ORIGINAL CONTRIBUTION

Health Care–Associated Invasive MRSA Infections, 2005-2008

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Context Methicillin-resistant *Staphylococcus aureus* (MRSA) is a pathogen of public health importance; MRSA prevention programs that may affect MRSA transmission and infection are increasingly common in health care settings. Whether there have been changes in MRSA infection incidence as these programs become established is unknown; however, recent data have shown that rates of MRSA bloodstream infections (BSIs) in intensive care units are decreasing.

Objective To describe changes in rates of invasive health care–associated MRSA infections from 2005 through 2008 among residents of 9 US metropolitan areas.

Design, Setting, and Participants Active, population-based surveillance for invasive MRSA in 9 metropolitan areas covering a population of approximately 15 million persons. All reports of laboratory-identified episodes of invasive (from a normally sterile body site) MRSA infections from 2005 through 2008 were evaluated and classified based on the setting of the positive culture and the presence or absence of health care exposures. Health care–associated infections (ie, hospital-onset and health care–associated community-onset), which made up 82% of the total infections, were included in this analysis.

Main Outcome Measures Change in incidence of invasive health care–associated MRSA infections and health care–associated MRSA BSIs using population of the catchment area as the denominator.

Results From 2005 through 2008, there were 21 503 episodes of invasive MRSA infection; 17 508 were health care associated. Of these, 15 458 were MRSA BSIs. The incidence rate of hospital-onset invasive MRSA infections was 1.02 per 10 000 population in 2005 and decreased 9.4% per year (95% confidence interval [CI], 14.7% to 3.8%; $P = .005$), and the incidence of health care–associated community-onset infections was 2.20 per 10 000 population in 2005 and decreased 5.7% per year (95% CI, 9.7% to 1.6%; $P = .01$). The decrease was most prominent for the subset of infections with BSIs (hospital-onset: –11.2%; 95% CI –15.9% to –6.3%; health care–associated community-onset: –6.6%; 95% CI –9.5% to –3.7%).

Conclusion Over the 4-year period from 2005 through 2008 in 9 diverse metropolitan areas, rates of invasive health care–associated MRSA infections decreased among patients with health care–associated infections that began in the community and also decreased among those with hospital-onset invasive disease.

JAMA. 2010;304(6):641-648 www.jama.com

An estimated 1.7 million health care–associated infections are associated annually with 99 000 deaths in US hospitals.[1] Although many pathogens can cause health care–associated infections, about 16% of those recently reported to the Centers for Disease Control and Prevention's (CDC's) National Healthcare Safety Network were associated with pathogens that were resistant to the antimicrobials traditionally used to treat them.[2] These multidrug-resistant organisms pose important treatment challenges, so preventing their transmission in health care facilities is an important patient safety priority. Perhaps no organism has garnered more attention than methicillin-resistant *Staphylococcus aureus* (MRSA), and preventing health care–associated MRSA infections has become a goal for public health agencies and policy makers.[3]

For editorial comment see p 687.

Although several studies have demonstrated reductions in health care–associated MRSA infections following the implementation of prevention in-

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terventions, these studies have primarily been limited to single or small collections of centers.[4-9] Demonstration of similar reductions on a larger scale in the United States have been limited to evaluations of central line–associated MRSA bloodstream infections (BSIs) in intensive care units.[10] Large decreases in MRSA BSIs have also been reported in England following a government mandate.[11,12]

National data describing changes in incidence in US acute care hospitals are not available. Therefore, to better characterize changes in MRSA infections in the United States, we used a population-based surveillance system to evaluate the incidence of invasive health care–associated MRSA infections from 2005 through 2008.

