of Rates of Device-Associated Infection in Intensive Care Unit (ICU) A and ICU B According to the Availability of Alcohol-Based Hand Gel

<table>
<thead>
<tr>
<th>Infection</th>
<th>No. of infections per 1,000 device-days</th>
<th>Unit A, by study period</th>
<th>Unit B, by study period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>No gel&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Gel&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Catheter-associated UTI</td>
<td>1.10</td>
<td>1.98</td>
<td>3.87</td>
</tr>
<tr>
<td>CVC-associated BSI</td>
<td>1.51</td>
<td>3.49</td>
<td>1.49</td>
</tr>
<tr>
<td>VAP</td>
<td>0.00</td>
<td>0.68</td>
<td>0.73</td>
</tr>
</tbody>
</table>

**Note.** BSI, bloodstream infection; CVC, central venous catheter; UTI, urinary tract infection; VAP, ventilator-associated pneumonia.

<sup>a</sup> Period when alcohol-based hand gel was not available for hand hygiene.

<sup>b</sup> Period when alcohol-based hand gel was available for hand hygiene.
Frequent washing with soap and water leads to inflammatory responses, and hygiene is often impractical because of time constraints, and frequent washing with soap and water leads to inflammatory skin reactions and interferes with the skin’s own antimicrobial properties.4,16

Recently, alcohol-based hand gels have been introduced, with variable results. Some trials of alcohol-based hand gels have documented improvement in hand hygiene, whereas others have revealed disappointing results that indicate the importance of education, behavior modification, and logistical issues.10,17-20 Most studies linking hand hygiene and nosocomial infection have been performed in settings outside the hospital, during outbreaks, or have combined efforts to improve hand hygiene with other infection prevention programs, such as use of surveillance cultures, improved isolation measures, or antimicrobial stewardship programs. This study was conducted to better define the direct role of hand hygiene in the prevention of nosocomial infection.

A change in the nosocomial infection rate (ie, the rate of device-associated infections or the rate of nosocomial infections due to multidrug-resistant organisms) was not observed in association with improved hand hygiene. The lack of effect should not necessarily be interpreted to mean that hand hygiene is not important in the prevention of nosocomial infection, but it may serve to temper unrealistic expectations that healthcare-associated infection rates will plummet as a result of simple, unifocal interventions. It should be noted that the baseline rate of nosocomial infection in the units studied was low, and despite the 2-year length of the study, it was underpowered to detect small differences in rates of infection. An alternative explanation for the study observations is that the hand hygiene adherence rate of approximately 70% achieved in each unit when hand gel was available was simply not great enough to cross an unknown threshold at which transmission of nosocomial pathogens or infections is prevented. The threshold point may depend on the pathogenicity of the microbe, the size of the inoculum, host defenses, and a large variety of other risk factors for nosocomial infections.

Microbiologic Flora of Healthcare Workers’ Hands

The effect of the use of alcohol-based hand gel, nail length, and the wearing of hand jewelry (rings) on the microbial flora of healthcare workers’ hands was assessed. A total of 192 cultures were performed over the duration of the study, on samples obtained from the hands of 69 nurses. Coagulase-negative staphylococci were the predominant microbial isolate in 91.6% of the cultures. Table 3 summarizes the culture results. Briefly, nail length was associated with the number of microorganisms recovered from the hands (P = .008) as was the availability of alcohol-based gel (P = .006). The number of microorganisms increased with increasing nail length and was decreased by the availability of alcohol-based gel. Wearing at least 1 ring on the dominant hand was significantly associated with the number of species of microbes recovered (P = .002) and with the carriage of gram-negative bacilli (P = .049). Although aerobic gram-negative bacilli were recovered slightly more frequently from the hands of nurses with longer nails and when alcohol-based gel was not available, there were, overall, few instances in which gram-negative rods were recovered, and these associations were not significant. The wearing of artificial nails was prohibited by institutional policy and no use of artificial nails was noted during this study.

