ORIGINAL ARTICLE

The Epidemiology of Methicillin-Resistant *Staphylococcus aureus* on a Burn Trauma Unit

Marin Schweizer, PhD;[1,2] Melissa Ward, MS;[1] Sandra Cobb, BS;[1] Jennifer McDanel, MS;[2,3] Laurie Leder, MPH;[1,*]
Lucy Wibbenmeyer, MD, FACS;[4] Barbara Latenser, MD, FACS;[4]
Daniel Diekema, MD, D(ABMM);[1,3,5] Loreen Herwaldt, MD[1,2,5]

OBJECTIVE. We assessed the frequency and relatedness of methicillin-resistant *Staphylococcus aureus* (MRSA) isolates to determine whether healthcare workers, the environment, or admitted patients could be a reservoir for MRSA on a burn trauma unit (BTU). We also assessed risk factors for MRSA colonization among BTU patients.

DESIGN. Prospective cohort study and surveillance for MRSA carriage.

SETTING. BTU of a Midwestern academic medical center.

PATIENTS AND PARTICIPANTS. Patients admitted to a BTU from February 2009 through January 2010 and healthcare workers on this unit during the same time period.

METHODS. Samples for MRSA culture were collected on admission from the nares and wounds of all BTU patients. We also had collected culture samples from the throat, axilla, antecubital fossa, groin, and perianal area of 12 patients per month. Samples collected from healthcare workers' nares and from environmental sites were cultured quarterly. MRSA isolates were typed by pulsed-field gel electrophoresis.

RESULTS. Of 144 patients, 24 (17%) carried MRSA in their nares on admission. Male sex (odds ratio [OR], 5.51; 95% confidence interval [95% CI], 1.25–24.30), admission for necrotizing fasciitis (OR, 7.66; 95% CI, 1.64–35.81), and MRSA colonization of a site other than the nares (OR, 23.40; 95% CI, 6.93–79.01) were independent predictors of MRSA nasal carriage. Cultures of samples collected from 4 healthcare workers and 4 environmental cultures had positive results. Two patients were colonized with strains that were indistinguishable from strains collected from a healthcare worker or the environment.

CONCLUSIONS. Patients were a major reservoir for MRSA. Infection control efforts should focus on preventing transmission of MRSA from patients who are MRSA carriers to other patients on the unit.

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Compared with other hospitalized patients, burn patients have a higher risk of acquiring infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA) because they often stay in the hospital for prolonged periods, their skin is damaged, and their immunity is suppressed.[1-4] Prior studies have found that 23%–45% of healthcare-associated infections in burn units are caused by *S. aureus*.[5-9]

To prevent MRSA infections in burn patients and to prioritize infection control efforts, we must determine the primary reservoirs and modes of transmission for this organism on a specific unit. Endogenous transmission, in which MRSA is transferred from one body site on a patient to another on the same patient (eg, from the nares to a wound), can be prevented by decolonizing patients with agents such as mupirocin.[10-13] Exogenous transmission, in which MRSA is transferred from patient to patient or from the hospital environment to a patient, can be prevented by enhancing healthcare workers' (HCWs') hand hygiene, isolating colonized or infected patients, and enhancing environmental cleaning and disinfection.[10-17]

A previous study conducted in our burn trauma unit (BTU) found that many of the MRSA isolates collected from patients were related via molecular typing, suggesting a common source.[18] Thus, this study aimed to determine whether HCWs on the BTU or the BTU's environment could be a source of MRSA for patients admitted to this unit, so that we could determine which infection prevention and control measures might be most effective. Additionally, we aimed to

Affiliations: 1. University of Iowa Carver College of Medicine, Department of Internal Medicine, Iowa City, Iowa; 2. University of Iowa College of Public Health, Department of Epidemiology, Iowa City, Iowa; 3. University of Iowa Carver College of Medicine, Department of Pathology, Iowa City, Iowa; 4. University of Iowa Carver College of Medicine, Department of Surgery, Iowa City, Iowa; 5. University of Iowa Hospitals and Clinics, Program of Hospital Epidemiology, Iowa City, Iowa.

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identify risk factors for MRSA colonization so that we could identify patients who should be targeted for infection control efforts such as active surveillance and isolation.

