

Universal Surveillance for Methicillin-Resistant *Staphylococcus aureus* in 3 Affiliated Hospitals

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Background: The effect of large-scale expanded surveillance for methicillin-resistant *Staphylococcus aureus* (MRSA) on health care-associated MRSA disease is not known.

Objective: To examine the effect of 2 expanded surveillance interventions on MRSA disease.

Design: Observational study comparing rates of MRSA clinical disease during and after hospital admission in 3 consecutive periods: baseline (12 months), MRSA surveillance for all admissions to the intensive care unit (ICU) (12 months), and universal MRSA surveillance for all hospital admissions (21 months).

Setting: A 3-hospital, 850-bed organization with approximately 40 000 annual admissions.

Intervention: Polymerase chain reaction-based nasal surveillance for MRSA followed by topical decolonization therapy and contact isolation of patients who tested positive for MRSA.

Measurements: Poisson and segmented regression models were used to compare prevalence density of hospital-associated clinical MRSA disease (bloodstream, respiratory, urinary tract, and surgical site) in each period. Rates of bloodstream disease with methicillin-susceptible *S. aureus* were used as a control.

Results: The prevalence density of aggregate hospital-associated MRSA disease (all body sites) per 10 000 patient-days at baseline,

during ICU surveillance, and during universal surveillance was 8.9 (95% CI, 7.6 to 10.4), 7.4 (CI, 6.1 to 9.0; $P = 0.15$ compared with baseline), and 3.9 (CI, 3.2 to 4.7; $P < 0.001$ compared with baseline and ICU surveillance), respectively. During universal surveillance, the prevalence density of MRSA infection at each body site had a statistically significant decrease compared with baseline. The methicillin-susceptible *S. aureus* bacteremia rate did not statistically significantly change during the 3 periods. In a segmented regression model, the aggregate hospital-associated MRSA disease prevalence density changed by -36.2% (CI, -65.4% to 9.8% ; $P = 0.17$) from baseline to ICU surveillance and by -69.6% (CI, -89.2% to -19.6% ; $P = 0.03$) from baseline to universal surveillance. During universal surveillance, the MRSA disease rate decreased during hospitalization and in the 30 days after discharge; no further reduction occurred thereafter. Surveillance with clinical cultures would have identified 17.8% of actual MRSA patient-days, and ICU-based surveillance with polymerase chain reaction would have identified 33.3%.

Limitation: The findings rely on observational data.

Conclusion: The introduction of universal admission surveillance for MRSA was associated with a large reduction in MRSA disease during admission and 30 days after discharge.

Ann Intern Med. 2008;148:409-418.

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Methicillin-resistant *Staphylococcus aureus* (MRSA) is now endemic in many U.S. hospitals (1, 2). Colonization with this organism is a risk factor for eventual MRSA clinical infection (3), which is associated with high cost (4) and poor clinical outcomes (5). The burden of health care-associated MRSA disease is high and may be increasing: In their multiregion survey of invasive MRSA disease, investigators for the Centers for Disease Control and Prevention noted substantial increases in both community- and health care-associated infections at several sites when comparing data from 2001 to 2002 with data from 2004 to 2005 (6). Driven by the emerging concern that community-associated MRSA has entered the hospital environment (7), the medical community and the public are seeking to limit the spread of this organism with increasing urgency (8). In the United Kingdom, the Department of Health has instituted mandatory reporting of MRSA infections in hospitals (9), and in the United States, state legislatures are considering (or have passed bills) requiring active surveillance for MRSA (10–12). Consumer organizations (13) and the media (14) also seek action. The Healthcare Infection Control Practices Advisory Committee of the Centers for Disease Control and Prevention (15) recently published guidelines rec-

ommending expanded surveillance of asymptomatic patients in settings in which multidrug-resistant organisms are poorly controlled with other measures. However, the evidence supporting this practice is limited to surveillance on circumscribed (for example, intensive care only) populations in small, single-center studies at large academic hospitals (16–18).

Because rates of MRSA infection remained unacceptably high despite conventional interventions, we implemented expanded surveillance at our 3-hospital health care organization in 2 steps. For 12 months, we implemented organization-wide, intensive care unit (ICU)-based MRSA

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Context

Efforts to reduce the frequency of methicillin-resistant *Staphylococcus aureus* (MRSA) infections have failed until now.

Contribution

After a baseline year, the authors screened all intensive care unit admissions for MRSA colonization using polymerase chain reaction. In year 3, they screened all hospital admissions. They placed patients who tested positive for MRSA on contact precautions. The prevalence density of MRSA clinical infection was 8.9, 7.4, and 3.9 per 10 000 patient-days in years 1, 2, and 3, respectively. Methicillin-sensitive *S. aureus* infection rates did not change.

Caution

There was no concomitant, unscreened control group.

Implication

Screening for MRSA colonization is associated with substantially reduced rates of MRSA clinical infection.