METHODS

Surveillance Population

Data on invasive MRSA infections were collected from facilities participating in the CDC's Emerging Infections Program/Active Bacterial Core surveillance system. This is an active population-based surveillance program that since mid-2004 has received laboratory reports on invasive MRSA in 9 geographically diverse metropolitan areas, covering a population of approximately 15 million persons in 2008, including the state of Connecticut (estimated population 3.5 million); the Atlanta, Georgia, metropolitan area (Clayton, Cobb, DeKalb, Douglas, Fulton, Gwinnett, Newton, and Rockdale counties; estimated population 3.8 million); the San Francisco Bay area, California (Alameda, Contra Costa, and San Francisco counties; estimated population 3.3 million); the Denver, Colorado, metropolitan area (Arapahoe county; estimated population 554 000); the Portland, Oregon, metropolitan area (Clackamas, Multnomah, Washington counties; estimated population 1.6 million); Monroe County, New York (estimated population 733 000); Baltimore City, Maryland (estimated population 637,000); Davidson County, Tennessee (estimated population 626 000); and Ramsey County, Minnesota (estimated population 501 000). This analysis included only population catchment areas participating in the surveillance program continuously since January 2005.

Definitions

Cases of invasive MRSA infection were defined as isolation of MRSA from a normally sterile body site in a resident of the surveillance area during 2005-2008. Cases were identified from microbiology reports provided by all clinical microbiology laboratories in acute-care facilities and reference laboratories that receive specimens for residents of the areas under surveillance. Surveillance personnel complete a standard case report form using data abstracted from inpatient and outpatient medical records. A more detailed description of the methods used for the project is available elsewhere.[13]

For analysis, cases of invasive MRSA infection were classified into mutually exclusive categories. Cases were considered hospital-onset if the clinical culture from which MRSA was isolated was obtained on or after hospital day 4 (day of admission counted as day 1); were considered health care–associated community-onset if MRSA was isolated from an outpatient or 3 or fewer calendar days after an admission but recent exposure to health care is documented for the case; and were considered community-associated if MRSA was isolated from an outpatient or 3 or fewer calendar days after an admission and no recent health care exposure is documented. The 3-calendar-day period is currently recommended as a proxy for laboratory-based categorization of multidrug-resistant organisms such as MRSA into hospital-onset and community-onset groups.[14] Recent health care exposures included presence of a central venous catheter at hospital admission or documentation of at least 1 of the following in the prior year: an overnight stay in an acute care or long-term care facility, receipt of dialysis, or surgery. For this analysis, documented history of either infection or colonization with MRSA was not sufficient to categorize cases as health care associated.

Cases were also categorized into infection syndromes based on diagnoses present in the medical records. Syndromes were classified as pneumonia or empyema, skin and soft tissue infections, bone and joint infections, urinary tract infections, endocarditis, or "other." Cases were categorized as BSIs if there was a positive blood culture for MRSA. Each case could represent more than one infection syndrome.

Human Subjects Considerations

The invasive MRSA surveillance project underwent ethical review at the CDC and was determined to be a nonresearch activity. It was therefore not subject to a review by a CDC institutional review board. This activity was also evaluated independently at each program site and either deemed a public health assessment or human subjects research and approved by local review boards when applicable.

Statistical Analysis

Because the focus of this evaluation was on health care–associated incidence rates, this analysis included only hospital-onset and health care–associated community-onset infections. Annual invasive MRSA infection pooled mean incidence was calculated by epidemiological category (ie, hospital-onset and health care–associated community-onset) for all sites combined; rates were also stratified for age, sex, and race-specific incidence rates by year and epidemiological category.

Rates were calculated using US census estimates of the surveillance area population for each year as the denominator. Denominators for annual pooled mean incidence rates of invasive MRSA infections among patients undergoing dialysis were calculated using data from the US Renal Data System (ie, the point prevalence of dialysis patients in the Medicare End-Stage Renal Disease program on December 31, 2004, 2005, 2006, or 2007); the numerator included patients who had dialysis within

1 year of their invasive infection. For each incidence rate, exact 95% confidence intervals (CIs) were calculated using a Poisson distribution.

