Transfer of Vancomycin-Resistant Enterococci via Health Care Worker Hands

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Background: The roles of the contaminated hospital environment and of patient skin carriage in the spread of vancomycin-resistant enterococci (VRE) are uncertain. Transfer of VRE via health care worker (HCW) hands is assumed but unproved. We sought to determine the frequency of VRE transmission from sites in the environment or on patients’ intact skin to clean environmental or skin sites via contaminated hands of HCWs during routine care.

Methods: We cultured sites on the intact skin of 22 patients colonized by VRE, as well as sites in the patients’ rooms, before and after routine care by 98 HCWs. Observers recorded sites touched by HCWs. Cultures were obtained from HCW hands and/or gloves before and after care. All isolates underwent pulsed-field gel electrophoresis. We defined a transfer to have occurred when a culture-negative site became positive with a VRE pulsortype after being touched by an HCW who had the same pulsortype on his or her hands or gloves and who had previously touched a colonized or contaminated site.

Results: Health care workers touched 151 negative sites after touching a site that was positive for VRE. Sixteen negative sites (10.6%) became positive after contact. The percentage of times that contact with a site led to a transfer was highest for antecubital fossae and blood pressure cuffs.

Conclusions: Vancomycin-resistant enterococci were transferred from contaminated sites in the environment or on patients’ intact skin to clean sites via HCW hands or gloves in 10.6% of opportunities. Controlling VRE by decontaminating the environment and patients’ intact skin may be an important adjunctive infection control measure.

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Health care workers (HCWs) may unintentionally act as vectors in the nosocomial spread of vancomycin-resistant enterococci (VRE). Seemingly innocuous acts, such as touching a VRE-colonized patient’s intact skin or resting a hand on a bed rail in the patient’s room, may result in HCW hand contamination.1,2 If the HCW does not then exercise hand hygiene, VRE may be transferred to another patient or environmental surface, perpetuating the chain of transmission. Transfer of VRE in this way is assumed but not proved; this assumption has been supported by studies that showed VRE to persist on hands and environmental surfaces after deliberate inoculation3 and by others that found the same pulsortype of VRE on inanimate objects in patients’ rooms and on the hands of HCWs after contact with those objects.1,4 To investigate these issues further, we designed a study to quantify the rate of transfer of VRE from contaminated environmental sites or from colonized sites on patients’ intact skin to clean sites via the contaminated gloved or ungloved hands of HCWs during the routine care of patients who were colonized with VRE.

METHODS

Setting

The study took place in the 21-bed medical intensive care unit of Rush University Medical Center, an 800-bed hospital in Chicago, Ill, over an 8-month period (2000-2001). Consent for hand and glove culturing was obtained from HCWs entering study patient rooms. The study was reviewed and approved by the Rush Investigational Review Board. Patient consent was waived.

Study Design

Rayon swabs (Copan Diagnostics, Corona, Calif) were used to obtain rectal cultures from all patients within 48 hours of admission to the medical intensive care unit and twice weekly thereafter. All patients who had gastrointestinal tract colonization with VRE were studied. Each culture event began at approximately 6 hours.
AM; we chose this early hour because only 1 to 2 HCWs at a time were likely to enter the patient's room. Monitoring of HCW contacts continued until 6 consecutive HCWs had been observed. Housekeepers did not enter patient rooms until the culture event ended. Medical intensive care unit staff members were notified of rectal culture results, and all patients who were found to be colonized with VRE were placed on contact precautions.

Quantitative cultures of sites on patients' intact skin and of environmental surfaces in rooms of VRE-positive patients were obtained using dual rayon swabs moistened with liquid Stuart medium (Copan Diagnostics) supplemented with 0.05% polysorbate (Tween) 80. The swab was rubbed over 50 cm² of the surfaces of up to 12 predetermined body sites and 34 predetermined environmental sites, if present, within each patient's room. Sites were cultured before any participating HCWs entered the room and again after all participating HCWs exited. Patient body sites that were not touched were not cultured as few as 1 log₁₀ colony-forming unit of VRE.

