Impact of a surveillance screening program on rates of methicillin-resistant *Staphylococcus aureus* infections with a comparison of surgical versus nonsurgical patients

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Methicillin-resistant *Staphylococcus aureus* (MRSA) is a significant cause of health care–associated infection. The overall effectiveness of surveillance screening programs is not well established. A retrospective cohort study was performed to evaluate the impact of a surveillance screening program on the rates of health care–associated MRSA infection (HA-MRSA-I) at a single institution. A subset of surgical patients was analyzed separately. Multivariate regression techniques were used to identify predictors of the desired outcomes. The overall MRSA infection rate was 1.3% in the before cohort and 3.2% in the after cohort. After excluding patients with a history of MRSA infection or MRSA colonization, HA-MRSA-I decreased from 1.2% to 0.87%. There was a similar overall increase in the surgical group, 1.4% to 2.3%, and decrease in HA-MRSA-I, 1.4% to 1.0% ($P < 0.001$). For all patients, surgery, African American race, and increased length of stay conferred an increased likelihood of HA-MRSA-I. Females and patients in the after cohort had a lower risk of HA-MRSA-I ($P < 0.01$). In the after cohort, the results were similar, with surgery, African American race, and length of stay associated with an increased risk, and female sex associated with a decreased risk ($P < 0.05$). African American race and increased age had a higher likelihood of screening positive for MRSA colonization, while the surgical group, females, and Hispanic patients were less likely ($P < 0.05$). HA-MRSA-I was associated with a higher mortality among all patients ($P < 0.001$). Mortality rates were similar with HA-MRSA-I for all patients (10.8% vs 9.5%, $P = 0.55$) and in the surgical group (8.3% vs 6.8%, $P = 0.58$). In conclusion, surveillance programs may be effective in decreasing HA-MRSA-I. Further studies are needed to determine how to reduce transmission, particularly among African Americans and those with increased lengths of stay.

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a significant cause of health care–associated infection (1) and is associated with increased hospital mortality (2, 3). In addition, MRSA is the leading cause of surgical site infection (4, 5). In 2003, the Society of Healthcare Epidemiology of America released guidelines strongly supporting the use of active surveillance cultures and contact isolation programs (6). A decrease in overall health care–associated MRSA infections (HA-MRSA-I) has since been demonstrated across a wide range of clinical and geographical settings in the United States (7). Surveillance programs have also proven to be effective in MRSA outbreaks in the intensive care unit (ICU) setting (8). Despite a decrease in overall HA-MRSA-I rates after implementation of active surveillance culture programs, the effect of HA-MRSA-I rates on specific patient populations, including patients undergoing invasive surgical procedures, is not well established (9, 10).

The purpose of this study was to evaluate rates of HA-MRSA-I before and after implementation of a hospitalwide screening program at a large teaching hospital with a high surgical volume. We examined the effect of this infection control initiative in the overall hospital population as well as for patients undergoing a wide range of common surgical procedures among a variety of specialties. We hypothesized that rates of HA-MRSA-I would decrease after implementation of a screening program, both hospitalwide and for patients undergoing surgical procedures.

METHODS

This institutional review board–approved retrospective cohort study took place at Baylor University Medical Center at Dallas, a 1000-bed academic medical center and level I trauma center in a large metropolitan area. Our current practice involves performing nasal swab MRSA polymerase chain reaction (PCR) screens on all patients who meet one of the following screening criteria: a prior history of MRSA colonization or infection (patient is placed in contact isolation); hospitalization within the preceding year; transfer from an extended care facility; presence of open or draining skin wounds (patient is placed in contact isolation); current admission to ICU; or current hemodialysis. Standard barrier and isolation precautions, including gown and gloves, are applied to all patients with a positive screen. With the exception of several four-bed pods in the surgical intensive care unit, all rooms are single rooms.