Changes in incidence over time, stratified by epidemiological category, were preliminarily assessed using a Poisson regression model among Emerging Infections Program sites. The outcome variable was number of invasive MRSA infections, the population of the catchment area was the offset, and time (year), as a continuous variable, was the predictor. To estimate the overall rate of change for all sites from 2005 through 2008, a hierarchical modeling method was used (hereafter referred to as the modeled rate). Because both the 2005 invasive MRSA infection incidence (intercepts) and the temporal trends (slopes for year) varied by site, a mixed model was fitted to include 2 additional sources of variation, the intercept and the slope for year at each site, which were included in the model as random effects.

Models were fitted for all invasive MRSA infections initially and subsequently for MRSA BSIs. The models for all invasive MRSA and for MRSA BSIs were adjusted for 2 site-level variables, age (ie, proportion >65 years) and race (ie, proportion black race). When using different dichotomous age break points (ie, ≤18 vs >18 years, and ≤40 vs >40 years) in separate models, the change estimate did not differ substantially from the estimate generated by the primary model. In addition, including age as a continuous variable (without race in the model) did not change the point estimates. Including age as a continuous variable with race in the same model could not be accomplished do to limited power in the resulting individual strata. Therefore, we chose to include both age and race as dichotomous variables. Because the highest incidence of invasive MRSA occurred in patients aged 65 years or older, we used this as our age break point in the final model.

The yearly decrease in dialysis patients was also modeled using a similar hierarchical modeling method; however, because race and age information was not available for the dialysis denominator, we were unable to adjust these models for these variables. Point estimates and 95% CIs for the yearly percent change were determined using each model. *P* values <.05 were considered statistically significant. These final models were also used to determine the adjusted incidence for each epidemiology category for each year studied. Forest plots were constructed to demonstrate the differences in crude yearly percent changes and 95% CIs for each site. Analyses were performed using Stata software version 9.2 (Stata Corp, College Station, Texas) and SAS software version 9.2 (SAS Institute Inc, Cary, North Carolina).

RESULTS

Case Characteristics

Overall, Emerging Infections Program/Active Bacterial Core surveillances sites reported 21 503 cases of invasive MRSA infections for the years 2005 through 2008. Of these, 21 333 reports (99%) allowed categorization into epidemiological classes: 12 235 infections (57%) were health care–associated community-onset, 5273 (25%) were hospital-onset, and 3825 (18%) were community-associated. The percentage of overall infections that were health care–associated community-onset did not change significantly over the 4

Table 1. Invasive Methicillin-Resistant *Staphylococcus aureus* Infections Representing Specific Syndromes, January 2005-December 2008

	No. (%) of Patients With Hospital-Onset Invasive Infections					
	Year					
Syndrome	2005	2006	2007	2008	Total	*P* Value[a]
Bloodstream infection	1305 (87)	1161 (86)	1081 (84)	949 (84)	**4496 (85)**	.06
Bloodstream infection only	790 (61)	750 (65)	620 (57)	518 (55)	**2678 (60)**	<.01
Pneumonia or empyema	258 (17)	210 (16)	242 (19)	229 (20)	**939 (18)**	.01
Skin or soft tissue infection	105 (7)	88 (7)	95 (7)	91 (8)	**379 (7)**	.50
Bone or joint infection	104 (7)	94 (7)	111 (9)	104 (9)	**413 (8)**	.07
Urinary tract infection	81 (5)	62 (5)	73 (6)	54 (5)	**270 (5)**	.55
Endocarditis	36 (2)	35 (3)	38 (3)	42 (4)	**151 (3)**	.21
	Health Care–Associated Community-Onset Invasive Infections					
Bloodstream infection	2912 (91)	2823 (90)	2742 (89)	2485 (88)	**10 962 (90)**	.01
Bloodstream infection only	1337 (46)	1405 (50)	1197 (44)	986 (40)	**4925 (45)**	<.01
Pneumonia or empyema	384 (12)	293 (9)	383 (12)	428 (15)	**1488 (12)**	<.01
Skin or soft tissue infection	385 (12)	364 (12)	362 (12)	371 (13)	**1482 (12)**	.27
Bone or joint infection	384 (12)	366 (12)	416 (14)	426 (15)	**1592 (13)**	<.01
Urinary tract infection	219 (7)	215 (7)	182 (6)	221 (8)	**837 (7)**	.04
Endocarditis	205 (6)	155 (5)	193 (6)	175 (6)	**728 (6)**	.06

[a] *P* values were derived by Fisher exact test.