HCW hands or gloves was not quantified.

Microbiologic analysis

Rectal swab cultures (Copan Diagnostics) were plated directly onto bile esculin azide (Enterococcus; BBL Microbiology Systems, Cockeysville, Md) agar containing 6 µg/mL of vancomycin hydrochloride. For other patient body sites and for all environmental sites, 1 of the 2 swabs collected was placed directly into bile esculin azide broth containing 6 µg/mL of vancomycin; the other swab was streaked for isolation onto bile esculin azide agar containing 6 µg/mL of vancomycin to quantify growth. Hand and glove culture specimens were filtered through a 0.45-µm sterile filter. Filters were plated onto bile esculin azide agar containing 6 µg/mL of vancomycin. Before the study began, we evaluated the sensitivity of the culture methods and found that rectal swab culture detected 3 log₁₀ or more colony-forming units of VRE per gram of stool, and environmental swab cultures protected as few as 1 log₁₀ colony-forming unit of VRE.

All cultures were incubated for 48 hours at 35°C in ambient air. Growth of VRE in cultures from environmental and patient body sites was quantified as growth in broth only, as countable colonies, or as growth on the first, second, third, or fourth quadrant of the agar surface. Growth from rectal swabs and from HCW hands or gloves was not quantified.

VRE confirmation and strain differentiation

To differentiate VRE pulstotypes for analysis of transmission, each unique colony morphotype of VRE growing on bile esculin azide agar containing 6 µg/mL of vancomycin was subjected to chromosomal DNA extraction, Smal digestion, and pulsed-field gel electrophoresis (CHEF Mapper; Bio-Rad, Hercules, Calif). Pulsotypes were deemed distinct if their patterns differed by more than 6 bands. Each unique VRE pulstotype underwent genus and species confirmation with commercially available streptococcal identification kits (API 20 Strep kits; bioMerieux, Hazelwood, Mo), motility testing, and observation of pigment production on blood agar. Vancomycin resistance was confirmed by microtiter dilution. The vancomycin resistance genotype was determined using polymerase chain reaction assays for vanA, vanB, vanC1, and vanC2. Only Enterococcus faecium and Enterococcus faecalis strains harboring the vanA or vanB gene were included in the epidemiologic analysis.

Epidemiologic analysis

We analyzed the sequence of sites touched by HCWs whose hands were VRE negative on room entry. Sites that were VRE negative on initial culture and that were then touched by a HCW who had previously touched a positive site were evaluated. If these sites were found to be positive for VRE when cultured a second time, ie, after exit of all participating HCWs, transfer of VRE was said to have occurred (Figure 1).

To determine the most common pattern of transfer (environmental site to body site, environmental site to environmental site, body site to environmental site, or body site to body site), origin and destination sites were determined for each transfer. If more than 2 VRE-positive sites were touched before the negative site, the origin site was determined as body or environment based on which category of site was in the majority. If an equal number of body and environmental sites were possible origin sites, the density of VRE growth was evaluated, and the origin site was said to be the one with more abundant growth of VRE. If the amount of growth in all possible sites was equivalent, the designation of origin site was alternated.

In a previous study, we determined that the quantity of VRE present at many environmental sites was near the limit of detection of the swab culture method. Therefore, we calculated the "background" rate of apparent transmission, ie, the number of initially negative environmental sites that were culture positive at the end of the culture event, without HCW contact, as well as the number of initially positive environmental and skin sites that were negative for VRE when cultured again, with or without HCW contact.

Definitions

Culture event: The period of time during which environmental and patient body sites were cultured and during which HCW contacts were observed in a VRE-positive patient's room and HCW gloves and/or hands were cultured. Cultures of environmental and patient body sites were obtained before the first participating HCW entered the room and after the last observed HCW left.

Potential site of origin: A VRE-positive site that was touched by an HCW who subsequently touched a VRE-negative site(s).

Destination site: A VRE-negative site that, after having been touched by an HCW with VRE-contaminated hands or gloves,
became culture positive for the same pulsotype of VRE present on the HCW's hands or gloves.

