Background: Cross-transmission of microorganisms by the hands of health care workers is considered the main route of spread of nosocomial infections.

Objective: To study the process of bacterial contamination of health care workers' hands during routine patient care in a large teaching hospital.

Methods: Structured observations of 417 episodes of care were conducted by trained external observers (S.T. and V.S.). Each observation period started after a hand-cleansing procedure and ended when the health care worker proceeded to clean his or her hands or at the end of a coherent episode of care. At the end of each period of observation, an imprint of the 5 fingertips of the dominant hand was taken and bacterial colony counts were quantified. Regression methods were used to model the intensity of bacterial contamination as a function of method of hand cleansing, use of gloves during patient care, duration and type of care, and hospital ward.

Results: Bacterial contamination increased linearly with time on ungloved hands during patient care (average, 16 colony-forming units [CFUs] per minute; 95% confidence interval, 11-21 CFUs per minute). Patient care activities independently (P < .05 for all) associated with higher contamination levels were direct patient contact, respiratory care, handling of body fluid secretions, and rupture in the sequence of patient care. Contamination levels varied with hospital location; the medical rehabilitation ward had higher levels (49 CFUs; P = .03) than did other wards. Finally, simple hand washing before patient care, without hand antisepsis, was also associated with higher colony counts (52 CFUs; P = .03).

Conclusions: The duration and type of patient care affect hand contamination. Furthermore, because hand antisepsis was superior to hand washing, intervention trials should explore the role of systematic hand antisepsis as a cornerstone of infection control to reduce cross-transmission in hospitals.

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MATERIALS AND METHODS

HOSPITAL

The University of Geneva Hospitals, Geneva, Switzerland, provide primary and tertiary medical care for Geneva and the surrounding area (about 800 000 population). Approximately 40 000 patients are admitted annually. During the study, 1382 beds were available for adult or infant care; among them, 76 beds were available for critical care.

STUDY PROCEDURES

Two infection control observers (S.T. and V.S.) monitored patient care provided by HCWs in a predetermined sample of wards chosen to be representative of different patient populations. The observations were distributed equally (Monday to Friday) for 3 months (February to April 1996). Assessment of patient care was recorded on a specifically designed case report form. Reliability of data collection was evaluated in a pilot phase during 25 monitoring sessions when 2 observers worked simultaneously. Fifteen variables were systematically recorded: professional activity of the observed HCW; use of gloves; number, type, and duration of care (Table 1); method of hand cleansing; and hospital ward. Concordance among observers was excellent: observers identified 359 (95.7%) of 375 predetermined variables assessed, and intrarater reliability was high for all variables (mean κ, 0.90; range, 0.83-1.00).

STUDY VARIABLES

The main outcome variable was the number of bacterial colonies grown from the fingertips of the HCW’s dominant hand at the end of the observation period. The maximum colony count was fixed at 300 colony-forming units (CFUs); beyond this, colonies formed a confluent surface. Predictor variables included the method of hand cleansing (hand washing, hand antisepsis, or both), whether the HCW wore gloves during patient care, type of patient care performed, duration of care (rounded off to the nearest minute), and hospital ward in which the observation was conducted.

DEFINITIONS

Patient care activities were coded according to standard definitions3,9,10,14 and included direct patient contact, wound care, blood sampling, intravenous or arterial site catheter care, respiratory tract care (in particular, endotracheal tube or tracheostomy site care), handling of body fluid secretions, and rupture in the sequence of patient care (ie, the staff person left the patient to answer a telephone or prepare materials or a drug for patient care). Observation of HCWs involved in housekeeping activities was also included.