—The Editors

surveillance. On 1 August 2005, we initiated the first program (to our knowledge) of universal surveillance of all hospital admissions in the United States. We aimed to determine whether expanded surveillance was associated with changes in the rate of MRSA clinical disease.

METHODS

We measured the utility of expanded surveillance for MRSA by using a 3-period before-and-after design (Figure 1). Period 1 (no active surveillance) was the baseline. In periods 2 and 3, we introduced ICU-based surveillance and universal admission surveillance, respectively. We compared MRSA disease rates during and after hospitalization in the 3 periods.

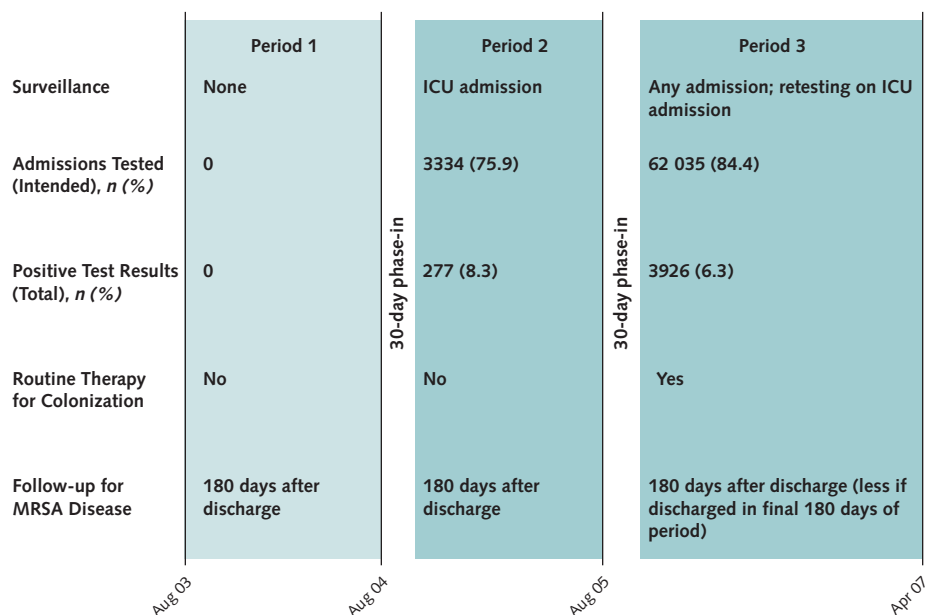
Outcomes

The primary outcome was aggregate hospital-associated MRSA infection rate, defined as the sum of all MRSA bloodstream, respiratory, urinary tract, and surgical site clinical infections occurring more than 48 hours after admission through day 30 after discharge. Secondary outcomes were rates of health care-associated MRSA and methicillin-susceptible *Staphylococcus aureus* (MSSA) bacteremia, rates of aggregate MRSA infections occurring up to 180 days after discharge, and adherence to MRSA surveillance. We defined adherence as the percentage of admissions (ICU or whole house, depending on the period) in which surveillance testing was done.

Study Sites

Evanston Northwestern Healthcare, Evanston, Illinois, is a 3-hospital organization with approximately 40 000 annual admissions, 75 affiliated off-site offices, 450 staff physicians, and more than 1000 affiliated physicians. Hospital 1 is an academic facility with several residency programs, 476 beds, and a high proportion of surgical patients. Hospital 2 is a primary care teaching hospital with 143 beds

Figure 1. Intervention timeline.



ICU = intensive care unit; MRSA = methicillin-resistant *Staphylococcus aureus*.

that serves a large population of long-term care facility residents (the elderly) relative to the other 2 hospitals. Hospital 3 is a community hospital with 239 beds. The total number of ICU beds was 45 (5.2% of all beds).

Surveillance, Isolation, and Decolonization

During the baseline year (period 1), routine surveillance for MRSA colonization did not occur. Patients who were MRSA-colonized on the basis of clinical cultures were placed in contact isolation, and decolonization was not attempted. During all periods, contact isolation consisted of a private room or a shared room with another MRSA-colonized patient. Gowns and gloves were required for all room entries, and patient rooms were supplied with dedicated equipment (for example, stethoscopes) for staff use. During period 2, a policy of nasal surveillance for MRSA colonization was enforced for all ICU admissions. Test turnaround time was 2.5 days. Colonized patients were isolated; decolonization therapy was not standard policy. During period 3, a policy of nasal surveillance for MRSA colonization was enforced for all hospitalizations on entry into a ward room (that is, day 1 of admission). A nurse or patient care technician obtained the specimen. Average test turnaround time was 0.67 day. Nursing staff were notified of results by telephone. Adherence was promoted through in-service education for all nursing staff and educational rounds for physicians (19). During this period, we monitored adherence and provided feedback in real time to underperforming nursing units. The infection control department recommended treatment of colonized patients with a 5-day regimen comprising mupirocin calcium, 2% twice daily to the nares, and a chlorhexidine 4% wash or shower every 2 days during period 3. Patients who were discharged before therapy was complete were sent home with prescriptions to complete this regimen. Because we felt that the decision to decolonize should be at the discretion of the physician, we did not monitor adherence to decolonization, nor did we define it as an outcome of the study. However, we had access to pharmacy data for most patients who tested positive for MRSA during the first 12 months of period 3, and we used it to determine adherence to at least 1 chlorhexidine wash and 4 or more doses of mupirocin (a quantity that seems as effective as 10 doses [20]). Patients were not removed from isolation after decolonization therapy unless another test (done at least 7 days after decolonization therapy during the same hospitalization or on repeated hospitalization) was negative for MRSA.