METHODS

Setting

This prospective cohort study included patients who were admitted to the BTU of a teaching hospital with a level-1 trauma center. The BTU has 16 beds (2 double rooms, 12 single rooms) and admits a mean of 25 patients per month, including 15 burn patients. The BTU is a regional unit that serves the state of Iowa; the unit also serves as a step-down unit for general surgical and trauma patients. Throughout the study period, nurses on the BTU obtained nasal swab samples from patients at admission and weekly to identify those who were colonized with MRSA. Routine wound samples were obtained weekly from burn and wound patients. Contact precautions were taken with all patients admitted to the unit until negative results were obtained for initial screening tests. Contact precautions were retained for patients whose nares or wounds were colonized with MRSA.

We have conducted several studies on the epidemiology of MRSA on this BTU.[7,13,18-20] The prevalence of MRSA on admission was approximately 5.1%, the overall prevalence of MRSA colonization or infection was estimated to range from 6.0% to 8.9%,[13,19] and MRSA caused more than one-third of the bloodstream infections and burn wound infections in this unit.[7] Care of burns in this unit has been described previously.[20] In short, we excised full-thickness wounds early and applied either split-thickness autografts or cadaver skin. We then performed staged autografting of the cadaver-grafted areas. Dressings were changed in the hydrotherapy room.

Study Design

From February 2009 through January 2010, we obtained informed consent from and enrolled 12 randomly selected patients per month. Each study patient's throat, axillae, antecubital fossae, groin, and perianal area were swabbed. In addition, BTU nurses collected the standard surveillance samples from each patient's nares and wounds. However, for the purposes of this study, we were unable to distinguish between wound colonization and wound infection. We reviewed each patient's medical record and abstracted information onto a standardized form that included data such as patient demographics, admitting diagnosis, medical history, devices present, and history of MRSA colonization or infection before study enrollment (Table 1).

Research assistants swabbed HCWs' nares and potential fomites in the patient environment quarterly. Potential fomites were located in patient rooms (eg, bed trays, supply cabinets, and bed rails) and shared areas (eg, tubs, hoses, shower heads, tub handles, sinks, computers, phones, playroom toys, door handles, door plates, refrigerator, microwave, therapy gym equipment, physical therapy room equipment, and soap dispensers). The University of Iowa's Institutional Review Board approved this study.

Microbiologic and Molecular Typing Methods

Nurses on the BTU rubbed premoistened swabs in patients' nares to obtain samples to perform admission MRSA surveillance cultures. Samples were inoculated into 2 mL of brain-heart-infusion broth. After 24 h of incubation at 35°C, a 1 : 100 dilution was made and inoculated onto selective MRSA agar plates (BBL CHROMagar MRSA, Becton Dickinson). These plates were incubated for 24–48 hours at 35°C and then examined for MRSA.[21] Isolates were confirmed to be *S. aureus* when their appearance was observed with Gram staining and following positive results of the catalase test, the *S. aureus* latex agglutination assay (Pastorex Staph-plus, Bio-Rad), and the tube coagulase test, as required. Admission and weekly wound cultures were processed by staff in the Clinical Microbiology Laboratory, using standard microbiological methods.

Upon a patient's enrollment into the study, research assistants rubbed premoistened swabs in the patient's throat, axillae, antecubital fossae, groin, and perianal area to obtain samples for MRSA culturing. Research assistants also used premoistened swabs to collect environmental samples. All patient and environmental samples were processed as outlined above. Laboratory personnel used the Clinical and Laboratory Standards Institute broth microdilution method to perform antimicrobial susceptibility testing on all MRSA isolates.[22] Low-level mupirocin resistance was defined as a minimum inhibitory concentration (MIC) of 8–256 μg/mL, and high-level mupirocin resistance was defined as an MIC greater than 512 μg/mL.[22] We performed pulsed-field gel electrophoresis (PFGE) on all MRSA isolates that had been collected for research purposes,[23] and we used the BioNumerics software to compare the PFGE patterns with those of the Centers for Disease Control and Prevention's USA-type strains.[24] A similarity coefficient of 75% was used to determine PFGE subtypes.