Opportunity for transfer: When a VRE-negative site was touched by an HCW who had previously touched a VRE-positive site.

VRE transfer: A culture-negative site becoming positive with a VRE pulsotype after having been touched by an HCW who had the same pulsotype of VRE on his or her hands or gloves and who had previously touched a site contaminated or colonized by that pulsotype (Figure 1).

Relative efficiency of VRE transfer: The percentage of times that contact with a specific potential site of origin led to VRE transfer. Each time a particular site was a potential site of origin it was included in the calculation, even if it was touched multiple times during the same series of contacts, leading to a transfer.

RESULTS

Twenty-two VRE-positive patients and their rooms were studied during 27 culture events. For each culture event, an average of 75%±24% (mean±SD) body sites and 17%±12% environmental sites were VRE positive. By quantitative culture, patient body sites were more heavily contaminated than environmental sites; 65% of positive sites yielded growth of VRE on the plate medium as well as in broth, while 62% of positive environmental sites produced growth in broth only. The HCs contacted a total of 243 patient body sites and 673 environmental sites. One hundred thirty-one sets of gloved or ungloved hand cultures were obtained from 98 unique HCs. Health care workers donned gloves on entering a study patient's room in 102 culture events (78%). Fifteen pulsotypes of VRE were identified: 12 were E faecium and 3 were E faecalis. Six E faecium pulsotypes were transferred (Table).

Sixteen transfers (10.6%) occurred in 151 opportunities (Table). Thirteen transfers occurred in rooms of unconscious patients who were unable to spontaneously touch their immediate environment. Among the 16 transfers, 12 were from patient body sites. Nine transfers had either all body or all environmental sites as potential sites of origin; 8 of these had only 1 possible site of origin. Two transfers involved different destination sites but shared the same 2 potential sites of origin: one a body site and the other an environmental site. Because both sites had an equal amount of VRE growth, each was designated as the origin site 1 time. Five transfers had 3 or more potential sites of origin: 3 with a majority of body sites (all with environmental cultures yielding growth only in broth) and 2 with a majority of environmental sites as potential sites of origin (all with growth only in broth from environmental and patient body sites). There was no difference in the proportion of transfers made by any category of HCW. All transfers occurred via gloved hands.

The antecubital region and the blood pressure cuff were highly “efficient” sites of origin (Figure 2); each of the 4 and 2 contacts with these sites, respectively, resulted in a transfer. Two of the 4 sites with the highest relative efficiency of transfer were environmental. Lower transfer rates were observed from the following origin sites: ankles, soap dispenser, bed, and bed table.

We evaluated the number of negative sites that became positive without observed HCW contact. Twenty-three (2.9%) of 800 environmental sites that were culture negative before HCW room entry were culture positive at the end of the culture event, without observed HCW contact. Six of these 23 conversions involved items that were close to, or touching, the patient: bedding, bed rail, sequential compression device, and blood pressure cuff. Seventeen were outside the patient’s area of direct contact: hygiene products, monitor dial, countertop, and fecal incontinence collection graduated cylinder. Three HCs who did not consent to hand cultures entered rooms in which culture-negative sites became positive, and 7 culture-negative sites of the 23 that became culture positive without documented contact could potentially be explained by unobserved contacts by these HCs. One hundred one (54.6%) of 185 sites that were initially culture positive for VRE were negative when cultured again after all participating HCs had left the patients’ rooms, suggesting that the culture method itself had removed viable organisms.

The density of contamination, as determined by quantitative cultures, was comparable for all destination sites, for negative sites that became culture positive without contact, and for positive sites that became culture negative; 69%, 61%, and 57% of these sites, respectively, were positive in broth only, without growth on agar plate medium, indicating low numbers of VRE recovered. Low density did not prevent transfer: 69% of origin site cultures had growth in broth only.