Laboratory Methods

Polymerase chain reaction tests for *S. aureus* colonization have better sensitivity than culture-based assays, but they may yield more false-positive results (21). Real-time polymerase chain reaction was used for MRSA detection in periods 2 (22) and 3 (21). Our in-house method and the commercial assay (BD-GeneOhm real-time polymerase chain reaction test, Becton Dickinson, Franklin Lakes,

New Jersey) have equal sensitivity (21, 22). For the commercial assay, we modified the package insert protocol for specimen processing to facilitate high-volume testing (21).

Data Collection

Demographic Characteristics

Administrative data were used to determine admission, procedure, and demographic data for all patients hospitalized from 1 August 2003 to 30 April 2007. We used International Classification of Diseases, Ninth Revision, diagnostic and procedure codes to generate comorbidity data according to the method of Elixhauser and coworkers (23) with Healthcare Cost and Utilization Project comorbidity software, version 3.2 (Agency for Healthcare Research and Quality, Rockville, Maryland) (24).

Infections

To measure the effect of our intervention, we were interested in true clinical disease due to MRSA. Therefore, we reviewed the records of all patients with positive inpatient or outpatient clinical cultures for MRSA from 1 August 2003 to 30 April 2007. Infections were determined as follows: bacteremia = any positive blood culture; bloodstream infection = positive blood culture in the absence of a positive clinical culture from another site; respiratory tract infection = positive respiratory culture, compatible chest radiograph, and decision to treat; urinary tract infection = positive urine culture and either a decision to treat or growth of more than 100 000 colony-forming units/mL plus at least 50 leukocytes per high-power field; and surgical site infection = positive culture of a surgical site. These infection types, although not encompassing all MRSA infections at our organization, represent the major body sites affected by culture-demonstrable MRSA disease.

Our primary outcome measure was the rate of clinical hospital-associated MRSA infections. Infections occurring more than 2 days after the admission date and within 30 days after discharge were considered hospital-associated. Rates of hospital-associated MRSA and hospital-associated MSSA were expressed as prevalence density of infections, that is, the number of infections per 10 000 inpatient-days. Patients were counted once every 30-day period. In a separate analysis of the timing of MRSA infections, disease prevalence (that is, infections per 10 000 admissions) was measured during admission and in 6 postdischarge, 30-day time frames.

Statistical Analysis

Rates of MRSA Infection

For 1 hospital-associated infection analysis, we compared infection rates among the 3 study periods with Poisson models that we implemented by using SAS PROC GENMOD (SAS software, SAS Institute, Cary, North Carolina) with Poisson distribution, log-link function, and log of patient days as the offset. Clinical MRSA infection count was the dependent variable, and study period was the independent variable (that is, period 1, 2, or 3). Fol-

lowing guidelines outlined by Shardell and colleagues (25), we further analyzed aggregate hospital-associated MRSA rates by using a segmented Poisson regression model. We did not do a time-series analysis because the number of time points was limited; however, serial data of this nature could exhibit autocorrelation, thus violating the independence assumption of the Poisson model. We therefore used the Durbin–Watson test to check for statistically significant first-order autocorrelation ($P = 0.37$). Furthermore, we calculated 95% CIs for all model measurements by using bootstrap resampling techniques stratified by hospital. The bootstrap does not require independent observation for valid inference (26). For this model, monthly infection count was the dependent variable, log of patient days was the offset, and study period and time (months) since the start of each study period were the independent variables. Admitting hospital was included as an additional independent variable because it is a potential confounding factor. Only the aggregate hospital-associated MRSA rates were analyzed in this manner because of concern that small rates of infection for the nonaggregate categories (for example, urinary tract infection and bacteremia) would lead to unstable model estimates. For both models, we excluded infections that occurred during the first month of each surveillance period (August 2004 and August 2005) (phase-in period).

To evaluate the effect of surveillance on the timing of aggregate MRSA infections relative to admission, we used the Poisson distribution to compare infection rates in the 3 study periods within categories defined by time since the most recent hospitalization (during admission, 1 to 30 days, 31 to 60 days, 61 to 90 days, 91 to 120 days, 121 to 150 days, and 151 to 180 days), with log of patient admissions as the offset. For this model, we attributed an infection to an admission if it occurred more than 48 hours after admission. Otherwise, we attributed it to the most recent previous admission within 180 days. We used SAS software for all analyses.