Statistical Analysis

We assessed bivariable associations using the χ^2 test or the Fisher exact test for categorical variables and the Student t test or the Wilcoxon rank-sum test for continuous variables. We used logistic regression analysis to identify independent risk factors for MRSA colonization. We included all variables that were significant in the bivariable analyses ($\alpha < 0.1$) in the initial model and then removed in succession those variables that were not significantly associated with MRSA-positive surveillance cultures ($\alpha < 0.05$). We created contingency tables to calculate the sensitivity, specificity, positive predictive value, and negative predictive value of nasal surveillance cultures to predict MRSA colonization at other body sites. We used SAS software (SAS Institute), version 9.1, for all analyses.

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TABLE 1. Patient Demographics Stratified by the Results of the Admission Nares Screen

	Nares screen result for MRSA on admission			
	Positive[a] (n = 24)	Negative (n = 119)	All participants (n=144)	P
Male sex	21 (87.5)	74 (62.2)	95 (66.0)	.02
Age, median years (IQR)	59 (52–62)	53 (38–64)	54 (39–63)	NS
Place of residence				NS
Home	21 (87.5)	113 (95.0)	135 (93.7)	
Skilled nursing facility	3 (12.5)	3 (2.5)	6 (4.2)	
Nursing home	0 (0)	1 (0.8)	1 (0.7)	
Homeless	0 (0)	2 (1.7)	2 (1.4)	
Admitting diagnosis				.002
Burn	4 (16.7)	27 (22.7)	31 (21.5)	
Necrotizing fasciitis	6 (25.0)	6 (5.0)	12 (8.3)	
Trauma	1 (4.2)	37 (31.1)	38 (26.4)	
Wound care	6 (25.0)	30 (25.2)	37 (25.7)	
Other[b]	7 (29.2)	19 (16.0)	26 (18.1)	
Medical history before study enrollment				
Prior receipt of antimicrobial agents	21 (87.5)	81 (68.9)	104 (72.2)	.06
Prior surgery	18 (75.0)	75 (63.0)	94 (65.3)	NS
Devices present before study enrollment				
Foley catheter	19 (79.2)	76 (63.9)	96 (66.7)	NS
Central venous catheter	9 (37.5)	31 (26.1)	41 (28.5)	NS
Enteral feeding tube	6 (25.0)	14 (11.8)	20 (13.9)	NS
Ventilator	9 (37.5)	30 (25.2)	39 (27.1)	NS
History of MRSA colonization or infection before study enrollment	24 (100)	4 (3.4)	29 (20.1)	<.01

NOTE. Data are no. (%) of admissions, unless otherwise indicated. IQR, interquartile range; MRSA, methicillin-resistant *Staphylococcus aureus*; NS, not significant.

[a] One nares screen was not performed.

[b] Including postoperative admission, soft tissue infection, abdominal issue (eg, pancreatitis), skin issue (eg, erythroderma), overflow, cancer, inhalation injury, and gallstones.

Results

During the entire study period, 595 patients were admitted to the BTU. Approximately 7% carried MRSA in their nares on admission, 2% acquired nasal colonization during their BTU admission, and for 8%, a clinical culture had positive results for MRSA during the BTU admission.

Twelve individual patients per month were enrolled in this study, for a total of 144 patients. The median age of the study patients was 54 years (IQR, 39–63), and 66% of the patients were male. Twenty percent of the study patients had a history of MRSA colonization or infection before they were admitted to the BTU. Most study patients resided in their own homes (93.7%; Table 1). The most common reasons for admission to the BTU were trauma (26.4%), wound care (25.7%), burn (21.5%), and necrotizing fasciitis (8.3%). MRSA was isolated from 3 patients who had necrotizing fasciitis; from 1 of these, group G *Streptococcus* was also isolated. Other organisms causing necrotizing fasciitis were as follows: methicillin-susceptible *S. aureus* and group B *Streptococcus* (n = 1), group G *Streptococcus* and *Prevotella* spp. (n = 1), group G *Streptococcus* (n = 1), and vancomycin-susceptible *Enterococcus* (n = 1). Three patients had negative culture results while at the University of Iowa Hospitals and Clinics but had received antimicrobial agents at other hospitals, which may have affected these results.