COMMENT

Our results confirm that HCs can contaminate their hands with VRE from inanimate objects or from intact patient skin surfaces and move these organisms to other surfaces within patients' rooms and potentially to new patients. Transfer of VRE from a contaminated patient body or environmental site to another site within a patient room via HCW hands occurred in 10.6% of opportunities. These data provide, to our knowledge, the first quantification of VRE transfer rates. The number of transfers of VRE that occurred in a short period during early morning patient care suggests that over the course of a day there will be many such transfers and helps to explain how VRE quickly has become a prominent nosocomial and intensive care unit pathogen.

We believe that this calculation is a reasonable estimate of the true occurrence and mechanism of transfer. The low number of culture-negative sites that became positive (23 [2.9%] of 800) without documented HCW contact suggests that the documented transfers are valid. The strict definition used for transfer—requiring that the transferred VRE pulsotype was recovered from the HCW's gloves or ungloved hands and that it was not present on hands or gloves before the HCW's contact with a contaminated body or environmental site—provides strong molecular epidemiologic support for the mechanism of transfer. Importantly, we note that transfer from environmental surfaces occurred with a relative efficiency comparable to that from body surfaces, despite the overall lower density of environmental contamination. This finding extends earlier11 and other12 observations of the po-
tential role of environmental reservoirs and, at least for VRE, expands the current concept of nosocomial bacterial cross-acquisition, which has placed less emphasis on environmental surfaces as a potential reservoir of hospital-acquired pathogens.13

In 8 of 16 transfers, only 1 site was implicated as the site of origin. Multiple VRE-positive sites were touched before the destination site in the other 8 transfers. Because there was no certain way to know which origin site was responsible for the latter transfers, we calculated the relative efficiency of VRE transfer using all potential sites of origin. Two of the 4 sites with the greatest efficiency of transfer were environmental sites, but patient body sites were more frequently origins of transfer, which probably reflects the fact that they were more often contaminated. Interestingly, 2 highly efficient origins of transfer

<table>
<thead>
<tr>
<th>No. of Culture Events</th>
<th>Health Care Worker No.</th>
<th>Origin Site*</th>
<th>Destination Site</th>
<th>VRE Pulsotype†</th>
<th>Vancomycin Resistance Type‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>Inguinal region</td>
<td>Bed rail</td>
<td>16</td>
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</tr>
<tr>
<td>3</td>
<td>2</td>
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<td>Blood pressure cuff</td>
<td>5</td>
<td>B</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Chest</td>
<td>Bed rail</td>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Chest</td>
<td>Bed rail</td>
<td>Transducer</td>
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<tr>
<td>6</td>
<td>4</td>
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<td>Chest</td>
<td>Ankle</td>
<td>10</td>
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<tr>
<td>7</td>
<td>5</td>
<td>Inguinal region</td>
<td>Suction equipment</td>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>Inguinal region</td>
<td>Bed table</td>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>Chest</td>
<td>Antecubital region</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>Chest</td>
<td>Bed rail</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>Wrist</td>
<td>Inguinal region</td>
<td>19</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>Inguinal region</td>
<td>Drawer handle</td>
<td>19</td>
<td>A</td>
</tr>
<tr>
<td>16</td>
<td>9</td>
<td>Antecubital region</td>
<td>Back</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>16</td>
<td>9</td>
<td>Antecubital region</td>
<td>Bed table</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>19</td>
<td>10</td>
<td>Antecubital region</td>
<td>Back</td>
<td>21</td>
<td>B</td>
</tr>
<tr>
<td>19</td>
<td>10</td>
<td>Antecubital region</td>
<td>Bed rail</td>
<td>Ankle</td>
<td>21</td>
</tr>
<tr>
<td>25</td>
<td>11</td>
<td>Soap dispenser</td>
<td>Wrist</td>
<td>4</td>
<td>A</td>
</tr>
</tbody>
</table>

*Sites are listed in order of contact and according to the number of times that they were contacted.
†No Enterococcus faecalis strain was involved in a transfer.
‡Letter designates vanA or vanB resistance genotype.
were the antecubital fossae and the blood pressure cuff, which are commonly considered “clean” areas that are remote from the rectal reservoir of VRE. This finding provides a rationale for the cleaning of blood pressure cuffs and for the implementation of hand hygiene measures between contacts in a hospital patient’s room as a method to reduce VRE cross-contamination.