Sensitivity of Each Surveillance Strategy

We compared the number of isolation-days captured (that is, days during which a patient colonized or infected with MRSA was appropriately placed in isolation) for each study period. This measure of the effectiveness of surveillance strategies is important because contact isolation of colonized patients protects uncolonized patients from acquiring MRSA (27).

We estimated the number of captured isolation-days that could have occurred during periods 1 and 2 by using data from patients seen during the first 12 months of period 3, when the MRSA status of all patients was known. We assumed that patients with MRSA would have been isolated during period 1 (no surveillance) if they had a positive clinical culture (any site), with isolation beginning 3 days after this culture was collected (an expected turn-

around time) and continuing until the end of the admission. We assumed that these patients would have been isolated during period 2 (ICU surveillance) if they had a positive clinical culture or if they had a positive surveillance test and were admitted to ICU during their admission, starting 2.5 days after their ICU admission began (the surveillance test turnaround time in period 2) and continuing until the end of the admission. We assumed that patients were isolated during period 3 (universal surveillance) if they had a positive clinical culture or a positive surveillance test, starting 0.67 days after admission (the surveillance test turnaround time in period 3) and continuing until the end of the admission. For this analysis, we assumed that all positive nasal test results indicated true colonization and that once colonized, patients required isolation until discharge.

Role of the Funding Source

This study received no external funding, and only the authors had a role in the study design, data analysis, data interpretation, or writing of this article. The corresponding author had full access to all the data and had final responsibility for the decision to submit for publication.

RESULTS

Surveillance and Decolonization

The number and characteristics of patients admitted during the 3 periods were similar (Table 1). During ICU surveillance, 3334 of 4392 (75.9%) ICU admissions were tested for MRSA, and 277 (8.3%) were positive. Adherence to universal surveillance was initially 75% but steadily increased to 90% by the end of period 3 (Figure 2). Overall, during universal surveillance, 62 035 of 73 464 (84.4%) admissions were tested, and 3926 (6.3%) were positive. Data on mupirocin administration were available for 2085 admitted patients who tested positive for MRSA. At least 4 doses of mupirocin were administered in 1288 (62%) instances. Data on chlorhexidine administration were available for 1883 admissions; 1044 (55%) patients received at least 1 chlorhexidine wash.

Methicillin-Resistant *Staphylococcus aureus* Clinical Disease

Throughout the study period, we monitored for MRSA infections by checking clinical cultures from all inpatient and outpatient locations and using standardized criteria to determine whether they represented true disease. The aggregate hospital-associated MRSA prevalence density per 10 000 patient-days at baseline, during ICU surveillance, and during universal surveillance was 8.9 (95% CI, 7.6 to 10.4), 7.4 (CI, 6.1 to 9.0), and 3.9 (CI, 3.2 to 4.7), respectively. Therefore, the absolute change between baseline and ICU surveillance was -1.5 infections per 10 000 patient-days (CI, -3.4 to 0.5 infections per 10 000 patient-days), and the absolute change between baseline and universal surveillance was -5.0 infections per 10 000

