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Original Article

Shedding of methicillin-resistant *Staphylococcus aureus* by colonized patients during procedures and patient care activities

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Abstract

Objective: Medical procedures and patient care activities may facilitate environmental dissemination of healthcare-associated pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA).

Design: Observational cohort study of MRSA-colonized patients to determine the frequency of and risk factors for environmental shedding of MRSA during procedures and care activities in carriers with positive nares and/or wound cultures. Bivariate analyses were performed to identify factors associated with environmental shedding.

Setting: A Veterans Affairs hospital.

Participants: This study included 75 patients in contact precautions for MRSA colonization or infection.

Results: Of 75 patients in contact precautions for MRSA, 55 (73%) had MRSA in nares and/or wounds and 25 (33%) had positive skin cultures. For the 52 patients with MRSA in nares and/or wounds and at least 1 observed procedure, environmental shedding of MRSA occurred more frequently during procedures and care activities than in the absence of a procedure (59 of 138, 43% vs 8 of 83, 10%; $P < .001$). During procedures, increased shedding occurred ≤0.9 m versus >0.9 m from the patient (52 of 138, 38% vs 25 of 138, 18%; $P = .0004$). Contamination occurred frequently on surfaces touched by personnel (12 of 38, 32%) and on portable equipment used for procedures (25 of 101, 25%). By bivariate analysis, the presence of a wound with MRSA was associated with shedding (17 of 29, 59% versus 6 of 23, 26%; $P = .04$).

Conclusions: Environmental shedding of MRSA occurs frequently during medical procedures and patient care activities. There is a need for effective strategies to disinfect surfaces and equipment after procedures.

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Methicillin-resistant *Staphylococcus aureus* (MRSA) is an important healthcare-associated pathogen that can be spread from patient to patient. The hands of healthcare personnel are generally considered the most important vector for MRSA transmission. However, environmental surfaces may also contribute to transmission.[1–3] Patients may acquire MRSA through direct contact with contaminated surfaces, or indirect transfer may occur when personnel touch contaminated surfaces prior to contacting patients.[2]

To prevent MRSA transmission, there is a need for a better understanding of patient and medical care characteristics that confer an increased risk for shedding MRSA. In previous studies, skin and/or environmental contamination has been associated with increased nasal density of MRSA, indwelling devices, decreased mobility, and diarrhea in the setting of a high burden of MRSA in stool.[4–9] Recently, Pineles et al[10] identified certain types of care activities that were associated with increased risk for contamination of cover gowns and gloves, including wound care, dressing, and providing hygiene and bathing assistance. We hypothesized that medical procedures and patient care activities would similarly facilitate environmental dissemination of MRSA. To test this hypothesis, we conducted an observational cohort study of MRSA-colonized patients to determine the frequency of and risk factors for environmental shedding during procedures and care activities.

Methods

Setting

The Louis Stokes Cleveland VA Medical Center includes a 215-bed hospital and an adjacent 250-bed long-term care facility (LTCF). For routine surveillance, the anterior nares of all patients are screened for MRSA upon admission, ward transfer, and discharge. Patients

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with MRSA colonization or infection are placed in contact precautions. A commercial bleach product is used for postdischarge cleaning of all patient rooms. Daily cleaning is performed in MRSA isolation rooms only if surfaces are visibly soiled.

Participants and procedures

The study protocol was approved by the facility's institutional review board. Between February 1, 2016, and June 30, 2017, we conducted an observational cohort study of hospitalized patients in contact precautions for MRSA colonization or infection. BBL culture swabs (Becton Dickinson, Cockeysville, MD) were used to sample the anterior nares, chest and abdomen, hands, and any open wounds. Initial studies demonstrated that shedding of MRSA was rare for patients in isolation for prior detection of MRSA but with negative current nasal and wound cultures. Therefore, we examined the frequency and distribution of shedding of MRSA during medical and nonmedical procedures in the subset of patients with positive anterior nares and/or wound cultures. Nonmedical procedures included bathing, eating meals, bedding change, and transfer from bed to chair or to a gurney. Medical procedures included wound care, respiratory therapy, physical therapy, medication administration, ostomy change, and ultrasound testing.