Table 2. Crude Rates of All Invasive Methicillin-Resistant *Staphylococcus aureus* Infections and Bloodstream Infections, January 2005-December 2008

		Methicillin-Resistant *Staphylococcus aureus*			
		All Invasive		Bloodstream Infections	
Epidemiological Category and Year	Population (Denominator)	Case Count	Pooled Mean Incidence Per 10 000 Person-Years (95% CI)	Case Count	Pooled Mean Incidence Per 10 000 Person-Years (95% CI)
Hospital-onset					
2005	14 755 694	1500	1.02 (0.97-1.07)	1305	0.88 (0.84-0.93)
2006	14 954 451	1354	0.91 (0.86-0.96)	1161	0.78 (0.73-0.82)
2007	15 155 918	1289	0.85 (0.81-0.90)	1081	0.71 (0.67-0.76)
2008	15 316 152	1130	0.74 (0.70-0.78)	949	0.62 (0.58-0.66)
Health care–associated community-onset					
2005	14 755 694	3217	2.18 (2.11-2.26)	2912	1.97 (1.90-2.05)
2006	14 954 451	3125	2.09 (2.02-2.16)	2823	1.89 (1.82-1.96)
2007	15 155 918	3074	2.03 (1.96-2.10)	2742	1.81 (1.74-1.88)
2008	15 316 152	2819	1.84 (1.77-1.91)	2485	1.62 (1.56-1.69)
Dialysis within 1 y: health care–associated community-onset					
2005	16 850	884	524.63 (490.61-560.39)	845	501.48 (468.24-536.47)
2006	17 531	907	517.37 (484.24-552.17)	866	493.98 (461.63-528.01)
2007	18 431	935	507.30 (475.30-540.89)	894	485.05 (453.77-517.92)
2008	19 111	816	426.98 (398.18-457.31)	773	404.48 (376.46-434.03)

Abbreviation: CI, confidence interval.

Table 3. Modeled Yearly Percent Change for All Invasive Methicillin-Resistant *Staphylococcus aureus* (MRSA) Infections and Bloodstream Infections, January 2005-December 2008

Epidemiological Category	Modeled Yearly Percent Change (95% Confidence Intervals), %[a]	*P* Value
All invasive MRSA infections		
Hospital-onset	–9.4 (–14.7 to –3.8)	.005
Health care–associated community-onset	–5.7 (–9.7 to –1.6)	.01
MRSA bloodstream infections		
Hospital-onset	–11.2 (–15.9 to –6.3)	.001
Health care–associated community-onset	–6.6 (–9.5 to –3.7)	<.001
Dialysis in last year	–6.4 (–11.4 to –1.1)[b]	.02
No dialysis in last year	–7.2 (–11.4 to –2.8)[b]	.006

[a] Multilevel model adjusted for age and race unless otherwise specified.
[b] Unadjusted multilevel model.

years, but the percentage of overall infections that were hospital-onset decreased from 26% to 23% over the period (*P*=.002) while the percentage of infections that were community-associated increased from 17% to 19% (*P*=.01). Overall, 17 508 cases were either hospital-onset or health care–associated community-onset and were included in this analysis. The mean age of case-patients with these infections was 61 years and did not vary significantly over time. Similarly, the age distribution in the catchment area did not change significantly over the study period.