Table 1. Characteristics of Hospitalized Patients in the 3 Study Periods*

Characteristic	Patients, n (%)		
	No Active Surveillance (n = 39 521)	Intensive Care Unit Surveillance (n = 40 392)	Universal Surveillance (n = 73 427)
Demographic			
Sex			
Female	24 616 (62.3)	25 074 (62.1)	45 343 (61.8)
Male	14 904 (37.7)	15 318 (37.9)	28 083 (38.2)
Ethnicity			
White	31 015 (78.5)	31 251 (77.4)	56 100 (76.4)
Black	3187 (8.1)	3164 (7.8)	5952 (8.1)
Other	2958 (7.5)	3401 (8.4)	6690 (9.1)
Hispanic	1472 (3.7)	1654 (4.1)	2930 (4.0)
Asian	783 (2.0)	815 (2.0)	1526 (2.1)
Native American	106 (0.3)	107 (0.3)	229 (0.3)
Long-term care residence	4212 (10.7)	4710 (11.7)	8697 (11.8)
Hospital admission in the past year	12 924 (32.7)	13 316 (33.0)	25 415 (34.5)
Admission			
Admission type			
Emergent	23 550 (59.6)	24 602 (60.9)	45 511 (62.0)
Elective	15 971 (40.4)	15 790 (39.1)	27 885 (38.0)
Admitting service			
Medicine	23 696 (60.0)	24 573 (60.8)	48 322 (65.8)
Surgery	7059 (17.9)	7296 (18.1)	10 429 (14.2)
Obstetrics	5507 (13.9)	5307 (13.1)	9195 (12.5)
Pediatrics	1380 (3.5)	1460 (3.6)	2508 (3.4)
Psychiatry	953 (2.4)	904 (2.2)	1663 (2.3)
Other	926 (2.3)	852 (2.1)	1310 (1.8)
Discharge disposition			
Home	31 188 (78.9)	30 768 (76.2)	55 057 (75.0)
Long-term care	3797 (9.6)	4476 (11.1)	8694 (11.8)
Home with care	3203 (8.1)	3742 (9.3)	7321 (10.0)
Died	719 (1.8)	754 (1.9)	1353 (1.8)
Hospital	377 (1.0)	381 (0.9)	666 (0.9)
Against medical advice	160 (0.4)	195 (0.5)	294 (0.4)
Other	77 (0.2)	76 (0.2)	39 (0.1)
Admitted to intensive care during admission	4187 (10.6)	4392 (10.9)	8050 (11.0)
Central line during admission	1470 (3.7)	1602 (4.0)	3258 (4.4)
Surgery during admission	10 576 (26.8)	10 665 (26.4)	19 057 (26.0)
Medical conditions			
Positive MRSA clinical culture in past year	415 (1.0)	454 (1.1)	779 (1.1)
Comorbid condition†			
Diabetes mellitus	5159 (13.2)	5651 (14.0)	10 745 (14.6)
Chronic lung disease	4347 (11.1)	4567 (11.3)	8526 (11.6)
Congestive heart failure	2671 (6.8)	2923 (7.2)	5611 (7.6)
Cancer	1829 (4.7)	1780 (4.4)	3494 (4.8)
Renal failure	1070 (2.7)	1108 (2.7)	3675 (5.0)
Liver failure	539 (1.4)	617 (1.5)	1115 (1.5)

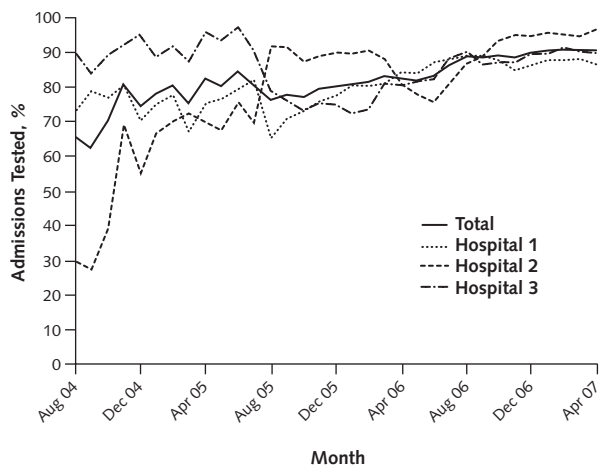
* MRSA = methicillin-resistant *Staphylococcus aureus*.

† Combines “diabetes without chronic complications” with “diabetes with chronic complications,” and “solid tumor without metastases” with “metastatic cancer” and “lymphoma.”

patient-days (CI, -6.6 to -3.5 infections per 10 000 patient-days) (Table 2). In the segmented Poisson regression model, the change from baseline to ICU surveillance was -36.2% (CI, -65.4% to 9.8%). The change from ICU surveillance to universal surveillance was -52.4% (CI, -78.3% to -9.3%), and the change from baseline to universal surveillance was -69.6% (CI, -89.2% to -19.6%). The slopes of the regression lines during the 3 periods did not differ (Table 3 and Figure 3). Admitting hospital was not independently associated with differences in MRSA prevalence density.

In the simple Poisson analysis, rates of all MRSA infections were reduced during universal surveillance relative to baseline, and rates did not change from baseline to ICU surveillance. To control for the possibility that the reduction in MRSA disease was due to an unrecognized co-intervention, we compared changes in prevalence density of hospital-associated MRSA bacteremia with those of hospital-associated MSSA bacteremia. Rates of MRSA bacteremia statistically significantly decreased after implementation of universal surveillance compared with baseline values (absolute reduction, 1.1 per 10 000 patient-days [CI, -1.9

Figure 2. Adherence to methicillin-resistant *Staphylococcus aureus* admission testing during intensive care unit surveillance (August 2004 to August 2005) and universal surveillance (August 2005 to April 2007).



to -0.2 per 10 000 patient-days]), whereas rates of MSSA bacteremia did not change (absolute reduction, 0.5 per 10 000 patient-days [CI, -1.4 to 0.3 per 10 000 patient-days]) (Table 2).

The effect of universal surveillance on rates of MRSA disease extended for 30 days after discharge but did not

affect the rate of infection 31 to 180 days after discharge, which was the same in the 3 study periods (Figure 4).

Surveillance Strategy Sensitivity

Patients spent a total of 11 454 patient-days in isolation during the first 12 months of universal surveillance. In the absence of a surveillance strategy (for example, period 1), patients whose MRSA was detected by clinical cultures alone would have spent 2036 isolation-days (17.8% of the total number of MRSA-related isolation-days seen during universal surveillance). In the setting of an ICU-based program (for example, period 2), 3814 (33.3%) of the isolation-days seen during universal surveillance would have been identified.