A hospitalwide MRSA surveillance program was implemented in January 2009. Prior to this initiative, standard barrier and isolation practices were implemented only if patients had a documented MRSA infection or if the patient or patient's history indicated prior MRSA infection. For purposes of this study, the term "MRSA infection" is used if a positive MRSA culture was

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obtained on a patient from any source. The term "positive screen" is used for patients who had a positive nasal PCR screen denoting MRSA colonization, but not an active MRSA infection.

All inpatient hospital admissions from October 1st to September 30th for 2007 to 2008 (before cohort) and 2010 to 2011 (after cohort) were analyzed. The 12-month interval between cohorts was included to allow full implementation across all units of the hospital. All patients in the after cohort underwent nasal MRSA PCR screening under the criteria mentioned above. Patients with a previous MRSA infection, as well as those readmitted with a previous positive screen for MRSA, were excluded. Patients who initially screened negative and subsequently developed an MRSA infection were considered to have HA-MRSA-I. A subset of patients undergoing a wide array of surgical procedures across multiple specialties in the before and after cohort were analyzed separately. These included general surgical, gynecologic, orthopedic, cardiothoracic, transplant, oral-maxillofacial, plastics, and urologic procedures. International Classification of Diseases, Clinical Modification, ninth revision (ICD-9) procedure codes were used to identify procedures by those specialties. Procedures were included in the analysis if at least 50 were performed during the study period. Logistic regression analysis was performed to determine which factors contributed to predicting HA-MRSA-I and how HA-MRSA-I affected patient mortality. P values <0.05 were considered significant.

Our primary endpoint was the incidence of HA-MRSA-I. The secondary endpoint was the impact of HA-MRSA-I on patient mortality. Multivariate regression techniques were used to elucidate predictors of these outcomes.

RESULTS

There were 36,244 patients in the before cohort, of whom 16,740 underwent a surgical procedure, and 36,068 in the after cohort, of whom 15,044 underwent a surgical procedure. Patient characteristics are shown in *Tables 1 and 2.*

Table 1. Patient characteristics for all patients and patients in the surgical group

	Combined	Before	After
All patients			
N	72,312	36,244	36,068
Age at admit, mean ± SD (years)	54.2 ± 19.2	54.1 ± 19.1	54.2 ± 19.3
Male	29,465 (41%)	15,020 (41%)	14,445 (40%)
Female	42,837 (59%)	21,216 (59%)	21,621 (60%)
Race			
White	43,215 (60%)	22,609 (63%)	20,606 (57%)
African American	18,473 (26%)	8,712 (24%)	9,761 (27%)
Hispanic	8,324 (12%)	3,770 (10.5)	4,554 (12.7%)
Asian	705 (1%)	289 (0.8%)	416 (1.2%)
Other	1047 (1.5%)	431 (1.2%)	616 (1.7%)
Length of stay, median (IQR) (days)	3.8 (2.3, 6.8)	3.8 (2.2, 6.8)	3.8 (2.3, 6.9)
Discharged alive	69.761 (97%)	34,917 (96%)	34,844 (97%)
Died	2,551 (4%)	1,327 (4%)	1,224 (3%)
Surgical group			
N	31,784	16,740	15,044
Age at admit, mean ± SD (years)	50.7 ± 18.5	51.1 ± 18.2	50.3 ± 18.8
Male	11,667 (37%)	6,416 (38%)	5,251 (35%)
Female	20,109 (63%)	10,317 (62%)	9,792 (65%)
Race			
White	21,021 (67%)	11,460 (70%)	9,561 (64%)
African American	5,820 (19%)	2,901 (18%)	2,919 (20%)
Hispanic	3,705 (12%)	1,727 (11%)	1,978 (13%)
Asian	373 (1.2%)	151 (1%)	222 (1.5%)
Other	473 (1.5%)	183 (1.1%)	290 (2%)
Length of stay, median (IQR) (days)	3.6 (2.3, 6.8)	3.7 (2.3, 6.7)	3.5 (2.3, 6.9)
Discharged alive	31,239 (98%)	16,430 (98%)	14,809 (98%)
Died	545 (1.7%)	310 (2%)	235 (2%)

SD indicates standard deviation; IQR, interquartile range.