Most health care–associated infections (ie, hospital-onset or health care-associated community-onset) 15 458 (88%), involved a positive blood culture and were classified as a BSI (4496 were hospital-onset and 10 962 were health care–associated community-onset). Of these, 7603 (49%) had no other infection syndrome identified. Other common infection syndromes included pneumonia or empyema (2427 [14%]), skin and soft tissue infections (1861 [11%]), bone and joint infections (2005 [11%]), urinary tract infections (1107 [6%]), and endocarditis (879 [5%]). The most common syndromes varied slightly by year, with a slightly lower proportion of cases classified as bloodstream infections in later years (TABLE 1).

Invasive MRSA Infection Incidence

The actual case counts and pooled mean rates of invasive MRSA infections decreased incrementally each year in all categories except among patients undergoing dialysis where the largest decrease was in 2008 (TABLE 2). The modeled incidence, adjusted for age and race, of hospital-onset invasive MRSA infections significantly decreased 9.4% per year from 2005 through 2008; while there was a significant 5.7% decrease per year in the modeled incidence of health care–associated community-onset infections (TABLE 3). This would equate to about a 28% decrease in all hospital-onset invasive MRSA infections and about a 17% decrease in all invasive health care–associated community-onset infections over the 4-year period. Decreases in crude incidence of invasive MRSA infection over the study period were apparent across virtually all age, sex, and race categories (TABLE 4).

Table 4. Incidence of Invasive Methicillin-Resistant *Staphylococcus aureus* Infections, by Select Demographics and Epidemiological Classification, Active Bacterial Core Surveillance/Emerging Infection Program Sites, by Year, 2005-2008

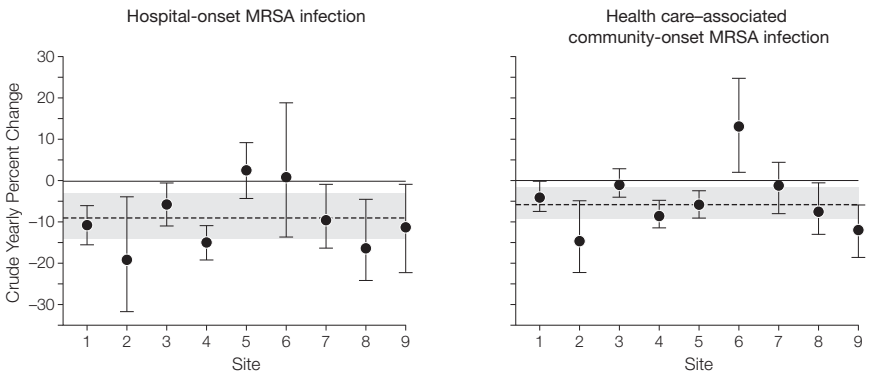
					Incidence per 10 000[a]											
	Actual Count				Health Care–Associated Community-Onset				Hospital-Onset				Total Health Care–Associated			
Demographic	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
Sex																
Male	2679	2592	2611	2314	2.54	2.49	2.52	2.17	1.14	1.04	0.98	0.91	3.69	3.53	3.51	3.08
Female	2038	1887	1752	1635	1.82	1.70	1.55	1.53	0.89	0.78	0.72	0.57	2.71	2.48	2.27	2.10
Age, y[b]																
<1	48	56	41	41	0.34	0.50	0.43	0.47	1.90	2.16	1.42	1.37	2.24	2.66	1.85	1.85
1	1	5	4	3	0	0.20	0.10	0.19	0.10	0.20	0.19	0.05	0.10	0.40	0.29	0.24
2-4	11	11	15	7	0.08	0.07	0.16	0.08	0.11	0.11	0.66	0.03	0.20	0.18	0.23	0.11
5-17	26	7	22	25	0.06	0.02	0.05	0.06	0.04	0.02	0.04	0.04	0.10	0.03	0.09	0.10
18-34	312	307	293	267	0.57	0.57	0.58	0.53	0.34	0.33	0.28	0.25	0.91	0.90	0.86	0.77
35-49	909	862	779	660	1.88	1.72	1.56	1.29	0.68	0.68	0.59	0.54	2.57	2.40	2.15	1.83
50-64	1208	1216	1253	1136	3.24	3.15	3.27	2.75	1.50	1.39	1.24	1.20	4.73	4.54	4.50	3.95
≥65	2202	2014	1956	1808	9.24	8.77	8.15	1.83	4.31	3.43	3.50	2.67	13.56	12.2	11.65	10.50
Race[c]																
White	2436	2315	2253	1991	1.54	1.49	1.44	1.32	0.78	0.72	0.67	0.54	2.33	2.21	2.12	1.86
Black	1760	1627	1640	1442	4.30	3.90	3.92	3.29	1.70	1.50	1.40	1.35	6.00	5.39	5.33	4.65
Other	136	150	137	145	0.59	0.75	0.60	0.70	0.33	0.26	0.30	0.20	0.93	1.01	0.90	0.91
Overall	4717	4479	4363	3949	2.20	2.10	1.97	1.88	1.02	0.92	0.83	0.75	3.21	3.00	2.80	2.63