Discussion

Hand hygiene is universally acknowledged as a crucial component of effective infection prevention.4 However, numerous studies have documented poor adherence to hand hygiene recommendations.11-15 Traditional soap-and-water hand hygiene is often impractical because of time constraints, and frequent washing with soap and water leads to inflammatory

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of subjects sampled</th>
<th>No. of microbes recovered</th>
<th>Carriage of gram-negative enteric microbes</th>
<th>No. of species of microbes recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Log_{10} count, mean ± SD</td>
<td></td>
<td>As % of all microbes recovered</td>
<td>Species count, mean ± SD</td>
</tr>
<tr>
<td>Nail length</td>
<td></td>
<td></td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>0-1 mm</td>
<td>59</td>
<td>3.54 ± 0.96</td>
<td>...</td>
<td>6.8</td>
</tr>
<tr>
<td>1-2 mm</td>
<td>40</td>
<td>3.91 ± 0.74</td>
<td>...</td>
<td>10.0</td>
</tr>
<tr>
<td>≥2 mm</td>
<td>75</td>
<td>3.98 ± 0.78</td>
<td>.008</td>
<td>13.3</td>
</tr>
<tr>
<td>Availability of hand gel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Available</td>
<td>97</td>
<td>3.65 ± 0.94</td>
<td>...</td>
<td>7.2</td>
</tr>
<tr>
<td>Not available</td>
<td>77</td>
<td>4.01 ± 0.73</td>
<td>.006</td>
<td>11.7</td>
</tr>
<tr>
<td>Rings worn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥1</td>
<td>122</td>
<td>3.8 ± 0.9</td>
<td>...</td>
<td>17.3</td>
</tr>
<tr>
<td>None</td>
<td>52</td>
<td>3.81 ± 0.84</td>
<td>.92</td>
<td>7.4</td>
</tr>
</tbody>
</table>

...
infection. The prevention of nosocomial infection is a multifaceted issue and hand hygiene is only one part of the equation. Also, although clinically evident infections were diagnosed through standard clinical practice and surveillance, we did not use routine surveillance cultures to detect asymptomatic colonization with MRSA or VRE in the units during the study period. For every clinically evident infection due to MRSA or VRE, there may be numerous cases of asymptomatic colonization. Therefore, nosocomial transmission of these organisms could potentially have gone undetected in this study.

Several other findings in this study are noteworthy. First, the importance of education and behavioral modification is emphasized. In the ICU in which the alcohol-based hand gel was initially not provided, education resulted in a significant and sustained improvement in adherence to hand hygiene recommendations (38% to 52% of opportunities; \( P < .001 \)). This was most apparent among nursing staff, whose adherence rate rose from 47% to 62% (\( P = .027 \)), and was less apparent among physicians and allied health personnel (\( P = \text{NS} \)). The difference in rates of adherence is perhaps explained by the fact that the education program was directed at those personnel physically present in the ICU (nurses) and was thus less effective among those groups less frequently available for exposure to the educational message (physicians and allied healthcare personnel). Contrary to the results of many studies examining the relationship between education and hand hygiene, the increased rate of adherence to hand hygiene observed in nurses in unit A was persistent over the initial 1-year observation period, most likely as a result of frequent reinforcement achieved with ongoing surveillance and periodic culture sampling. However, the same phenomenon was not observed in unit B, where the rate of hand hygiene adherence fell precipitously after the hand gel was no longer available (from 68% to 32% of opportunities; \( P < .001 \)), despite ongoing surveillance and periodic culture sampling to reinforce the initial educational program. The same pattern found among unit B nurses was observed for all healthcare worker job categories (Figure 2), underscoring the need for additional research in behavioral psychology and improved understanding of how best to realize behavioral change.

In both units, the availability of the alcohol-based gel allowed for improved adherence to hand hygiene despite increased work load (Figure 3), confirming the observations of Pittet et al. and emphasizing the importance of making hand gel conveniently accessible and easy to use, as well as the importance of time constraints on adherence to hand hygiene. As the activity index increased, the rate of adherence decreased in both units, regardless of whether gel was available. However, the rate of decrease in the rate of adherence was less in each unit during the period when gel was available (\( P = .02 \)). The preservation of hand hygiene adherence despite increased work load is particularly important as healthcare facilities attempt to make the most efficient use of staff, and it has significant implications as institutions plan how to provide services during an event with mass casualties or an epidemic.