Prior to the procedures, high-touch environmental surfaces in the room were cleaned and disinfected with a commercial 1-step cleaner and disinfectant containing 30% ethanol and allowed to air dry for at least 5 minutes. For the first 30 procedures, cultures were obtained to ensure that no MRSA was recovered after cleaning. Research staff observed the procedures and recorded information regarding contact between environmental surfaces in the room and personnel, patients, and portable equipment used for the procedures. After completion of the procedures, replicate organism detection and counting (RODAC) plates containing BBL CHROMagar with cefoxitin 6 μg/mL were used to sample a standardized group of high-touch environmental surfaces; separate plates were used to sample surfaces ≤0.9 m (eg, bed rails, bedside tables, call button, telephone, vital signs equipment) and >0.9 m (eg, chair, door knob, closet, night stand) from the patient. The RODAC plates were applied to 3 separate areas on each sampled surface. In addition to the standardized culture sites, we sampled additional surfaces in the room or bathroom that were observed to be contacted by the personnel performing the procedures and portable equipment used during the procedures. To assess shedding in the absence of procedures, we cleaned and disinfected the high-touch surfaces at a time when the patient was in the room but no procedures or activities were scheduled and collected were cultures after 1 hour.

A medical record review was conducted to obtain information on demographics, medical conditions, wounds, antibiotics, chlorhexidine bathing, mobility, devices (central venous catheters and urinary catheters), fecal incontinence or diarrhea, and ward. Antibiotics were classified as anti-MRSA agents if they are commonly used to treat MRSA infections (eg, vancomycin, linezolid, daptomycin, ceftaroline, doxycycline, and trimethoprim/sulfamethoxazole).[11]

Microbiology and molecular typing

Swabs were plated on BBL CHROMagar containing cefoxitin 6 μg/mL for isolation of MRSA. Colonies consistent with *S. aureus* on RODAC or CHROMagar plates were tested for coagulase production using a Staphaurex kit (Remel, Lenexa, KS). The number of MRSA colony-forming units (CFUs) per swab were counted. For a subset of 40 patients, spa typing of nasal isolates as well as selected skin, wound, and environmental isolates was performed according to previously described methods.[12] For individual patients, skin and environmental isolates were considered concordant with nares isolates if the same spa type was present.[13]

Statistical analysis

Procedures with and without shedding were aggregated within patients. Patients were classified as having no shedding if all environmental cultures were negative for all procedures performed. Patients were classified as shedding if 1 or more environmental cultures were positive during 1 or more procedures. We performed χ^2 tests to identify patient-level factors associated with environmental shedding of MRSA and to compare the frequencies of shedding for different procedures. For participants classified as shedding with data available from 3 or more procedures, we assessed characteristics of the subset with positive cultures for >50% of procedures. Data were analyzed using R version 3.5.0 software (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Figure 1 shows a flow diagram for the study participants. Of 86 MRSA colonized patients eligible for enrollment, 75 (87%) participated in the study. Of the 75 participants, 55 (73%) had positive nares and/or wound cultures for MRSA, and 18 (24%) had negative nares and wound cultures and negative skin cultures, whereas 2 (3%) had negative nares and wound cultures but positive skin cultures (ie, 1 had MRSA on the chest/abdomen and the other had MRSA on the chest/abdomen and on hands). The mean density of nasal MRSA was 1.4 $\log_{10}$colony-forming units per swab (range, 0.3–4). Of the 52 patients with positive nares and/or wound MRSA cultures and at least 1 procedure or care activity assessed, 23 (44%) had positive chest/abdomen cultures and 25 (48%) had positive hand cultures.

Figure 2 shows the frequency of environmental shedding of MRSA associated with procedures for the 52 patients with MRSA in nares and/or wounds. All 30 of the pre-procedure cultures collected after cleaning of the surfaces were negative for MRSA. Of the 52 patients, 29 patients (56%) shed MRSA to the environment during 1 or more procedures. For these 29 patients, environmental shedding of MRSA was detected on 1 or more of the standard surfaces sampled in 59 of 138 (43%) procedures versus 8 of 83 (10%) sets of cultures collected in the absence of a procedure ($P < .001$). During procedures, shedding was detected significantly more often on the sites ≤0.9 m versus >0.9 m from the patient (52 of 138, 38% vs 25 of 138, 18%; $P < .001$). The procedures associated with the highest frequency of contamination included both medical (ie, physical/occupational therapy, respiratory therapy, and wound care) and nonmedical procedures (ie, bathing and changing bedding). There were no statistically significant differences in the frequencies of shedding for different procedure types. In addition to the standardized sites, contamination occurred frequently on other surfaces that were observed to be contacted by personnel (12 of 38, 32% positive) and on portable equipment used for procedures (25 of 101, 25%). The median number of colonies recovered from contaminated sites was 4 (range, 1–253).