In this article, “hand washing” refers exclusively to the use of unmedicated soap and water or water alone,3 “hand antisepsis” refers to the application of an alcohol-based (70% vol/vol) preparation of chlorhexidine gluconate (0.5%), and “hand cleansing” refers to either action.3

DATA COLLECTION PROCEDURE

Structured observation sessions were performed at random during day shifts only on weekdays. Observed HCWs were mostly registered nurses (90%), but nursing assistants, physicians, and respiratory therapists were also observed occasionally. A single HCW could not be observed more than once during the same day. Health care workers were aware of being observed, but observation sessions were as unobtrusive as possible. The observation period started when the HCW cleaned his or her hands, and ended when (1) the HCW proceeded to clean the hands again or (2) a coherent episode of care was completed as determined by the observer. The observer noted the method of hand cleansing, use of gloves, and type and duration of care.

MICROBIOLOGIC PROCEDURES

At the end of each observation, the observer took an imprint of the 5 fingertips of the HCW’s dominant hand on commercial contact plates (COUNT-TACT; BioMérieux SA, Marcy l’Etoile, France). Fingertips were gently pressed for 5 seconds. Plates were then incubated at 35°C under aerobic conditions. An initial colony count was performed at 24 hours and a final count was performed after 48 hours of incubation. Bacteria were identified by standard microbiologic procedures. No anaerobic cultures were performed.

STATISTICAL ANALYSIS

Regression methods were used to model the bacterial contamination count as a function of predictor variables. With categorical predictors, we used analysis of variance models. For continuous variables, relationships were first explored using nonparametric regression methods (locally weighted regression and smoothing scatterplot, LOWESS). Linear regression models were used when appropriate. To identify independent predictors of bacterial contamination, we used an analysis of covariance model. Analyses were conducted using SPSS software (SPSS Inc, Chicago, Ill).

Eight hospital wards participated in the study. About half of the observations (213 of 417) were performed in intensive care services (medical, surgical, and neonatology); the other half (n = 204) was split among medical and surgical acute care and rehabilitation wards. The types of patient care activities that were recorded before hand culture represented a wide spectrum of patient care (Table 1). During each obser-
vation, 266 hospital staff members (63.8%) performed a single type of activity, 125 (30.0%) performed 2 types, 25 (6.0%) performed 3 types, and 1 (0.2%) performed 4 types.

**BACTERIAL CONTAMINATION LEVELS**

Total number of bacterial CFU grown from 5 fingertips ranged from 0 (n = 34, 8.2%) to 300 CFU (n = 77, 18.5%). The mean ± SD number of CFU was 100 ± 114 CFU (95% confidence interval [CI], 89-111 CFU), and quartiles were 6, 39 (median), and 200 CFU, respectively.

A total of 372 specimens were culture positive. The predominant flora was normal skin flora: coagulase-negative staphylococci, Corynebacterium species, and Micrococcus species. There were also isolates of Staphylococcus aureus (n = 39, 10.5%) and gram-negative bacilli (n = 54, 14.5%).

**DURATION OF CARE**

Duration of patient care was positively associated with amount of bacterial contamination in HCWs who did not wear gloves, whereas wearing gloves effectively protected against bacterial contamination of hands (Figure 1). In linear regression models of the number of colonies as a function of time, HCWs who did not wear gloves acquired on average 16 CFU per minute (95% CI, 11-21 CFU per minute), whereas the acquisition rate was only 3 CFU per minute (95% CI, −1 to 7 CFU per minute) for those who wore gloves (P < .001 for the difference between groups). Subsequent analyses were therefore restricted to the 287 observations of care performed without gloves.

**TYPE OF PATIENT CARE**

All care activities except housekeeping activities were positively associated with bacterial contamination (Table 2). Association was significant only for activities involving close contact with the patient or contact with the patient’s body fluid secretions. Average number of colonies acquired on ungloved fingertips ranged from 16 to 21 CFU per minute for direct patient contact, rupture in the sequence of patient care, endotracheal tube or tracheostomy care, and handling of patient’s body fluid secretions (Table 2).

