Evaluation of Stethoscopes as Vectors of Clostridium difficile and Methicillin-Resistant Staphylococcus aureus

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Completeness of Surveillance Data Reported by the National Healthcare Safety Network: An Analysis of Healthcare-Associated Infections Ascertained in a Tertiary Care Hospital, 2010

The Centers for Disease Control and Prevention (CDC) has estimated that there are 1.7 million healthcare-associated infections (HAIs) annually in the United States, which result in 99,000 deaths and $4.5 billion in excess healthcare costs.\(^1\) A key intervention to control HAI is ongoing surveillance with feedback to healthcare providers.\(^2\) Surveillance provides data that allow the determination of endemic infection rates, early detection of epidemics, and assessment of the efficacy of interventions.

Currently, the premier surveillance system for HAI in the United States is the National Healthcare Safety Network (NHSN), which is managed by the CDC.\(^3\) The NHSN was established in 2005 to integrate and supersede 3 legacy surveillance systems at the CDC: the National Nosocomial Infections Surveillance System (NNIS), the Dialysis Infections Surveillance Network, and the National Surveillance System for Healthcare Workers.\(^4\) NHSN reports have provided data on device-associated HAI (ie, central line–associated bloodstream infections, ventilator-associated pneumonia, and catheter–associated urinary tract infections) and selected surgical site infections. Unlike the NNIS, the NHSN has provided device-associated infection rates for patients housed both in intensive care units (ICUs) and in non-ICU wards. Our study was undertaken at an 800-bed tertiary care facility to determine the completeness of NHSN data; specifically, to determine what fraction of all HAIs would have been included in a data report issued by the NHSN.

This study was conducted at the University of North Carolina Hospitals using our surveillance data for the year 2010. Infection control surveillance was conducted by 5 infection preventionists in consultation with 2 full-time faculty members. Comprehensive hospital-wide surveillance that included all CDC-defined sites was performed in accordance with CDC criteria.\(^5\) Sources for identification of healthcare-associated infections included laboratory reports of positive culture results, results of serological testing or molecular-based diagnostic tests, morbidity and mortality conferences, autopsies, and administrative charge code data to assist in identifying surgical site infections. All surveillance data are entered into an electronic database.

We subdivided our 2010 nosocomial infection data into 2 categories: HAIs that had been included in an NHSN report, and HAIs that had not been included in an NHSN report (Table 1). Overall, approximately 50% of our ascertained HAIs could have been included in a published NHSN report. For example, NHSN reports focus on device-associated infections.\(^6\) Our data revealed that pneumonias that were not associated with receipt of mechanical ventilation (ie, all hospital-acquired pneumonias), bloodstream infections that were not associated with a central line, and urinary tract infections that were not associated with a urinary catheter accounted for 29.5%, 22.3%, and 37.7% of these body site infections, respectively. In a broader sense, ventilator-associated pneumonias accounted only for 18.6% of respiratory tract infections. NHSN reports include data on surgical site infections only for selected surgical procedures.\(^7\) For example, NHSN reports do not include the following surgical procedures: plastic surgery, ear, nose and throat surgery; and burn surgery. Our data revealed that 25.4% of our surgical site infections were not captured by NHSN-reported procedures. Infections classified as “other,” which is a heterogeneous group of infections (eg, endocarditis, osteomyelitis, conjunctivitis, and epidural/subdural abscess), accounted for 16.5% of all infections that were not reported to the NHSN. Our database also included the number of bloodstream infections secondary to infections at other body sites. In 2010, 125 secondary bloodstream infections were reported, including 18 that were secondary to urinary tract infections (data not shown).

NHSN is the premier surveillance system in the United States for healthcare-associated infections. Certain infections (ie, central line–associated bloodstream infections) must be reported to the NHSN by hospitals that receive funding from the Center for Medicare and Medicaid Services.\(^8\) Twenty-three states now require hospitals to report selected HAIs to the NHSN.\(^9\) The NHSN reports provide data that allow hospitals to benchmark their HAI rates against collated data from a large number of US hospitals.\(^1\) This is a crucially important use of NHSN data, because it allows hospitals to focus their prevention efforts on those HAIs for which their hospital has high rates, compared with rates at other facilities.