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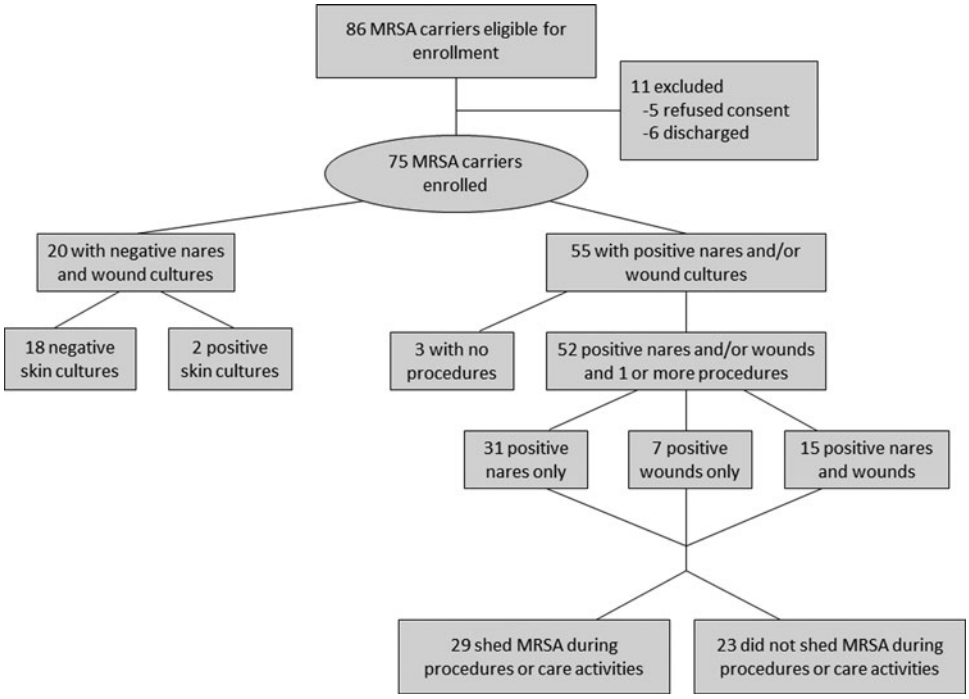

Fig. 1. Flow diagram for the study participants.

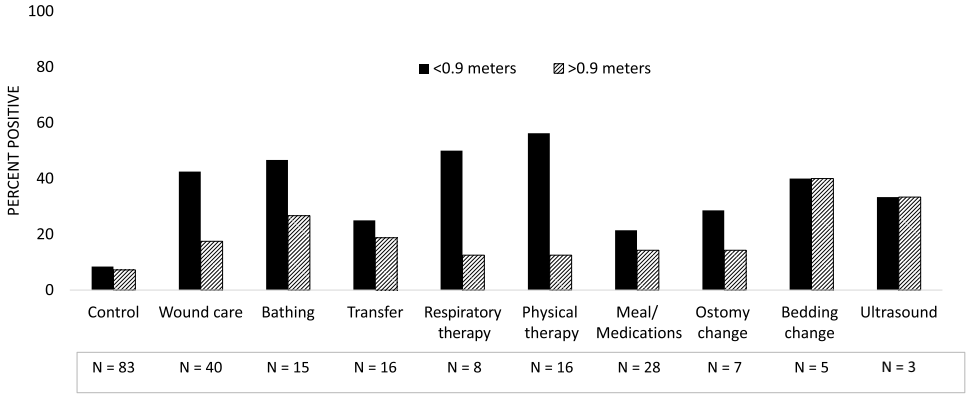

Fig. 2. Frequency of environmental shedding of methicillin-resistant *Staphylococcus aureus* (MRSA) associated with medical procedures and patient care activities for 52 patients with MRSA in nares and/or wounds.