The overall MRSA infection rate was 1.3% (453 patients) in the before cohort and 3.2% (1136 patients) in the after cohort (P< 0.001). When patients with previous MRSA infection or colonization were excluded, those with HA-MRSA-I decreased from 1.2% to 0.87% *(Table 3).* Similarly, there was an increase in the rate of overall MRSA infection in the surgical group, from 1.4% to 2.3%, along with a decrease in HA-MRSA-I, from 1.4% to 1.0% *(Table 3).*

For the total patient population, including both before and after cohorts, patients in the surgical group, African Americans, and patients with an increased length of stay had an increased likelihood of developing HA-MRSA-I. Female patients and patients in the after cohort were less likely to develop HA-MRSA-I *(Table 4).* When only patients in the after cohort were analyzed, the results were similar, with surgery, African American race, and length of stay associated with an increased risk of HA-MRSA-I, and female sex associated with a decreased risk *(Table 4).*

With regards to the likelihood of screening positive for MRSA colonization, African American race and increased age were associated with a higher likelihood of screening positive, while patients in the surgical group, female patients, and Hispanic patients were less likely to screen positive *(Table 5).* HA-MRSA-I was associated with a higher mortality for both the entire patient population and surgical group in both cohorts *(Table 5).* There was no significant difference in the overall mortality of patients with HA-MRSA-I

Table 2. Comparison of surgical versus nonsurgical patients

Variable	Surgical (N = 31,784)	Nonsurgical (N = 40,528)	*P* value
Age at admit, mean ± SD (years)	50.7 ± 18.5	56.9 ± 19.3	<.0001
Male	11,667 (37%)	17,798 (44%)	
Female	20,109 (63%)	22,728 (56%)	<.0001
Race			
White	21,021 (67%)	22,194 (55%)	
African American	5,820 (19%)	12,653 (31%)	
Hispanic	3,705 (12%)	4,619 (11%)	
Asian	373 (1.2%)	332 (0.8%)	
Other	473 (1.5%)	574 (1.4%)	<.0001
Length of stay, median (IQR) (days)	3.6 (2.3, 6.8)	3.9 (2.2, 6.8)	<.0001
Discharged alive	31,239 (98%)	38,522 (95%)	
Died	545 (1.7%)	2006 (5%)	<.0001

SD indicates standard deviation; IQR, interquartile range.

for all patients (10.8% vs 9.5%, $P = 0.55$) as well as the surgical group (8.3% vs 6.8%, $P = 0.58$).

DISCUSSION

Our data indicate that the overall MRSA infection rate increased during the study period for the entire patient population as well as for patients in the surgical group. This occurred despite implementation of the screening program. This is consistent with an overall increase in community-acquired MRSA infections, which Mera and colleagues demonstrated as an increase from 22.3% in 1998 to 66.1% in 2007 (11). The purpose of the MRSA screening program is to protect patients without previous colonization from acquiring an MRSA infection while in the hospital (HA-MRSA-I). While the desired outcome is to decrease MRSA infection rates hospitalwide, surveillance programs can also have a positive impact on HA-MRSA-I, despite an overall increase in MRSA infection rate.

When excluding patients with a history of MRSA infection or MRSA colonization, the overall HA-MRSA-I rate decreased by 27.5% for the overall patient population and 28.6% for the patients in the surgery group. Patients with MRSA nasal colonization are at a significant increased risk for the development of MRSA infections. Stenehjem and colleagues demonstrated this regardless of the quantitative burden detected on PCR screening. During their study period, 4.3% of noncarriers developed a MRSA infection compared with 18.5% and 17.2% of low- and high-burden patients, respectively (12).