DISCUSSION

On 1 August 2005, we initiated the first (to our knowledge) multihospital, universal MRSA surveillance effort in the United States and the first such program worldwide to use a rapid-turnaround molecular diagnostic test. The principal novel contributions of our study are to report outcomes associated with universal inpatient surveillance for MRSA, to compare the sensitivity for detecting MRSA colonization and the effect on MRSA disease of several surveillance strategies, and to examine the effect of a hospital-based MRSA control intervention on community-onset, health care-associated MRSA disease after a hospital stay.

The effect of focused MRSA surveillance in high-risk

Table 2. Prevalence Density of Hospital-Associated Methicillin-Resistant *Staphylococcus aureus* and Methicillin-Susceptible *Staphylococcus aureus* Infections in 3 Periods*

Criteria	No Active Surveillance	Intensive Care Unit Surveillance	P Value†	Universal Surveillance	P Value†
Total patient-days	172 876	150 418	–	275 862	–
Prevalence density‡ of MRSA infection (95% CI)					
Bloodstream	1.45 (0.94 to 2.13)	1.26 (0.76 to 1.97)	–	0.44 (0.22 to 0.76)	–
Respiratory	2.89 (2.15 to 3.81)	2.93 (2.13 to 3.93)	–	1.05 (0.70 to 1.51)	–
Urinary tract	1.74 (1.17 to 2.48)	1.20 (0.71 to 1.89)	–	0.76 (0.47 to 1.16)	–
Surgical site	2.83 (2.10 to 3.75)	2.06 (1.40 to 2.93)	–	1.63 (1.19 to 2.18)	–
Bacteremia					
MRSA	2.14 (1.51 to 2.95)	1.99 (1.35 to 2.85)	–	1.09 (0.73 to 1.55)	–
MSSA	2.14 (1.51 to 2.95)	1.93 (1.29 to 2.77)	–	1.60 (1.16 to 2.14)	–
Total	8.91 (7.56 to 10.43)	7.45 (6.13 to 8.96)	–	3.88 (3.18 to 4.69)	–
Absolute change in prevalence density from baseline (95% CI), %					
Bloodstream	–	-0.18 (-0.99 to 0.62)	0.66	-1.01 (-1.63 to -0.39)	<0.001
Respiratory	–	0.03 (-1.15 to 1.21)	0.96	-1.84 (-2.79 to -0.90)	<0.001
Urinary tract	–	-0.54 (-1.37 to 0.29)	0.21	-0.97 (-1.62 to -0.33)	0.004
Surgical site	–	-0.77 (-1.85 to 0.30)	0.165	-1.20 (-2.07 to -0.34)	0.008
Bacteremia					
MRSA	–	-0.15 (-1.14 to 0.85)	0.77	-1.05 (-1.87 to -0.24)	0.006
MSSA	–	-0.21 (-1.20 to 0.77)	0.77	-0.55 (-1.39 to 0.30)	0.30
Total	–	-1.46 (-3.43 to 0.51)	0.149	-5.03 (-6.59 to -3.47)	<0.001

* “Hospital-associated” is defined as infection occurring >48 hours after admission and ≤30 days after discharge. MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-susceptible *Staphylococcus aureus*.

† Compared with baseline.

‡ Expressed as infections/10 000 patient-days.

Table 3. Segmented Poisson Regression Model: Aggregate Hospital-Associated Methicillin-Resistant *Staphylococcus aureus* Infections*

Data	Surveillance Period		
	Baseline	Intensive Care Unit	Universal
Adjusted prevalence density† ratio (95% CI)			
Relative to previous period	–	0.64 (0.35–1.10)	0.48 (0.22–0.91)
Relative to baseline	–	–	0.30 (0.11–0.80)
Time parameter estimate of regression line segment‡ (95% CI)	1.00 (0.94–1.07)	1.04 (0.95–1.12)	0.95 (0.89–1.02)

* “Hospital-associated” is defined as infection occurring >48 hours after admission and ≤30 days after discharge. The model is adjusted for potential confounding influence of hospital; 95% CIs are based on the bootstrap resampling, stratified by hospital.