The ultimate goal of infection control is to reduce all HAIs, ideally to zero. Surveillance is an important component of infection control. Infection control surveillance includes ascertainment of nosocomial infections with use of standard definitions, aggregation of the data, analysis of the data, and feedback of the data to key decision leaders. The NHSN performs a crucial function by allowing hospitals to benchmark their data. The strengths of the NHSN include the following: a large number of hospitals are currently reporting data, standard HAI definitions are used, data are reported for specific hospital units (eg, coronary care unit and medical ward), and surgical site infection rates are risk adjusted. However, it is important to realize that NHSN reports do not include all HAIs that may be ascertained in a healthcare facility. It is noteworthy that, although we included twice as many HAIs
**Table 1.** Percentage of Healthcare-Associated Infections (HAIs) Included in Surveillance by the National Healthcare Safety Network (NHSN), University of North Carolina (UNC) Hospitals, 2010

<table>
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<th>HAI</th>
<th>Included in NHSN surveillance (n = 633)</th>
<th>Not included in NHSN surveillance (n = 631)</th>
<th>Total (n = 1,264)</th>
<th>HAIs included in NHSN surveillance reports, %</th>
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**Note.** Data do not include bloodstream infections secondary to urinary tract infections (urosepsis).

as would have been included in NHSN reports, our data still did not include all possible HAIs. For example, our hospital does not perform active surveillance for surgical site infections that occur after discharge from the hospital. Such surveillance has been demonstrated to increase detection of surgical site infections.9

Our data suggest that approximately 50% of HAIs that occur in a tertiary care hospital are not included in published NHSN reports. Surveillance for nosocomial infections that are not included in NHSN reports still allows hospitals to detect epidemics and assess the impact of interventions on reducing HAI incidence, even in the absence of the ability to benchmark the data.

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**References**


Evaluation of Stethoscopes as Vectors of *Clostridium difficile* and Methicillin-Resistant *Staphylococcus aureus*

Healthcare workers’ stethoscopes are potential vectors for transmission of pathogens because they frequently come in contact with the skin of patients and are not routinely cleaned between examinations. Point-prevalence culture surveys have demonstrated that stethoscope diaphragms may be contaminated with pathogens such as *Clostridium difficile* and methicillin-resistant *Staphylococcus aureus* (MRSA). However, previous publications have not directly quantified the risk for transmission of *C. difficile* and MRSA by stethoscopes. Here, we examined the risk for transmission of these pathogens by stethoscopes in the laboratory and during simulated examinations of patients and evaluated methods to disinfect contaminated stethoscopes.

The study protocol was approved by the Cleveland Veterans Affairs Medical Center’s Institutional Review Board. The efficiency of direct and indirect transfer of nontoxicogenic *C. difficile* spores (American Type Culture Collection 43593) and MRSA (a clinical isolate of pulsed-field gel electrophoresis type USA300) by stethoscope diaphragms was tested in the laboratory. Ten-microliter aliquots containing 1–4 log_{10} colony-forming units (CFUs) of spores or 1–3 log_{10} CFUs of MRSA were inoculated directly onto disinfected diaphragms (McCoy) or onto skin surfaces and allowed to dry for 10 minutes. For *C. difficile*, the skin site was the forearm of a human volunteer. For MRSA, a processed pig skin surface was used. To assess direct transfer, the contaminated diaphragms were imprinted for 10 seconds directly onto pre-reduced *C. difficile* brucella agar for isolation of *C. difficile* and onto CHROMagar (Becton Dickinson) containing 10 μg/mL cefoxitin for MRSA. To assess indirect transfer, disinfected stethoscope diaphragms were pressed onto contaminated skin sites for 10 seconds and imprinted onto selective agar. *Clostridium difficile* brucella agar plates were incubated anaerobically, and MRSA plates were incubated in room air at 37°C for 48 hours. All experiments were repeated 3 times, with the inclusion of uninoculated control stethoscopes in each experiment.