MRSA Surveillance among Patients

Seventeen percent (24/144) of the study patients carried MRSA in their nares on admission. Male sex, a prior history of MRSA colonization or infection, and an admitting diagnosis of necrotizing fasciitis were significantly associated with MRSA nasal carriage on admission (Table 1). Conversely, patients admitted to the BTU for trauma were significantly less likely than other patients to be carrying MRSA in their nares when they were admitted (Table 1). A higher percentage of the patients who carried MRSA in their nares on admission to the BTU had received treatment with antimicrobial agents in the period between hospital admission and admission to the BTU, but the difference is not statistically significant. Age, place of residence, surgery in the period between hospital

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TABLE 2. Number of Body Sites Testing Positive for Methicillin-Resistant *Staphylococcus aureus*

Body site	No. of patients (N = 144)
Five body sites (%)	1 (0.7)
Groin, perianal area, throat, wound, nares	1
Four body sites (%)	4 (2.8)
Perianal area, throat, wound, nares	3
Groin, perianal area, throat, nares	1
Three body sites (%)	5 (3.5)
Groin, perianal area, wound	1
Perianal area, throat nares	1
Throat, wound, nares	1
Axilla, wound, nares	1
Antecubital fossae, wound, nares	1
Two body sites (%)	7 (4.9)
Wound, nares	4
Perianal area, wound	1
Perianal area, nares	1
Groin, nares	1
One body site (%)	19 (13.2)
Nares	9
Wound	8
Throat	2[a]
No body sites (%)	108 (75.0)

[a] A nares sample culture was not performed for 1 patient.

admission and BTU admission, and the presence of a central venous catheter, Foley catheter, or enteral feeding tube before enrollment or at the time of enrollment were not associated with MRSA carriage in the nares at admission (Table 1).

Of the 36 patients who had MRSA colonization at any body site, 25.7% were colonized in the nares only, 31.4% were colonized at a body site other than the nares, and 42.8% were colonized in both the nares and another body site. The most common extranasal carriage sites were wounds (n = 12), the throat (n = 9), and the perianal area (n = 9). Eleven (9.2%) of the 120 patients who did not have MRSA carriage in the nares had MRSA colonization at another site. The body sites where we found MRSA colonization are listed in Table 2.

The sensitivity of cultures of nasal swabs at admission to be able to predict MRSA colonization at other body sites was only moderate (sensitivity, 57.7%), because nasal carriage on admission identified only 52.3% of the patients who had MRSA in their wounds (colonization or infection). In contrast, 78.6% of the patients who had MRSA-positive cultures of samples collected from body sites other than wounds were also found to be carrying MRSA in their nares. The combined sensitivity of nares and wound screens (ie, if one or the other is positive) to predict a positive culture result for another body site was 92.9% (Table 3).

Three factors were independently associated with MRSA nasal carriage on admission: male sex (adjusted OR, 5.51; 95% CI, 1.25–24.30), necrotizing fasciitis as the reason for admission (adjusted OR, 7.66; 95% CI, 1.64–35.81), and cultures that grew MRSA of samples obtained from a body site other than the nares (adjusted OR, 23.40; 95% CI, 6.93–79.01). Risk factors independently associated with MRSA at a body site other than the nares included a prior history of MRSA colonization or infection (adjusted OR, 43.64; 95% CI, 12.70–150.00) and wound care as the reason for admission (adjusted OR, 4.90; 95% CI, 1.36–17.52).

HCW Colonization with MRSA and Environmental Contamination with MRSA

The nares of 67 unique HCWs on the BTU were swabbed for culturing (n = 238 samples). Four HCWs were colonized with MRSA at least once during the study period. Eighty percent (54/67) of HCWs, including the 4 carriers, were screened during all 4 quarters of the study period. One HCW was colonized for 3 quarters, 1 was colonized for 2 quarters, and 2 were colonized for 1 quarter. Colonized HCWs were treated with nasal mupirocin.