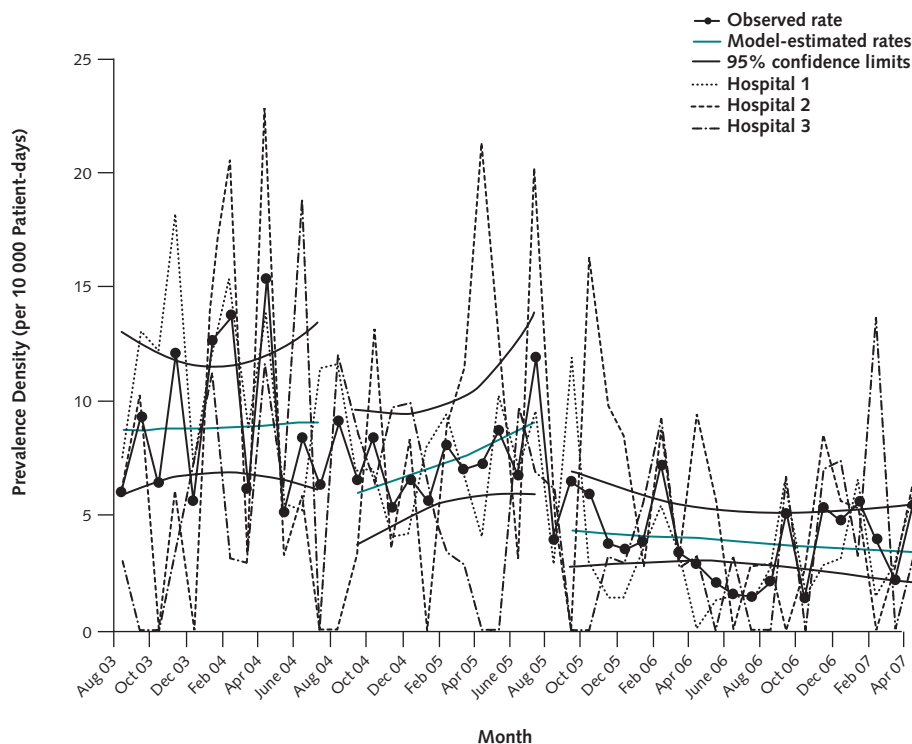
† Expressed as infections/10 000 patient-days.

‡ Multiplicative slope estimate for regression segment (monthly multiplier for change in prevalence density).

units, such as ICUs, has been previously examined. Huang and colleagues (16) reported a 67% reduction in the predicted rate of MRSA bacteremia after the implementation of nasal surveillance in their ICU. However, the single hospital involved had a very high projected incidence of intrahospital MRSA bacteremia (4.6 hospital-acquired MRSA bloodstream infections per 1000 admissions compared with our incidence of 0.46 per 1000 admissions before universal surveillance), a higher proportion of ICU beds (10% compared to 5% in our hospital group), and a

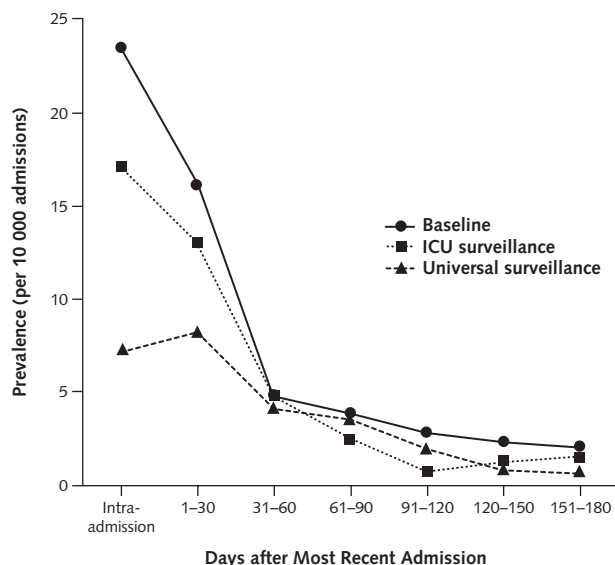
relatively long length of stay of their MRSA-colonized ICU patients (35 days compared with 10.5 days in our study) (28). Whereas other investigators have reported success with ICU-only surveillance (29), some have had disappointing results (30, 31), just as we did when we used surveillance confined to the ICU. Some also achieved MRSA disease reductions through active surveillance of “high-risk” patient populations (17, 32).

Previous work suggests that performing culture in patients with suspected infection identifies only 15% of pa-

Figure 3. Segmented Poisson regression model: aggregate hospital-associated methicillin-resistant *Staphylococcus aureus* prevalence density throughout the study time frame.


Intensive care unit surveillance was initiated on 1 August 2004, and universal admission surveillance was initiated on 1 August 2005. “Hospital-associated” is defined as infection occurring >48 hours after admission and ≤30 days after discharge.

Figure 4. Timing of methicillin-resistant *Staphylococcus aureus* infections relative to admission during the 3 study periods.



All intra-admission differences are statistically significant, as are the differences between universal surveillance and the other periods at 1 to 30 days. ICU = intensive care unit.

tients with MRSA infection (33), similar to the 18% sensitivity that we found for the same strategy. Jernigan and associates (27) estimated a 0.14 patient-per-day rate of MRSA transmission by a carrier who is not subject to contact isolation, a rate that is 16-fold higher than when contact isolation is used (27). During the first year of universal surveillance, our 3 hospitals had 11 454 MRSA isolation-days. With no surveillance, clinical cultures alone would have captured 2036 of those days. Thus, 9418 MRSA patient-days would have been spent without infection control contact precautions to limit MRSA spread. Using Jernigan and associates' transmission rate estimates that 1319 transmissions of MRSA (from the 9418 MRSA patient-days not spent in isolation) would have occurred. With universal surveillance, 82 transmissions would be expected among these patients, an improvement that could plausibly account for the marked reduction in MRSA infections in our hospitals.