To assess methods of stethoscope disinfection, 10-μL aliquots of the pathogens were inoculated onto the diaphragm and allowed to dry. The diaphragm was wiped for 10 seconds with a 1 × 2-inch 70% isopropyl alcohol pad (Medline), a 2 × 2-inch gauze pad (Tyco Healthcare) moistened with sterile water, or the same gauze pad moistened with 70% ethanol. The diaphragm was imprinted onto selective agar and cultured as described previously.

We assessed the transfer of pathogens by stethoscopes from the skin of patients with *C. difficile* infection or MRSA colonization during a standardized simulated examination of the heart, lungs, and abdomen (12 skin sites total and 5-second contact time for each site). After auscultation, the diaphragm was imprinted onto selective agar and cultured as described previously. For comparison, the same skin sites were palpated with sterile gloves premoistened with sterile water, and the fingers were imprinted onto selective agar. Identification and susceptibility testing for MRSA was performed on the basis of Clinical and Laboratory Standards Institute guidelines. Suspected *C. difficile* isolates were confirmed as previously described. Paired *t* tests were used to compare colony counts transferred by stethoscopes versus hands. A Fisher exact test was used for categorical data.

Figure 1 shows the findings for direct and indirect transfer of the pathogens by stethoscopes. Stethoscopes directly transferred nearly 100% of *C. difficile* spores inoculated onto the diaphragm to agar plates, whereas the number of MRSA colonies transferred directly to the agar plate was ~2 log_{10} CFUs fewer than the original inoculum, presumably due to loss of viability with desiccation. For indirect transfer from skin, stethoscopes acquired and transferred on average 1–1.5 log_{10} CFU fewer spores or MRSA than were transferred directly.

Gauze moistened with sterile water or alcohol was more effective than alcohol wipes in removing *C. difficile* spores from stethoscope diaphragms (98%–99% vs 92%–94% removal; *P* < .05). Alcohol wipes and ethanol-moistened gauze were more effective than water-moistened gauze for removal of MRSA (100% vs 94% removal).

Simulated examinations were conducted on 35 *C. difficile* infection patients and 57 MRSA carriers. In comparison to hand imprints, stethoscope imprints resulted in nonsignificant trends toward less frequent acquisition and transfer of *C. difficile* (5/35 [14%] vs 11/35 [31%]; *P* = .15) and MRSA (11/57 [19%] vs 15/57 [26%]; *P* = .5). The numbers of *C. difficile* colonies acquired and transferred by stethoscopes and gloved hands were similar (mean ± SD, 1.2 ± 2.0 and 7.3 ± 14.6; *P* = .20), but stethoscopes acquired and transferred fewer colonies of MRSA (mean ± SD, 5.9 ± 8.6 and 14.3 ± 11.4; *P* = .01).

Our findings suggest that stethoscopes may be an under-appreciated vector for transmission of pathogens. During
simulated examinations, stethoscopes acquired and transferred \textit{C. difficile} and MRSA nearly as often as gloved hands. These findings provide support for the recommendation that healthcare workers should use dedicated ward stethoscopes when caring for patients carrying multidrug-resistant organisms or \textit{C. difficile}.\textsuperscript{8-9} Alternatively, healthcare workers may clean their stethoscopes after examination of these patients. Our data suggest that direct contact with friction is sufficient to remove more than 90\% of \textit{C. difficile} spores from stethoscope diaphragms. Pads or gauze containing alcohol removed 100\% of MRSA.