Fifty environmental samples were collected during the first quarter, 33 during the second quarter, 21 during the third quarter, and 32 during the fourth quarter, for a total of 136 cultures. None of the environmental samples obtained during quarters 1, 3, and 4 grew MRSA. During quarter 2, a total of 4 samples (2.9% of all samples, 12.1% of samples from quarter 2) grew MRSA. Samples obtained from the handles on the inside and the outside of the door to the physical

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TABLE 3. Sensitivity, Specificity, and Predictive Values of Admission Screening and Methicillin-Resistant *Staphylococcus aureus*–Positive Cultures of Samples Collected from Other Sites

	Sensitivity	Specificity	PPV	NPV
Association between admission nares screening results and				
Wound colonization or infection	52.3	89.4	45.8	91.6
Throat colonization	87.5	87.4	29.1	99.1
Groin colonization	75.0	84.9	12.5	99.2
Perianal area colonization	77.8	87.3	29.2	98.3
Antecubital fossae colonization	100	83.8	4.2	100
Axilla colonization	100	83.8	4.2	100
Any nonnasal colonization	57.7	92.3	62.5	90.8
Any nonnasal, nonwound colonization	78.6	89.9	45.8	97.5
Association between nares or wound screening results and colonization at other site	92.9	85.3	40.6	99.1

NOTE. Data are percentages. NPV, negative predictive value; PPV, positive predictive value.

therapy room, the bed mat in the physical therapy room, and a bed rail inside a patient's room grew MRSA.

Microbiologic and Molecular Results

Figure 1 includes PFGE patterns from patient isolates (axillae, antecubital fossae, groin, and perianal area), HCWs, and the environment. Most isolates from patients, all isolates from staff, and all isolates from the environment were USA100. Two patients were colonized with USA300, 1 patient was colonized with USA400, and 1 patient was colonized with USA700. Three of 4 environmental isolates had the same PFGE subtype. Staff members who were colonized at more than 1 time point were colonized by the same strain each time. Similarly, patients who carried MRSA at more than 1 body site carried the same strain at each body site. In 2 cases, isolates obtained from patients were indistinguishable from those obtained from HCWs or environmental strains. A USA100 subtype was shared by 3 patients and 1 HCW. One environmental isolate and 1 patient isolate were of the same USA100 subtype. In these cases, the patient was found to be colonized before either the HCWs or the environment were found to be colonized or contaminated.

Most MRSA isolates (91%) were resistant to erythromycin. Isolates from 6 patients and 1 HCW were resistant to clindamycin and erythromycin. All isolates were susceptible to linezolid, daptomycin, quinupristin-dalfopristin, rifampin, trimethoprim-sulfamethoxazole, gentamicin, and vancomycin. Two patients were colonized with a MRSA isolate that had low-level mupirocin resistance. All 3 MRSA isolates from HCW 1 had low-level mupirocin resistance, and both MRSA isolates from HCW 3 were highly resistant to mupirocin. HCW 1 did not have prior exposure to mupirocin before this study, whereas HCW 3 had received nasal mupirocin before employment on the BTU.