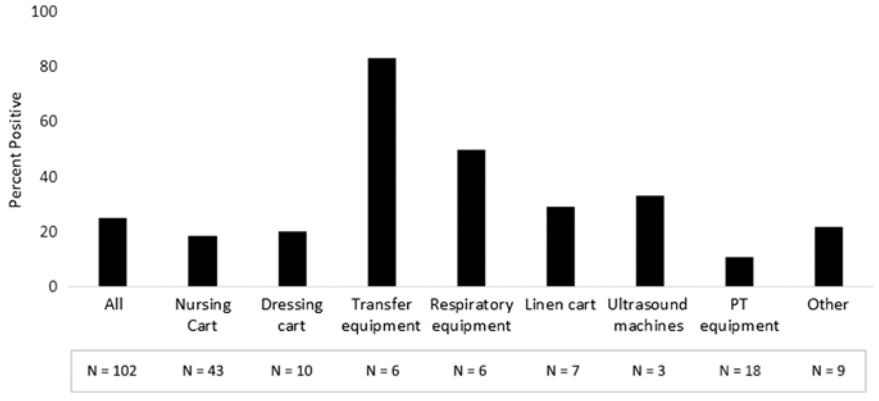

Fig. 3. Frequency of contamination of portable equipment used in procedures or patient care activities for 52 patients with methicillin-resistant *Staphylococcus aureus* (MRSA) colonization of nares and/or wounds. PT, physical therapy.

Figure 3 shows the frequency of contamination of portable equipment used in the procedures. Overall, 25 of 102 cultures of equipment (25%) were positive for MRSA, with the highest frequencies of contamination in transport equipment (eg, gurneys or wheelchairs), respiratory therapy equipment, and ultrasound machines. Of the 102 pieces of equipment cultured, 27 (26%) came in direct contact with patients and 75 (74%) did not. Of the 25 devices that became contaminated with MRSA, 8 came into direct

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Table 1. Risk Factors for Shedding of Methicillin-Resistant *Staphylococcus aureus* (MRSA) during Procedures by MRSA Carriers with Nasal and/or Wound Carriage

Characteristic	Shedding (n = 29), No. (%)[a]	No Shedding (n = 23), No. (%)[a]	*P* Value
Age, mean y	66	67	.62
Limited mobility[b]	24 (83)	19 (83)	1
Wounds with MRSA	17 (59)	6 (26)	.04
Nares culture positive	26 (90)	18 (78)	.46
Indwelling devices[c]	19 (66)	15 (65)	1
Antibiotics used to treat MRSA[d]	10 (35)	6 (26)	.73
Other antibiotics	9 (31)	12 (52)	.21
Diarrhea	6 (21)	5 (22)	1
Chlorhexidine bathing	1 (3)	1 (4)	1

Note. MRSA, methicillin-resistant *Staphylococcus aureus*.
[a]Unless otherwise indicated.
[b]Mobility score is a subcategory of the Braden score for prediction of pressure ulcer risk with 1–3 indicating limited mobility: 1 = completely immobile, 2 = very limited, 3 = slightly limited, 4 = no limitation.
[c]Central venous catheters and urinary catheters.
[d]Vancomycin, linezolid, daptomycin, ceftaroline, doxycycline, and trimethoprim/sulfamethoxazole.

contact with patients (ie, 1 ultrasound device, 2 pieces of physical therapy equipment, and 5 pieces of equipment used for patient transfer) and 17 did not; all 17 of the devices that became contaminated without touching patients were touched by the hands of personnel during the procedures.

A total of 88 MRSA isolates from 40 patients were subjected to spa typing. The nares isolates from 33 patients included 12 known spa types and 2 isolates that did not match previously identified spa types. The most common spa types were t008 (7 patients), t002 (6 patients), and t037 (4 patients). For 18 patients with concurrent nasal and environmental MRSA isolates subjected to spa typing, 16 (89%) had 1 or more environmental isolates with the same spa type as the nasal isolate. For 9 patients with concurrent nasal and skin MRSA isolates, 9 (100%) had skin isolates with the same spa type as the nasal isolate. For 5 patients with concurrent nasal and portable equipment MRSA isolates, 3 (60%) had equipment isolates with the same spa type as the nasal isolate. Finally, for 5 patients with concurrent nasal and wound MRSA isolates, 4 patients (80%) had wound isolates with the same spa type as the nasal isolate.

Table 1 shows the results of the patient-level bivariate analysis of risk factors associated with environmental shedding of MRSA during procedures. The only factor that was significantly associated with shedding (defined as 1 or more positive environmental culture during 1 or more procedures) was the presence of a wound that was culture-positive for MRSA. For carriers with positive nasal cultures, there was no significant difference in the burden of nasal MRSA for those with versus without shedding (2.4 vs 1.8 $\log_{10}$CFU per swab; $P = .72$).