Previous studies have demonstrated a greater than twofold increased incidence of MRSA infections among African Americans, 66.5 per 100,000, versus the standardized incidence rate of 31.8 per 100,000. Male patients had slightly higher infection rates at 37.5 per 100,000, while patients older than 65 years of age had rates of 127.7 per 100,000 (13). Our study showed that African American patients and patients with increased lengths of stay were at increased risk of developing MRSA infection, and that female patients had a decreased risk. Graffunder and colleagues identified previous surgery and longer lengths of stay before infection as independent risk factors for developing MRSA infection, along with previous hospitalization, enteral feedings, and macrolide and levofloxacin use (14).

The major limitation of this study is its retrospective design. Therefore, the majority of patients with a positive screen will be in the after cohort when the policy became hospitalwide. Since these patients are known to be at increased risk of developing MRSA infection and were omitted from the final analysis by our study criteria, this could potentially create a falsely elevated rate of HA-MRSA-I in the before group. However, given the retrospective observational nature of the study, the data pertaining to the rate of nasal carriage in the before group were not available. Nonetheless, the method of documenting HA-MRSA-I is consistent between the groups. Furthermore, no data regarding compliance with the screening protocol were available for our analysis. Suboptimal compliance with hand hygiene (52%, range 27%–86%), glove use (62%, range 11%–98%), and the use of gown or other protective clothing (57%, range 8%–93%) was reported by Gammon et al (15).

Improved MRSA infection rates have been demonstrated in certain patient populations where more aggressive measures were taken than standard barrier and isolation practices. MRSA infection rates decreased by 93% in cardiac surgical wounds after a program was initiated that not only screened patients, but included additional interventions such as decolonizing hospital staff who screen positive, providing vancomycin

Table 3. MRSA infection rates for patients in both cohorts

Cohort	Infection	Time	Yes	No	*P* value
All	All positive cultures	Before	453 (1.3%)	35,791 (98.8%)	
		After	1136 (3.2%)	34,932 (96.9%)	<.001
	Only HA-MRSA-I	Before	426 (1.2%)	35,791 (98.8%)	
		After	307 (0.87%)	34,932 (99.1%)	<.001
Surgical	All positive cultures	Before	236 (1.4%)	16,504 (98.6%)	
		After	345 (2.3%)	14,699 (97.7%)	<.001
	Only HA-MRSA-I	Before	229 (1.4%)	16,504 (98.6%)	
		After	148 (1.0%)	14,699 (99.0%)	0.002

HA-MRSA-I indicates health care–associated methicillin-resistant *Staphylococcus aureus* infection.

Table 4. Factors associated with health care–associated methicillin-resistant *Staphylococcus aureus* infection

Category	Variable	Odds ratio	95% CI	*P* value
In all patients				
Cohort	Before	—		
	After	0.73	(0.63, 0.85)	<.001
Surgery	No (referent)	—		
	Yes	1.3	(1.12, 1.51)	<.001
Age		1	(1.00, 1.01)	0.07
Sex	Male (referent)	—		
	Female	0.56	(0.48, 0.65)	<.001
Race	White (referent)	—		
	African American	1.31	(1.1, 1.55)	0.002
	Hispanic	0.99	(0.77, 1.28)	0.15
	Asian	0.29	(0.07, 1.18)	0.10
	Other	0.65	(0.31, 1.38)	0.65
Length of stay		1.05	(1.05, 1.06)	<.001
In the after cohort				
Surgery	No (referent)	—		
	Yes	1.33	(1.05, 1.70)	<.0167
Age		1.00	(1.0, 1.01)	0.3334
Sex	Male (referent)	—		
	Female	0.49	(0.39, 0.62)	<.0001
Race	White (referent)	—		
	African American	1.48	(1.45, 1.91)	0.0212
	Hispanic	1.00	(0.69, 1.47)	0.7821
	Asian	0.69	(0.17, 2.79)	0.5864
	Other	0.73	(0.27, 1.98)	0.5479
Length of stay		1.05	(1.03, 1.04)	<.0001