**HOSPITAL WARD**

Increasing bacterial contamination over time was seen in 6 clinical wards, the exceptions being the medical and neonatal intensive care wards (Figure 2). The downward trend seen in latter units may be caused by sampling different HCWs at different times; those engaged in “clean” activities may have waited longer before washing up. However, in terms of absolute contamination lev-

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**Table 1. Patient Care Activities Performed by Hospital Staff Before Hand Cultures Were Taken in 417 Observations Conducted at the University Hospitals of Geneva, Geneva, Switzerland, in 1996**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Observations, No. (%</th>
<th>Duration, min Mean*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct patient contact</td>
<td>120 (28.8)</td>
<td>4.1</td>
<td>496</td>
</tr>
<tr>
<td>Skin contact</td>
<td>109 (26.1)</td>
<td>4.5</td>
<td>485</td>
</tr>
<tr>
<td>Rupture in the sequence of care</td>
<td>167 (40.0)</td>
<td>2.5</td>
<td>411</td>
</tr>
<tr>
<td>Blood sampling and intravenous injection or care</td>
<td>100 (24.0)</td>
<td>3.4</td>
<td>342</td>
</tr>
<tr>
<td>Tracheostomy care</td>
<td>24 (5.8)</td>
<td>6.3</td>
<td>152</td>
</tr>
<tr>
<td>Handling body fluid secretions</td>
<td>45 (10.8)</td>
<td>2.9</td>
<td>130</td>
</tr>
<tr>
<td>Endotracheal tube care</td>
<td>12 (2.9)</td>
<td>5.6</td>
<td>68</td>
</tr>
<tr>
<td>Housekeeping activities</td>
<td>18 (4.3)</td>
<td>3.0</td>
<td>54</td>
</tr>
</tbody>
</table>

* Only among observations that included the activity.

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**Figure 1. Relationship between duration of patient care and bacterial contamination of hands of hospital staff who wore gloves (solid circles and dashed line) and those who did not wear gloves (open circles and solid line) in 417 observations conducted at the University Hospitals of Geneva, Geneva, Switzerland, in 1996. Lines represent the average trend in each group, obtained using nonparametric regression (LOWESS).**

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**Table 2. Relationships Between the Time Spent in Various Patient Care Activities and Bacterial Contamination of the Hands of Gloveless Hospital Staff, From Multiple Linear Regression Models, in 287 Observations Conducted at the University Hospitals of Geneva, Geneva, Switzerland, in 1996**

<table>
<thead>
<tr>
<th>Time Spent In</th>
<th>Bacterial Colonies, CFU/min (95% Confidence Interval)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct patient contact</td>
<td>20 (14 to 26)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Rupture in the sequence of care</td>
<td>19 (10 to 27)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Respiratory care*</td>
<td>21 (8 to 35)</td>
<td>.002</td>
</tr>
<tr>
<td>Handling body fluid secretions</td>
<td>16 (3 to 29)</td>
<td>.02</td>
</tr>
<tr>
<td>Blood sampling and intravenous injection or care</td>
<td>6 (−2 to 14)</td>
<td>.14</td>
</tr>
<tr>
<td>Skin contact</td>
<td>4 (−5 to 13)</td>
<td>.35</td>
</tr>
<tr>
<td>Housekeeping activities</td>
<td>−10 (−32 to 12)</td>
<td>.38</td>
</tr>
</tbody>
</table>

*Includes tracheostomy care and care of an endotracheal tube.

†CFU indicates colony-forming unit.
els, some wards fared better than others: 5 minutes after hand cleansing, average bacterial colony count was approximately 250 CFU in the medical rehabilitation ward but only approximately 25 CFU in the septic orthopedic surgery ward.

HAND-CLEANSING METHOD

The method of hand cleansing before patient care affected the amount of bacterial contamination: HCWs who washed their hands with only unmedicated soap and water had higher bacterial counts than those who used hand antisepsis with or without previous hand washing (Figure 3). Linear regression models confirmed that the method of hand cleansing affected the level of bacterial contamination: compared with hand washing and hand antisepsis, absence of hand washing was associated with a nonsignificant increase of 10 CFU (95% CI, −18 to 37 CFU), whereas absence of hand antisepsis was associated with an increase of 68 CFU (95% CI, 16-119 CFU).