Our study has some limitations. We studied 1 strain of
each pathogen in the laboratory. Desai et al.\(^1\) recently demonstrated significant variability among MRSA strains in survival and transmission from fomites. Therefore, we cannot be certain that the in vitro data are applicable to a majority of strains. We studied only stethoscope diaphragms. Stethoscope tubing could also contribute to pathogen transmission because it is infrequently cleaned and may come in contact with patients and healthcare workers’ hands and clothing.

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Quantitative Efficacy of Alcohol-Based Handrub against Vancomycin-Resistant Enterococci on the Hands of Human Volunteers

We recently reported an outbreak of vancomycin-resistant enterococci (VRE) colonization and disease due to a new VRE clone at our hospital\(^1\) that occurred despite the presence of an active alcohol-based handrub (ABHR) hand hygiene program, decreasing rates of methicillin-resistant Staphylococcus aureus (MRSA) bacteremia,\(^2\) and management of VRE-colonized patients according to Centers for Disease Control and Prevention (CDC) guidelines.\(^3\) To assess whether differences in the activity of ABHR against these strains may have explained the outbreak, we formally compared the in vivo efficacy of an ABHR product (70% isopropyl alcohol, 0.5% chlorhexidine, and skin emollient) against both the dominant preoutbreak VRE strain (AUS-0021) and the new outbreak strain (AUS-0085) among healthcare worker volunteers using a standard hand hygiene protocol that mimicked clinical day-to-day practice.

ABHR efficacy was assessed against 2 previously well-characterized nosocomial strains of vanB Enterococcus faecium: AUS-0021 (a 2004 bacteremia isolate typical of the dominant preoutbreak clones [CC17, ST 17]) and AUS-0085 (a 2009 outbreak bacteremia isolate [CC17, ST203]).\(^4\) Following an approach similar to that described elsewhere,\(^4\) 20 consenting volunteers each had the palm of their preferred hand contaminated with a high concentration of VRE (0.5 mL saline containing 1.5 × 10^6 colony-forming units [CFU]/mL E. faecium),\(^5\) which was massaged for 30 seconds using the fingertips of the participant’s alternate hand and then allowed to air dry. The presence of viable VRE was confirmed by placing the exposed hand into a sterile clipseal bag (Defries Industries) containing 10 mL of tryptone soy broth (TSB; Oxoid).\(^6\) The hand was gently massaged to ensure even distribution of the medium before removal of the TSB to obtain

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\(^1\) Desai R, Pannaraj PS, Agopian J, Sugar CA, Liu GY, Miller LG.


\(^3\) Cohen SH, Gerding DN, Johnson S, et al. Clinical practice guidelines for Clostridium difficile infection in adults: 2010 update by the Society for Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA).

\(^4\) Desai R, Pannaraj PS, Agopian J, Sugar CA, Liu GY, Miller LG.

\(^5\) Desai R, Pannaraj PS, Agopian J, Sugar CA, Liu GY, Miller LG.

\(^6\) Desai R, Pannaraj PS, Agopian J, Sugar CA, Liu GY, Miller LG.

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the baseline sample; after washing with tap water to remove any residual TSB, the participant’s hand was exposed to an identical inoculum of VRE (to ensure contamination with at least 1.5–3.0 × 10⁶ CFU/mL) and allowed to air dry. Hand hygiene was performed according to the World Health Organization (WHO) hand-rubbing procedure using 1.6–2.0 mL of ABHR (15–30 seconds drying), and the exposed hand was resampled to obtain the post-ABHR sample using 10 mL of TSB containing an appropriate neutralizing solution (3% v/v Tween 80 [Sigma-Aldrich], 3 g/L L-histidine [Sigma-Aldrich], and 3 g/L lecithin [BDH]). Finally, all participants thoroughly disinfected their hands by undertaking a supervised, detailed, final surgical scrub according to WHO guidelines.