prophylaxis for patients who screen positive, and administering mupirocin calcium nasal ointment for all patients regardless of screening status (16). MRSA infections at percutaneous gastrostomy sites decreased from 12% to 29% over a 33-month period to 2% after a screening and decontamination program was initiated. The protocol involved screening for MRSA from multiple sites, nasal treatment with mupirocin, and daily skin decontamination prior to the procedure (17). MRSA infection rates among ICU patients decreased from 3.0% to 1.5% when enhanced cleaning procedures were used in rooms previously occupied by patients with MRSA. A similar reduction in vancomycin-resistant enterococci infection rates from 3.0% to 2.2% was also demonstrated (18). However, Camus and colleagues did not show a reduction in MRSA acquisition in the ICU setting with more aggressive intervention protocols, including repeated MRSA screening, contact and droplet isolation precautions, and decontamination with nasal mupirocin and chlorhexidine body wash for MRSA-positive patients (19).

HA-MRSA-I remains a serious problem in the modern health care environment. Our study suggests that surveillance programs are effective in decreasing these infections, both hospitalwide and among surgical patients. We also confirm the increased mortality associated with HA-MRSA-I. Further studies are needed to aid in the reduction of the transmission of this disease among hospitalized patients, with particular focus on African American patients and those with increased lengths of stay.

1. Shorr AF. Epidemiology of staphylococcal resistance. *Clin Infect Dis* 2007;45(Suppl 3):S171–S176.
2. Cosgrove SE, Sakoulas G, Perencevich EN, Schwaber MJ, Karchmer AW, Carmeli Y. Comparison of mortality associated with methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* bacteremia: a meta-analysis. *Clin Infect Dis* 2003;36(1):53–59.
3. Blot SI, Vandewoude KH, Hoste EA, Colardyn FA. Outcome and attributable mortality in critically ill patients with bacteremia involving methicillin-susceptible and methicillin-resistant *Staphylococcus aureus. Arch Intern Med* 2002;162(19):2229–2235.
4. Anderson DJ, Sexton DJ, Kanafani ZA, Auten G, Kaye KS. Severe surgical site infection in community hospitals: epidemiology, key procedures, and the changing prevalence of methicillin-resistant *Staphylococcus aureus. Infect Control Hosp Epidemiol* 2007;28(9):1047–1053.
5. Hidron AI, Edwards JR, Patel J, Horan TC, Sievert DM, Pollock DA, Fridkin SK; National Healthcare Safety Network Team; Participating National Healthcare Safety Network Facilities. NHSN annual update: antimicrobial-resistant pathogens associated with healthcare-associated infections: annual summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2006–2007. *Infect Control Hosp Epidemiol* 2008;29(11):996–1011.
6. Muto CA, Jernigan JA, Ostrowsky BE, Richet HM, Jarvis WR, Boyce JM, Farr BM; SHEA. SHEA guideline for preventing nosocomial transmission of multidrug-resistant strains of *Staphylococcus aureus* and enterococcus. *Infect Control Hosp Epidemiol* 2003;24(5):362–386.
7. Kallen AJ, Mu Y, Bulens S, Reingold A, Petit S, Gershman K, Ray SM, Harrison LH, Lynfield R, Dumyati G, Townes JM, Schaffner W, Patel PR, Fridkin SK; Active Bacterial Core surveillance (ABCs) MRSA Investigators of the Emerging Infections Program. Health care-associated invasive MRSA infections, 2005–2008. *JAMA* 2010;304(6):641–648.
8. Thompson RL, Cabezudo I, Wenzel RP. Epidemiology of nosocomial infections caused by methicillin-resistant *Staphylococcus aureus. Ann Intern Med* 1982;97(3):309–317.
9. Parvez N, Jinadatha C, Fader R, Huber TW, Robertson A, Kjar D, Cornelius LK. Universal MRSA nasal surveillance: characterization of outcomes at a tertiary care center and implications for infection control. *South Med J* 2010;103(11):1084–1091.
10. Harbarth S, Fankhauser C, Schrenzel J, Christenson J, Gervaz P, Bandiera-Clerc C, Renzi G, Vernaz N, Sax H, Pittet D. Universal screening for methicillin-resistant *Staphylococcus aureus* at hospital admission and nosocomial infection in surgical patients. *JAMA* 2008;299(10):1149–1157.
11. Mera RM, Suaya JA, Amrine-Madsen H, Hogea CS, Miller LA, Lu EP, Sahm DF, O'Hara P, Acosta CJ. Increasing role of *Staphylococcus aureus* and community-acquired methicillin-resistant *Staphylococcus aureus* infections