MULTIVARIATE MODEL

Initial method of hand cleansing, type of patient care, and hospital ward remained independent predictors of bacterial contamination (Table 3). Absence of hand antisepsis was associated with an excess of 52 CFU on the 5 fingertips. Four types of patient care were independently associated with bacterial contamination of 14 to 20 CFU per minute of activity (whereas other activities were associated with an acquisition of only 5 CFU per minute; Table 3). Observations made in the medical rehabilitation ward showed 49 more colonies than in most other wards, and observations made in the septic orthopedic surgery ward yielded an average of 88 CFU less.

COMMENT

This study identified several predictors of bacterial contamination of hands of hospital staff. Contamination progressively increased during routine patient care; on average, HCWs who did not wear gloves acquired 16 CFU per minute. Patient care activities associated with

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**Table 3. Multivariate Analysis of Covariance Model of Predictors of Bacterial Contamination of the Hands of Gloveless Hospital Staff in 287 Observations Conducted at the University Hospitals of Geneva, Geneva, Switzerland, in 1996**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Bacterial Colonies, CFU (95% Confidence Interval)*</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No hand antisepsis with an antiseptic agent</td>
<td>52 (7 to 98)</td>
<td>.03</td>
</tr>
<tr>
<td>Each minute spent in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct patient contact</td>
<td>20 (14 to 25)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Rupture in the sequence of care</td>
<td>15 (7 to 24)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Respiratory care</td>
<td>20 (7 to 32)</td>
<td>.003</td>
</tr>
<tr>
<td>Handling body fluid secretions</td>
<td>14 (1 to 26)</td>
<td>.03</td>
</tr>
<tr>
<td>Other care</td>
<td>5 (−2 to 11)</td>
<td>.14</td>
</tr>
<tr>
<td>Specific hospital wards</td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Medical rehabilitation</td>
<td>49 (4 to 95)</td>
<td>.03</td>
</tr>
<tr>
<td>Septic orthopedic surgery</td>
<td>−88 (−129 to −48)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*CFU indicates colony-forming units.

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**Figure 2. Relationship between duration of patient care and bacterial contamination of hands of gloveless hospital staff in 281 observations conducted at the University Hospitals of Geneva, Geneva, Switzerland, in 1996 by clinical ward: 1 indicates medical rehabilitation; 2, acute care internal medicine; 3, orthopedic rehabilitation; 4, surgical intensive care; 5, abdominal surgery; 6, septic orthopedic surgery; 7, medical intensive care; and 8, neonatal intensive care. Lines represent the average trend in each group, obtained using nonparametric regression (LOWESS).**

**Figure 3. Relationship between duration of patient care and bacterial contamination of hands of gloveless hospital staff in 287 observations conducted at the University Hospitals of Geneva, Geneva, Switzerland, in 1996 by initial hand-cleansing method: hand washing with unmedicated soap and water or water alone (dotted line), hand antisepsis with hand antiseptic agents (dashed line), or both performed sequentially (solid line). Lines represent the average trend in each group, obtained using nonparametric regression (LOWESS).**
higher rates of hand contamination were direct patient contact, respiratory tract care, handling of body fluid secretions, and rupture in the sequence of patient care. These activities were associated with increased hand colonization independent of other factors such as hospital location and whether HCWs used hand disinfectant before patient care. A practical recommendation resulting from this observation is that hand washing or hand antisepsis immediately after these activities should be mandatory. In this, our data support and extend guidelines (based on the Fulkerson scale that ranks contacts of nursing personnel from clean to dirty) that call for hand cleansing after dirty contacts or contacts with infected sites.3,10,15,16

Bacterial contamination of HCWs' hands was highest on rehabilitation wards but lowest on septic orthopedic surgery wards. To our knowledge, our study is the first to relate hand contamination and hospital ward location. Consistent with these findings, reports17,18 of nosocomial infections resulting from cross-transmission showed high infection rates and poor compliance with hand-cleansing practices in rehabilitation wards and long-term care facilities.