[a] Sex-, age-, and race-specific rates are crude rates among all 9 Emerging Infection Program sites. Overall incidence rates are point estimates for each year using the modeled incidence adjusting for age (<65 vs ≥65 years) and race (black vs nonblack).
[b] Age is missing from 1 case in 2006 and 2 cases in 2008.
[c] Race of unknown origin was excluded from race-specific calculations.

A subset analysis limited to BSIs demonstrated a larger decrease in the modeled yearly incidence rates of both hospital-onset (–11.2%) and health care–associated community-onset (–6.6%) BSIs (Table 3). This would equate to about a 34% decrease in all hospital-onset MRSA BSIs and about a 20% decrease in all health care–associated community-onset BSIs over the 4-year period.

Because rates of invasive MRSA infections are much higher among patients undergoing dialysis,[15] we evaluated changes in incidence of MRSA BSIs among this subgroup. Unadjusted incidence rates of health care–associated community-onset MRSA BSIs decreased 6.4% per year (Table 3). This would represent about a 19% decrease in these infections over the 4-year period. However, most of the decrease in the number of MRSA BSIs among these patients occurred in 2008 (case counts: 2005, 1006; 2006, 997; 2007, 1040; and 2008, 898).

Figure. Unadjusted Yearly Percent Change of Invasive Methicillin-Resistant *Staphylococcus aureus* Infections



Error bars represent 95% confidence intervals (CIs); dashed line, modeled yearly percent change for all sites combined; shaded area, 95% CIs for modeled yearly percent change all sites combined. Numbers are used to represent the individual sites.

The changes in invasive hospital-onset and health care–associated community-onset MRSA infections stratified by sites are shown in the FIGURE. Seven of 9 sites had a statistically significant decrease in modeled hospital-onset invasive MRSA infections over the period. For health care–associated community-onset invasive MRSA infections, 8 sites demonstrated a decrease (6 statistically significant) and 1 demonstrated a significant increase over the period. The rates of invasive MRSA infections stratified by site, year, and epi-

demiological class are shown in the eTable (available at http://www.jama.com).

COMMENT

Since 2005, when population-based estimates of invasive MRSA infections first became available, the incidence of invasive health care–associated MRSA infections has decreased. The annualized decrease in incidence was greatest for hospital-onset infections (9.4% per year). Furthermore, there was a yearly 5.7% decrease in infections among patients who had onset of their infection outside the hospital but who had recent exposure to health care delivery. This would translate to about a 28% and 17% decrease in hospital-onset and health care–associated community-onset invasive MRSA infections over the 4-year study period, respectively. Larger decreases were seen among patients with BSIs. In addition, although rates of invasive MRSA BSIs among patients who had undergone dialysis within the previous year were high, there was a comparable proportionate decrease in these infections among this group.