Table 5. Odds ratio of screening positive for MRSA colonization and of death for patients with health care–associated MRSA infection

Category	Variable	Odds ratio	95% CI	*P* value
Screening positive for MRSA colonization				
Surgery	No (referent)			
	Yes	0.53	(0.45, 0.62)	<.0001
Age		1.02	(1.02, 1.03)	<.0001
Sex	Male (referent)	—		
	Female	0.77	(0.67, 0.89)	0.0003
Race	White (referent)	—		
	African American	1.41	(1.21, 1.64)	0.0312
	Hispanic	0.70	(0.53, 0.92)	0.0003
	Asian	1.50	(0.81, 2.76)	0.2783
	Other	1.31	(0.79, 2.17)	0.5250
Death for patients with health care–associated MRSA infection				
All patients	Before	3.27	(2.40, 4.46)	<.0001
	After	3.12	(2.12, 4.60)	<.0001
Surgical patients	Before	5.06	(3.12, 8.21)	<.0001
	After	4.84	(2.51, 9.32)	<.0001

MRSA indicates methicillin-resistant *Staphylococcus aureus.*

in the United States: a 10-year trend of replacement and expansion. *Microb Drug Resist* 2011;17(2):321–328.

12. Stenehjem E, Rimland D. MRSA nasal colonization burden and risk of MRSA infection. *Am J Infect Control* 2013;41(5):405–410.
13. Klevens RM, Morrison MA, Nadle J, Petit S, Gershman K, Ray S, Harrison LH, Lynfield R, Dumyati G, Townes JM, Craig AS, Zell ER, Fosheim GE, McDougal LK, Carey RB, Fridkin SK; Active Bacterial Core surveillance (ABCs) MRSA Investigators. Invasive methicillin-resistant *Staphylococcus aureus* infections in the United States. *JAMA* 2007;298(15):1763–1771.
14. Graffunder EM, Venezia RA. Risk factors associated with nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infection including previous use of antimicrobials. *J Antimicrob Chemother* 2002;49(6):999–1005.
15. Gammon J, Morgan-Samuel H, Gould D. A review of the evidence for suboptimal compliance of healthcare practitioners to standard/universal infection control precautions. *J Clin Nurs* 2008;17(2):157–167.
16. Walsh EE, Greene L, Kirshner R. Sustained reduction in methicillin-resistant *Staphylococcus aureus* wound infections after cardiothoracic surgery. *Arch Intern Med* 2011;171(1):68–73.
17. Thomas S, Cantrill S, Waghorn DJ, McIntyre A. The role of screening and antibiotic prophylaxis in the prevention of percutaneous gastrostomy site infection caused by methicillin-resistant *Staphylococcus aureus. Aliment Pharmacol Ther* 2007;25(5):593–597.
18. Datta R, Platt R, Yokoe DS, Huang SS. Environmental cleaning intervention and risk of acquiring multidrug-resistant organisms from prior room occupants. *Arch Intern Med* 2011;171(6):491–494.
19. Camus C, Bellissant E, Legras A, Renault A, Gacouin A, Lavoué S, Branger B, Donnio PY, le Corre P, Le Tulzo Y, Perrotin D, Thomas R. Randomized comparison of 2 protocols to prevent acquisition of methicillin-resistant *Staphylococcus aureus:* results of a 2-center study involving 500 patients. *Infect Control Hosp Epidemiol* 2011;32(11):1064–1072.