The alcohol-based gel contained 0.3% triclosan, which is a bisphenol compound with broad-spectrum antimicrobial activity. Resistance to triclosan is mediated by mutations in the fabI gene or through active efflux pumps. Both of these mechanisms of resistance have been observed in the common nosocomial pathogen \( P. aeruginosa \). There is concern that widespread use of a triclosan-containing hand hygiene preparation might select for resistant \( Pseudomonas \) strains. Therefore, we conducted surveillance to define the rate of nosocomial infection due to \( Pseudomonas \) species. It is reassuring to note that over 2 years of observation, no increase in the rate of infection due to \( Pseudomonas \) species was noted. Similarly, enterococci are intrinsically less susceptible to triclosan because they possess \( fabK \) genes, the products of which are 100-fold less susceptible to triclosan. No increase in the rate of infections due to enterococci (data not shown) was observed during the study period. However, due to concern about antimicrobial resistance, many experts recommend against the inclusion of longer-acting antiseptics, such as triclosan, in hand hygiene products and other consumer goods.

There was no clear association between the availability of alcohol-based hand gel and the rate of CDAD. In the unit in which the hand gel was initially not provided, the rate of CDAD declined from baseline during both intervention periods. In the other unit, the rate of CDAD increased from the baseline rate during the period when alcohol-based gel was available and declined when the gel was not available. However, the rate remained above the baseline rate throughout both intervention periods. A limitation of the study is that patients were followed up only 48 hours after transfer from the ICU, and longer-term healthcare-associated infections were not captured for analysis.

The cultures of samples from nurses’ hands yielded a number of interesting observations. The premise for performing the microbiologic sampling was to assess whether the use of an alcohol-based, triclosan-containing hand gel would influence the microbiologic flora of healthcare workers’ hands over the course of long-term use. In addition, fingernail length and the presence of rings were correlated with the microbiological flora of the hand. Use of the gel in the ICU was associated with a lower absolute number of microbes on the hands (\( P = .006 \)). An increase in microbial burden was observed when nails were greater than 2 mm in length (\( P = .008 \)). This 2-mm nail length threshold is considerably less than the current recommendation that nails be kept no longer than 0.25 inches (Centers for Disease Control and Prevention) or 0.5 cm (World Health Organization). The presence of rings was associated with recovery of a greater number of microorganism species from cultures (\( P = .002 \)) and with carriage of gram-negative bacilli (\( P = .049 \)).

In conclusion, this study demonstrated significant and sustained improvement in the rate of adherence to hand hygiene...
among broad groups of healthcare workers that was strongly associated with the availability of an alcohol-based hand hygiene preparation. A high rate of hand hygiene adherence was maintained when the hand gel was available, even at a higher activity index. Cultures of samples from the hands of nurses reinforced the finding that nail length and finger rings influence the microbial flora of the hands. Although an association was not observed between improvement in the rate of hand hygiene adherence and the nosocomial infection rate, this result may have been a result of the limited power of the study or a failure to achieve a high enough rate of hand hygiene adherence. Additional study is warranted to ascertain how to further increase hand hygiene adherence rates and how to better delineate the relationship between hand hygiene and nosocomial infection.

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Potential conflicts of interest. M.E.R. reports receiving a stipend from Gojo Industries to cover travel expenses associated with presentation of this study at the 14th Annual Scientific Meeting of the Society for Healthcare Epidemiology of America in 2004. Gojo Industries provided partial support of this study in the form of a study contract to the University of Nebraska Medical Center. Gojo Industries approved the study but did not have a role in study design, data acquisition, data analysis, or manuscript preparation.

Address reprint requests to Mark E. Rupp, MD, 984031 Nebraska Medical Center, Omaha, NE 68198-4031 (merupp@unmc.edu).

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