The baseline sample and the post-ABHR sample were aseptically decanted into sterile 50-mL tubes and immediately assessed for viable VRE as follows: samples were diluted 10-fold in TSB (for the baseline sample) and TSB containing a neutralizing solution (for the post-ABHR sample), after which 100 μL of 10⁻³, 10⁻⁴, and 10⁻⁵ dilutions were plated in triplicate onto 90-mm enterococcosel agar plates (EA; BBL). A 1-mL volume of the undiluted post-ABHR sample was also spread directly onto 140-mm EA plates to detect small concentrations of VRE. Cultures were incubated at 37°C and assessed after either 48 hours (for TSB cultures) or 72 hours (for EA cultures). Colony counts were also performed on the original inoculae to ensure standardization.

Mean values (± standard deviation [SD]) were compared using the Student’s t test, with a P value of less than .05 considered to be statistically significant. The study was approved by the Austin Health Human Research Ethics Committee.

The mean (± SD) recoverable inoculum on participants’ hands prior to ABHR use was identical for both strains (log₁₀ 7.51 ± 3.2 × 10⁶ CFU/mL). Results of ABHR efficacy are shown in Table 1. ABHR resulted in a similar reduction in contamination for both VRE strains. For AUS-0021, the mean (± SD) reduction was log₁₀ 3.64 ± 1.24 CFU/mL, and the median reduction was log₁₀ 3.50 CFU/mL (range, 1.59–5.75). For AUS-0085, the mean (± SD) reduction was log₁₀ 3.71 ± 1.46, and the median reduction was log₁₀ 3.91 CFU/mL (range, 1.58–6.08; P = .87). However, for both strains the degree of VRE reduction varied somewhat between participants. For example, 7 of 20 participants who were exposed to AUS-0085 achieved only a log₁₀ 1.5–2.5 CFU/mL reduction, whereas the remaining 13 participants had a reduction greater than log₁₀ 3.5 CFU/mL (Table 1).

This is, to our knowledge, the first study to assess the quantitative efficacy of ABHR in vivo against VRE under controlled conditions that mimicked the likely worst-case clinical exposure encountered by healthcare workers (HCWs). With mean reductions in hand contamination of log₁₀ 3.64–3.71 CFU/mL, ABHR appears to be effective against VRE at a level comparable to the EN 1500 standards applied to other pathogens. Our in vivo findings are consistent with previous in vitro studies of ABHR efficacy against various

<table>
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<tr>
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<th>Reduction</th>
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<td>7.56</td>
<td>5.42</td>
<td>2.14</td>
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<td>T</td>
<td>7.35</td>
<td>2.63</td>
<td>4.72</td>
<td>7.70</td>
<td>3.05</td>
<td>4.65</td>
</tr>
</tbody>
</table>

Mean value (± SD) 7.51 ± 0.19 3.81 ± 1.39 3.71 ± 1.46 7.51 ± 0.19 3.87 ± 1.14 3.64 ± 1.24

Note: SD, standard deviation.
VRE strains and clinical studies that have shown reductions in rates of VRE colonization and disease associated with improved compliance with ABHR use.\textsuperscript{6–10} However, for HCWs whose hands are heavily contaminated (ie, with contamination levels comparable to that on the hands that we tested), ABHR use would still be associated with contamination densities of $\log_{10}$ 3.5–4.0 CFU/mL per hand. In situations of obvious fecal contamination, hand washing is generally recommended,\textsuperscript{7} but if such contact is not recognized, use of ABHR would be expected.

Our findings of similar ABHR efficacy against both the preoutbreak VRE strain and the new outbreak VRE strain suggest that factors other than susceptibility to ABHR are likely to be responsible for our recent outbreak.\textsuperscript{1} Our study has a number of limitations. We assessed only one ABHR product, and we used high concentrations of 2 VRE strains. Thus, we cannot be certain whether other products, lesser degrees of compliance with ABHR technique,\textsuperscript{7} lower concentrations of VRE inoculae, or other enterococcal species, genotypes, or clones will be associated with similar results.

Although our findings highlight how difficult it can be to fully eradicate VRE from the hands of HCWs, the generally good in vivo efficacy of ABHR against VRE has led us to reassess ABHR use in our VRE control program.

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