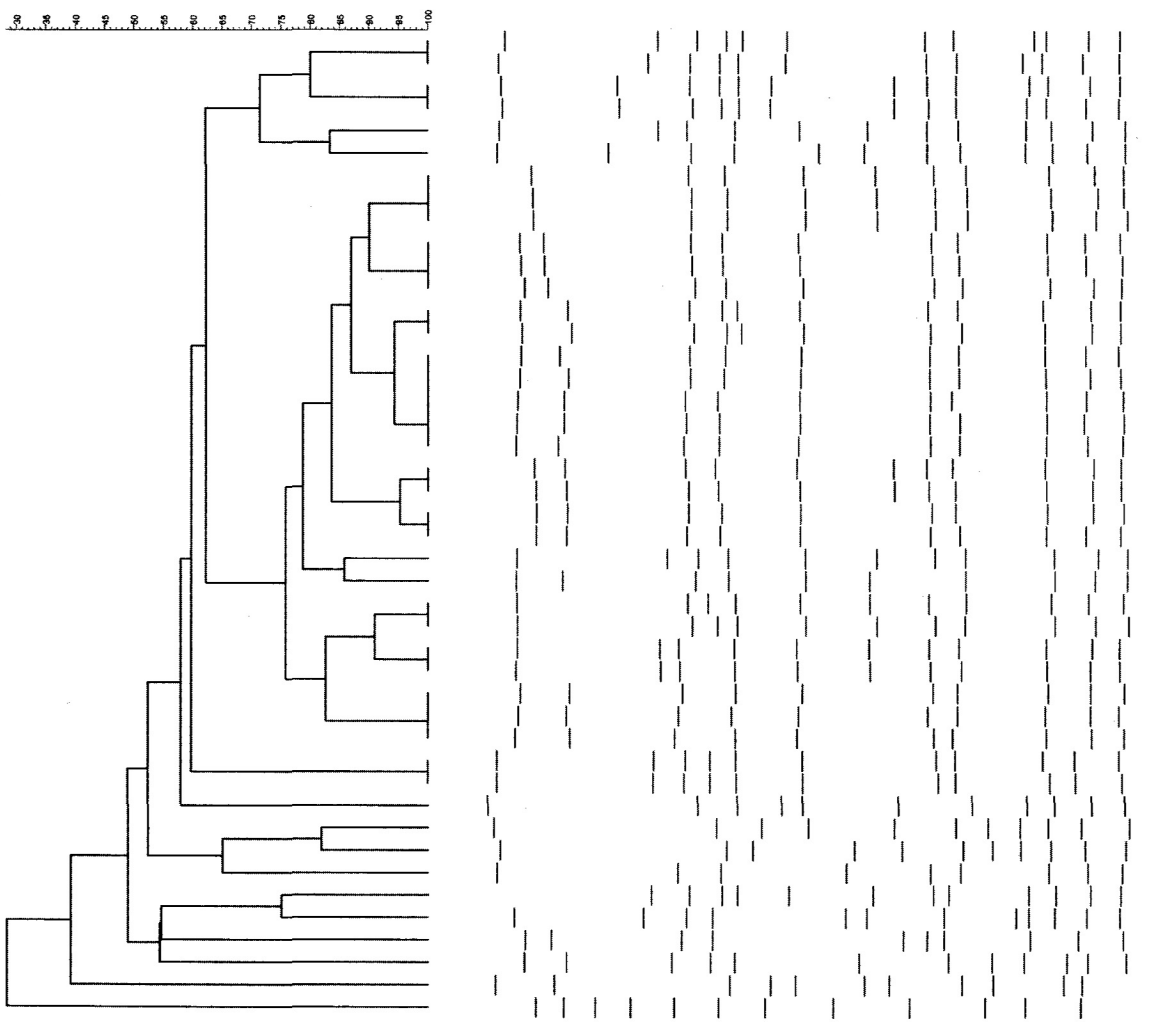
DISCUSSION

In this prospective cohort study performed on a BTU, we sought to assess the primary reservoir for MRSA. We found that HCWs and the environment were not major reservoirs for MRSA transmission. Rather, patients who had been admitted to the unit for reasons other than burns or trauma and who were carrying MRSA in their nares on admission were the primary MRSA reservoir. Moreover, all patients who carried MRSA in their nares on admission had prior histories of MRSA colonization or infection.

These results are consistent with the findings of a prior cross-sectional study[25] in which we obtained cultures from 112 HCWs on the BTU and found only 3 MRSA carriers (2.7%). Similarly, Dansby et al[26] obtained cultures from HCWs and the environment on their burn unit and found that all of the cultures of environmental samples had negative results and only 2.3% of the cultures of samples obtained from HCWs were positive for MRSA. In contrast to the findings in our study, a recent cross-sectional study conducted by Andrade et al[2] found that 30% of the environmental surfaces in a burn unit were contaminated with MRSA; however, the sites of contamination (eg, bed rails) in that study were similar to those in our study. In our study, only 4 cultures of environmental samples had MRSA-positive results, even though cultures were collected from high-risk environmental sites such as shared tub rooms. Thus, the environment probably does not play a large role in MRSA transmission in our BTU. The difference between our results and those of Andrade et al may be the result of variations in cleaning among the hospitals. Carling et al[27] found that among 27 intensive care units, thoroughness of cleaning varied substantially and did not correlate with hospital size, patient volume, case mix index, geographic location, or teaching status.