Whether use of hand antiseptic agents significantly reduces the rate of transient flora that is newly acquired during routine patient care is still a matter of debate.3 In the present study, hand cleansing with unmedicated soap and water before patient care was associated with significantly higher bacterial counts than was previous hand antisepsis with an antiseptic agent. By multivariate analysis, excess colonization reached 52 CFU in the absence of hand antisepsis before patient care independent of the type of nursing activity. Our findings are consistent with other evidence. Alcoholic hand rubs are the most effective measure to quickly release transient flora from hands.3,19 Consequently, alcohol-treated hands may be less likely to transfer bacteria than washed hands. In an experimental study,20 hand washing did not prevent the transfer of aerobic gram-negative bacilli by HCWs' hands from heavily colonized patient groins to urinary catheters in 12 of 12 experiments; in contrast, after hand treatment with 70% vol/vol isopropyl alcohol, bacteria were transferred in only 2 of 12 experiments. Use of unmedicated soap may not prevent transfer of gram-negative bacilli to medical devices from a heavily contaminated source.3,20 Our data extend these findings by providing quantitative assessment of contamination of the germ carrier, ie, HCWs' hands.

As expected, wearing gloves during patient care was associated with a marked reduction of bacterial contamination of HCWs' hands. These findings, however, do not support the routine use of gloves to stop cross-contamination. On rare occasions (data not shown), cultures of gloved hands were performed before glove removal and demonstrated significant bacterial colonization. Furthermore, wearing gloves can induce a false sense of security, and HCWs might forget to change gloves when appropriate and to wash hands after glove removal.17 It is not appropriate to wash and reuse gloves between patient contacts, and hand washing or hand antisepsis is strongly encouraged after glove removal.21 Health care workers were observed to wash their hands 23% to 27% of the time before putting on gloves17,22 and to change gloves 16% of the time after patient interactions17; Maki et al23 reported a cluster of infections in a critical care unit related to the use of gloves and lack of compliance with glove exchange. Finally—and as recently reemphasized in US national guidelines—gloves should be used as an adjunct to, not a substitute for, hand washing.

Our study has several limitations. First, observation bias might have accounted for earlier hand cleansing than during routine patient care in the absence of an external observer. However, because maximal bacterial colony counts were truncated at 300 CFU due to confluence, longer observation periods would have resulted in a higher proportion of maximal colony counts at later times; it is unlikely that such a bias would have changed the observed trends of bacterial colonization. Second, our findings may not be generalizable to the nondominant hand; however, the dominant hand is the most likely source of horizontal transmission. Third, identification of transient vs resident flora would require molecular typing of all bacterial strains recovered from the hands of HCWs and related patient and device contacts; such a study would require considerable resources. Finally, the threshold of bacterial hand contamination associated with an increased risk for subsequent infection remains unknown. However, cross-transmission of resistant microorganisms may first increase the reservoir of colonized patients before being associated with significant patient morbidity and mortality. The impact of cross-transmission on hospital ecological concerns extends far beyond infection rates. Thus, infection does not always constitute the best outcome measure for research in infection control. Prevention of cross-transmission should focus on timely hand cleansing during patient care; whether systematic hand antisepsis using a hand antiseptic agent should be recommended requires testing in controlled clinical trials.

In conclusion, bacterial contamination of the hands of hospital staff is a dynamic process that results from multiple factors. Whether our study included all relevant determinants is debatable. However, among modifiable causes of hand contamination that we identified, systematic hand antisepsis seems to be the most promising avenue for possible intervention and should be tested in clinical trials.

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