Our findings complement those from several smaller studies of infection prevention interventions, which demonstrate decreases in MRSA infections at individual or small collections of facilities.[4,6-8] National hospital-wide decreases have also been demonstrated in England, where the UK Department of Health set as a goal a 50% reduction in MRSA bacteremia by 2008. This goal was met with a 57% reduction in MRSA bacteremia from 2003-2004 to 2008.[11,12] On a national scale in the United States, Burton and colleagues described a significant decrease in MRSA central line–associated BSIs reported from intensive care units from 1997 through 2007.[10] Those data, however, do not reflect health care–associated MRSA infections that might manifest after the patient is discharged. The data presented herein complement and support the findings presented in that evaluation and also expand on it by demonstrating a decrease in invasive MRSA infections, not only among patients in hospitals but also among outpatients with health care exposure.

Although the reasons for the observed decrease in incidence of invasive health care–associated MRSA infections is not known, a number of factors might have contributed, including the dissemination of MRSA prevention practices in many US hospitals. Two groups, including the CDC's Healthcare Infection Control Practices Advisory Committee, have produced recommendations for preventing health care transmission of multidrug-resistant organisms such as MRSA.[16,17] These recommendations are supported by studies that have shown decreases in rates of MRSA infections following implementation of MRSA prevention practices, usually at individual or small groups of facilities.[4,5,9] In our study, the fact that the observed reductions were greater among hospital-onset infections than health care–associated community-onset infections suggests that prevention practices in acute care settings contributed to these decreases. In addition, colonized patients discharged from acute care settings appear to be at high risk of subsequent MRSA infections as outpatients.[18] Interventions that successfully decrease MRSA transmission in hospitals might therefore contribute to the observed decrease in rates of health care–associated community-onset infections.

Because 86% of the invasive MRSA infections reported to this surveillance system were BSIs, much of the estimated reduction in these infections might have been due to the dissemination of inpatient central line–associated BSI prevention efforts rather than MRSA-specific prevention efforts. Examples of such initiatives on a regional scale occurring outside of our surveillance program include the Michigan Keystone intensive care unit project and the Pittsburgh Regional Health Initiative project.[19,20]

One of the strengths of the Emerging Infections Program/Active Bacterial Core surveillances MRSA surveillance system is that rates are population-based, reflecting the burden of invasive MRSA infections in a diverse set of geographic areas and across a wide variety of health care and community settings. However, because the total population of the catchment areas is used as the denominator in these incidence measures and not hospital patient-days, shorter lengths of stay could reclassify some infections from hospital-onset to community-onset. Although the average length of stay in the United States decreased from 7.8 days in 1970 to 4.8 days in 2006, it has remained stable at 4.8 to 4.9 days during the years 2000-2006.[21,22] We are unable to determine the average length of stay during 2005-2008 for our surveillance area. If patient length of stay did decrease, the incidence of hospital-onset infections might decrease simply because more of these infections occur after patients are discharged. However, we also found significant, albeit smaller reductions, in the incidence of health care–associated, community-onset infections suggesting shorter length of stays does not explain all the observed changes in incidence rates.

One other possible reason for the decreases in incidence described herein is a change in the strains associated with invasive MRSA infections. USA300 MRSA strains have emerged as a common cause of infections in the community.[23,24] These isolates are also being recognized as a cause of infections in hospitals.[25-27] Previous analysis of isolates from 2005 and 2006 submitted from the surveillance MRSA program found that 18% of the isolates from a sample of hospital-onset infections were USA300.[26] Further analysis of isolates though 2008 has shown similar proportions of USA300 strains among hospital-onset infections.[28] The absence of major changes in the composition of strains associated with health care–associated invasive MRSA infections during the study period makes shifting strain composition an unlikely cause of the observed decreases in incidence. In addition, although USA300 strains are a well-described cause of invasive infections,[25,29-31] there are no con-

vincing data available that USA300 strains have a higher or lower propensity to cause invasive disease than other strains in the hospital setting.