Of the 29 MRSA carriers with shedding of MRSA to the environment during 1 or more procedures, 18 (62%) were assessed during 3 or more procedures. Of these 18 MRSA carriers, 6 (33%) had positive environmental cultures for MRSA during >50% of procedures. The characteristics of the subjects with shedding during >50% and <50% of procedures were similar. All 6 of the carriers with shedding during >50% of procedures had wounds and indwelling devices; for the 12 carriers with shedding during <50% of procedures, 9 (75%) had wounds and 10 (83%) had indwelling devices.

Discussion

In a cohort of MRSA carriers with positive nares and/or wound cultures, we have demonstrated that environmental shedding of MRSA occurred frequently during a wide range of medical procedures and patient care activities. Shedding occurred more often at sites ≤0.9 m than at sites >0.9 m from patients and was also common on sites touched by personnel and on portable equipment used for procedures. Most isolates detected in the environment and on equipment after procedures were genetically related to concurrent nasal isolates. The 2 most common spa types (t008 and t002) recovered are the predominant spa types in the United States.[14] Our findings have important implications for prevention of MRSA transmission.

It is plausible that measures such as chlorhexidine bathing and covering of open wounds might be useful as "source control" to reduce shedding of MRSA during procedures.[15] In the current study, only 4% of the MRSA carriers included in the assessment of shedding during procedures were receiving chlorhexidine bathing. Because MRSA carriers frequently have contamination on their clothing and hands, providing daily clothing changes and patient hand hygiene are other simple approaches that might be useful as components of a bundle of practices to reduce the risk for shedding.[16–18]

Our results also reinforce recommendations from current guidelines that equipment should be cleaned between patients, particularly when used in isolation rooms.[19] Recent studies suggest that cleaning of portable equipment is often suboptimal despite written protocols.[20,21] Thus, some method of monitoring equipment cleaning practices is needed to ensure compliance. Our results also suggest that it might be beneficial to clean surfaces after procedures, focusing on areas contacted by personnel or equipment. One practical approach might be to develop peri-procedure protocols based on our findings and on evidence that personnel frequently become contaminated during procedures.[10] Such peri-procedure protocols might include both routine cleaning of portable equipment and surfaces contacted during procedures and wearing of personal protective equipment for high-risk procedures. Increasing the frequency of cleaning by providing daily disinfection of high-touch surfaces in MRSA isolation rooms has previously been shown to reduce acquisition of MRSA on hands of personnel.[22] If peri-procedure cleaning protocols are recommended, it would be essential to ensure that personnel have easy access to disinfectant products (eg, cannisters of wipes located in patient rooms or directly attached to portable equipment).

It is generally accepted that the risk for shedding of pathogens may vary widely among patients and a subset of colonized or infected individuals may be classified as super-spreaders.[23–25] For MRSA, previous studies have identified increased nasal density, indwelling devices, and decreased mobility as patient characteristics associated with shedding.[2–9] It is also plausible that shedding varies with different patient care activities. Pineles et al[10] identified wound care as one of several patient care activities associated with MRSA contamination of cover gowns and gloves during care of LTCF residents with MRSA colonization. In the current study, the presence of a wound with MRSA was associated with shedding during procedures and care activities by bivariate analysis. However, shedding

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did not occur significantly more often for wound care procedures than for other procedures and patient care activities.

Our study has some limitations. The study was conducted in a setting with a predominantly male patient population, and most of the procedures and activities took place on medical-surgical wards. The number of procedures varied among participants and a multivariate analysis was not performed to assess risk factors for shedding given the small number of patients studied. Thus, additional studies are needed to confirm the finding that wounds with MRSA may be associated with increased risk for shedding during procedures. Our observations suggest that shedding of MRSA to surfaces often occurred through direct transfer via the hands of personnel or contaminated equipment used in procedures. However, we cannot exclude the possibility that airborne dispersal of MRSA contributed to shedding during procedures. Others have demonstrated that airborne dispersal may occur during activities such as bedding changes.[26] In a minority of cases isolates recovered from surfaces or equipment after procedures did not match the concurrent nasal isolate. Thus, it is possible that some of the MRSA shed during procedures was derived from healthcare personnel or from other sources.

In conclusion, our results suggest that environmental shedding of MRSA occurs frequently during medical procedures and patient care activities. Such shedding could contribute to transmission of MRSA in healthcare facilities. Studies are needed to determine whether measures such as cleaning of surfaces and equipment after procedures can reduce the risk for transmission.

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Conflicts of interest. C.J.D. has received research funding from Clorox, GOJO, PDI, Pfizer, Avery Dennison, and Boehringer Laboratories. All other authors report no potential conflicts.

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