In this study, admission to the BTU for necrotizing fasciitis was independently associated with MRSA colonization of the nares on admission, and admission to the BTU for wound care was independently associated with MRSA colonization at body sites other than the nares. Similarly, a prior case-control study found that admission to our BTU for burns or for trauma was associated with a lower risk of MRSA colonization or infection than were other reasons for admission,

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Source	Isolate Number	Body Site	Subtype
PATIENT	P1	ARMPIT	A1
USA300			
PATIENT	P2	PERIANAL	A2
PATIENT	P2	THROAT	A2
CONTROL			
USA500			
PATIENT	P3	THROAT	B1
PATIENT	P3	GROIN	B1
PATIENT	P3	PERIANAL	B1
ENVIRONMENT	E1		B2
ENVIRONMENT	E2		B2
ENVIRONMENT	E3		B2
PATIENT	P4	THROAT	B3
PATIENT	P4	PERIANAL	B3
PATIENT	P5	PERIANAL	B4
PATIENT	P6	THROAT	B4
PATIENT	P7	THROAT	B4
STAFF	S2		B4
USA100			
PATIENT	P8	THROAT	B5
PATIENT	P8	PERIANAL	B5
PATIENT	P9	THROAT	B6
ENVIRONMENT	E4		B6
PATIENT	P10	PERIANAL	B7
STAFF	S4		B8
STAFF	S3		B9
STAFF	S3		B9
PATIENT	P11	GROIN	B10
PATIENT	P11	PERIANAL	B10
STAFF	S1		B11
STAFF	S1		B11
STAFF	S1		B11
PATIENT	P12	GROIN	C1
USA700			
USA600			
USA200			
USA1100			
USA800			
PATIENT	P13	ELBOW	D1
USA400			
USA900			
USA1000			
USA1200			
LADDER			

FIGURE 1. Dendrogram of methicillin-resistant *Staphylococcus aureus* (MRSA) isolates collected from patients, the environment, and healthcare workers.

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including necrotizing fasciitis and wound care.[13] Moreover, a study from the Netherlands found that two-thirds of patients whose burn wounds were colonized with methicillin-susceptible *S. aureus* had acquired the organism exogenously.[28] Thus, infection control efforts in BTUs should focus on preventing transmission of MRSA from patient to patient, particularly from patients admitted for reasons other than burns or trauma. Potential infection prevention and control efforts could include conducting targeted active surveillance for MRSA, isolating patients who are carrying MRSA, decolonizing carriers, or placing patients who have admitting diagnoses other than burns or trauma on different units. Given that patients who were colonized at more than 1 body site were always colonized with a single MRSA strain, decolonization or decontamination efforts could help to prevent endogenous transmission.

Other studies have demonstrated that the sensitivity of nares sample cultures to detect MRSA colonization varies substantially, with rates ranging from 69% to 91%. Several investigators have found that sensitivity improved substantially when samples were obtained from other body sites.[29,30] In our study, the sensitivity of nares sample cultures to detect MRSA colonization at other body sites was low, primarily because these results did not predict wound colonization or infection. Screening both the nares and wounds would have missed only 1 patient who had MRSA carriage. Thus, the BTU's current policy of screening the nares and wounds on admission and screening wounds weekly has a high sensitivity for finding patients in our patient population who are colonized with MRSA.

Our study has some limitations. We evaluated a BTU in a single center that cares for a heterogeneous patient population. Thus, our results may not be generalizable to burn units that have different patient populations, such as units that admit only patients who have burns. Also, we were unable to type the isolates obtained from the nares of MRSA-colonized patients because those samples were evaluated by the clinical laboratory, not the research laboratory. However, we previously reported that 90% of the BTU patients who had *S. aureus* carriage in their nares and who were colonized or infected with *S. aureus* at another site had the same strain at each site.[31]

Future studies should assess other causes of MRSA transmission on burn units, such as MRSA aerosolization during dressing changes.[26] Future studies should also frequently sample patients, HCWs, and the environment to determine whether MRSA is transferred from HCWs or the environment to patients or from patients to HCWs or the environment.

In conclusion, we found that patients, not HCWs or the environment, were the most likely primary reservoir for MRSA in our BTU. Patients admitted to the BTU for reasons other than burns or trauma and patients who had a prior history of MRSA colonization or infection were the most likely to be colonized with MRSA. HCWs should use best infection prevention practices when caring for these patients, to prevent transferring the organism from one body site to another in colonized patients and to ensure that MRSA is not transmitted to highly susceptible patients with burns.

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Address correspondence to Marin Schweizer, PhD, 601 Highway 6 West (152), Iowa City, IA 52246 (marin-schweizer@uiowa.edu).

* Present address: Laurie Leder, MPH, Mercy Hospital, QSR Department, 4050 Coon Rapids Boulevard NW, Coon Rapids, MN 55433.

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