Origin site culture density did not correlate with efficiency of transfer; eg, antecubital fossae were less heavily colonized than inguinal regions but had a higher relative efficiency of transfer. Number or duration of contacts with the site may have more impact on the likelihood of transfer than does density of contamination. Pittet et al described a linear increase in bacterial contamination of ungloved hands that was associated with longer periods of patient care.

Our study contains several methodological limitations that may have affected our estimates of VRE transfer frequency. The rectal swab culture method that we used was able to detect a concentration of VRE equivalent to $3 \log_{10}$ colony-forming units of VRE per gram of stool, which is similar to stool concentrations of VRE reported by others for hospital patients. We do not know whether our findings apply to patients who are colonized with lower numbers of VRE and who may therefore be less likely to contaminate their skin or their environment. The number of VRE present at a site was often near the limit of detection of the enrichment broth culture method used. However, the epidemiologic or clinical significance of VRE present in numbers so low that they are not detected by culture is not known. Initially positive sites that became negative may reflect the limitations of the sensitivity of our assay or the removal of the VRE by the first culture swab and may have resulted in underestimation of transfer frequency. The designation of origin site was based on an arbitrary definition. Nevertheless, in 8 of 16 transfers only 1 possible site of origin was identified. Although more than 80% of transfers occurred in rooms of immobile patients, some transfers attributed to contaminated HCW hands may have resulted from passive movement of a contaminated patient body part to a clean site, eg, during bathing. Finally, we infer that, based on transfers within a patient’s room, transfers between patients or patients’ rooms would occur in the same manner. Although we believe that this inference is reasonable, we did not specifically study such cross-transmission. In fact, the data to conclusively support the occurrence of such transfers—culture of HCW gloves or hands between room entries—might actually abort the event by removing VRE during the hand culturing.

In conclusion, to our knowledge, our study provides the first quantitative estimate of the frequency of VRE transfer via HCW hands. These findings highlight the importance of the role that the environment, even when not visibly contaminated, and intact patient skin surfaces play in the spread of VRE and potentially of other hospital pathogens. Our estimate of transfer rates may be of potential use in future studies for modeling of transfer of VRE and for outcome analysis of infection control interventions. The infection control implications extend beyond the importance of HCW hand hygiene and of changing examination gloves between patients to the potential value of environmental cleaning and of decontamination of patient skin. The Centers for Disease Control and Prevention has recommended frequent cleaning of “high touch surfaces,” and our findings suggest the potential of routine, supervised cleaning to eliminate environmental reservoirs and thereby interrupt ongoing VRE transmission. The role of patient skin as a source of VRE suggests that skin surface decontamination, as with an antiseptic bath, has the potential to decrease risk of spread. In our experience, improving environmental cleaning and degumming patient skin with a daily medicated bath may be easier than improving HCW hand hygiene rates, which has been an elusive goal for most hospitals.

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REFERENCES


Table 3 is reprinted here with the correct data.

Table 3. Risk Factors for Atrial Fibrillation Among 40628 Patients With Hyperthyroidism in Denmark (January 1, 1980–December 31, 1999)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Adjusted OR (95% CI)*</th>
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<tbody>
<tr>
<td>Men (reference: women)</td>
<td>1.7 (1.6-1.9)</td>
</tr>
<tr>
<td>Age at diagnosis of hyperthyroidism</td>
<td>1.7 (1.7-1.8)</td>
</tr>
<tr>
<td>(risk per 10-y increment)</td>
<td></td>
</tr>
<tr>
<td>Medical condition before or at diagnosis of hyperthyroidism†</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.9 (0.8-1.0)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.9 (0.8-1.1)</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>1.3 (1.2-1.4)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>2.6 (2.6-3.1)</td>
</tr>
<tr>
<td>Aortic and/or mitral valve disease</td>
<td>1.9 (1.5-2.4)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; OR, odds ratio.
*Risk estimates are adjusted for the other characteristics in the table.
†Relative risk to no disease.