Illinois recently mandated ICU surveillance for MRSA in all short-term care hospitals (11), and the Veterans Health Administration system has adopted a similar strategy as a bridge to universal surveillance (34). Our study results showed a much smaller effect of surveillance confined to patients in the ICU, suggesting disappointing results from these 2 ICU-based efforts. Because our study was conducted at a single organization, our findings are not generalizable to everyone. However, given the intermediate size and community-based nature of our 3 hospitals, our

experience is probably representative of most U.S. hospitals.

As part of our assessment, we investigated the "reach" of our hospital-based intervention by examining its effect in different time frames during and after admission (Figure 4). Universal surveillance was accompanied by statistically significant reductions in intra-admission disease and in disease occurring up to 30 days after discharge. This suggests that the highest risk for disease occurs shortly after new MRSA acquisition, as is seen with other microorganisms (35, 36). Furthermore, it suggests that the metric for judging an MRSA control program is the rate of disease occurring during admission through 30 days after discharge.

Our study has several limitations. First, the temporal association between the initiation of universal surveillance and the decline in MRSA disease rates does not prove that surveillance caused the reduced disease rates. However, disease reduction persisted during the 21 months after the institution of universal surveillance, no statistically significant accompanying reduction in MSSA bacteremia occurred, and patients had similar baseline characteristics during all 3 periods (Table 1). In addition, these findings are consistent with those of previous smaller studies (16–18, 27, 29–32, 37) and are explained by our demonstration that universal surveillance identified more than 5 times more MRSA patient-days than did clinical culture alone. Of note, we may have missed MRSA infections that occurred after discharge if patients went outside our system for their care. However, our laboratory receives specimens from the 3 hospitals and 75 off-site facilities, and we represent the largest health care presence in our region. Therefore, we consider it reasonable to expect that we captured a large proportion of patients with culture-positive disease. Second, because we could not measure MRSA isolation-days directly, we estimated them by assuming that patients were isolated immediately after they reported positive test results. Surveys by our infection control practitioners confirm this assumption. Finally, a potential limitation is our approach to decolonization therapy. Some favor decolonization therapy for MRSA-colonized patients (32) and others do not (16). Our study was not designed to evaluate the relative effectiveness of decolonization, and we did not monitor for adherence to that part of our program. Thus, a decolonization component of an MRSA control program remains an important area of further study.

In conclusion, we have described what we believe is the first large-scale, universal-admission MRSA surveillance program in the United States. We did rapid-turnaround testing followed by isolation and decolonization of patients who tested positive for MRSA and did not presumptively isolate patients of unknown MRSA status. Our hospitals achieved 90% adherence to the surveillance program. The program was associated with a reduction by more than half of health care-associated MRSA bloodstream, respiratory, urinary tract, and surgical site disease occurring during admission and in the 30 days after discharge.

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Acknowledgment: The authors thank Judson Vosburg and the Evanston Northwestern Healthcare administration for their support, Toni-Marie Gonzalzes for chart review, and Ilana Segal and Michael Klompas for thoughtful comments on the manuscript.

Potential Financial Conflicts of Interest: *Consultancies:* R.B. Thomson (GlaxoSmithKline), K.L. Kaul (Roche). *Honoraria:* A. Robicsek (Becton Dickinson), S.M. Paule (Becton Dickinson), R.B. Thomson (Becton Dickinson), K.L. Kaul (Roche, Becton Dickinson), L.R. Peterson (Becton Dickinson). *Grants received:* K.L. Kaul (Roche), L.R. Peterson (Becton Dickinson, Cepheid, 3M, Roche, Nanosphere). *Grants pending:* A. Robicsek (Becton Dickinson), L.R. Peterson (Becton Dickinson, Cepheid, 3M, Roche).

Reproducible Research Statement: *Study protocol:* Available from Dr. Peterson (e-mail, lancer@northwestern.edu). *Statistical code:* Available from Dr. Robicsek (e-mail, ari.robicsek@gmail.com). *Data set:* Available from Dr. Robicsek (e-mail, ari.robicsek@gmail.com).

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Annals sends about half of submitted manuscripts for peer review and publishes about 12% of submitted material. The 2007 processing and notification turnaround time for manuscripts that were rejected without external peer review was within 2 weeks for more than 95% of submitted manuscripts. The processing and notification turnaround time for manuscripts that were received and rejected after external peer review was within 8 weeks for 90% and within 10 weeks for 95%. The processing and notification turnaround time for manuscripts that were expedited by editors was within 4 to 6 weeks for 95%.

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