We were able to evaluate changes in invasive MRSA infection incidence specifically among the population of patients undergoing dialysis. These patients have already been shown to be at more than 100 times the risk of acquiring invasive MRSA infections than the general population.[15] The decrease in MRSA BSIs among dialysis patients that we observed is encouraging although most of this decrease was observed in 2008; ongoing analysis will be needed to determine whether this decrease persists.

Most invasive MRSA infections in this evaluation had their onset outside of acute-care hospitals in patients with previous health care exposures such as dialysis or recent hospitalizations. Preventing health care–associated infections in these settings is a priority for the CDC. Further work is needed to understand the epidemiology of these infections among these groups, to guide the development and implementation of interventions aimed at prevention.

This report is subject to several limitations. First, data from the Emerging Infections Program/Active Bacterial Core surveillance system represent data from 9 metropolitan areas. These data are not nationally representative but do represent 1 of the largest populations evaluated for changes in incidence of invasive MRSA in the United States. Second, this surveillance system does not include nonresidents of the catchment area, so facility-specific incidence rates cannot be determined. For this reason, we are unable to use facility patient-days as a denominator to calculate valid facility-specific or overall incidence rates per patient-day. Third, the denominators used for both the primary and dialysis analyses are estimates and may not completely reflect the total number of patients nor their exact contribution in person-time; however, these issues would be unlikely to have changed over the study period.

Despite these limitations, this evaluation demonstrates that the incidence of hospital-onset and health care–associated community-onset invasive MRSA infections has decreased dramatically and significantly in this large geographically diverse population. Taken together with data from more than 600 intensive care units nationwide,[10] these findings suggest that there is a real decrease in MRSA infection rates among patients in US hospitals. As highlighted in the recently finalized US Department of Health and Human Services Action Plan to Prevent Healthcare-Associated Infections,[3] prevention of invasive MRSA infections is a national priority. Although these data suggest progress has occurred in preventing health care–associated MRSA infections, more challenges remain. Increasing adherence to existing recommendations and addressing MRSA transmission and prevention beyond inpatient settings are challenges that will require further effort and investigation if eliminating the goal of preventable health care–associated invasive MRSA infections is to be attained.

Author Contributions: Dr Kallen had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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Obtained funding: Reingold, Schaffner, Fridkin.
Administrative, technical, or material support: Bulens, Reingold, Ray, Harrison, Lynfield, Schaffner.
Study supervision: Gershman, Dumyati, Townes, Schaffner, Fridkin.
Financial Disclosures: Dr Kallen reports that his spouse has been a consultant for Kimberly-Clark.
Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC. Some of the data reported herein have been supplied by the United States Renal Data System. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of the US government.
Previous Presentation: Some of the data contained in this report were presented in preliminary form as an abstract at the 19th Annual Scientific Meeting of the Society for Healthcare Epidemiology of America, March 19-22, 2009, San Diego, California
Online-Only Material: The eTable is available at http://www.jama.com.
Additional Contributions: We thank the following: Joelle Nadle, MPH, and Elizabeth Partridge, MPH, California Emerging Infections Program; Steve Burnite, Deborah Aragon, MSPH, Allison Daniels, MSPH, Jonathan Schwartz, MSPH, Meghan Barnes, MSPH, Jennifer Sadlowski, MSPH, Tiffany White, MSPH, Kerri McClory, MSPH, Ashley Juhl, MSPH, and Amy Conroy, MSPH, Colorado Department of Public Health and Environment; Zack Fraser, James L. Hadler, MD, MPH, Connecticut Emerging Infections Program; Monica M. Farley, MD, Wendy Baughman, MSPH, Janine Ladson, MPH, Paul Malpiedi, MPH, Betsy Siegel, RN, and Lewis Perry, RN, MPH, Georgia Emerging Infections Program; Rosemary Hollick, MSc, Angela Badcon, RN, MS, Joanne Benton, RN, BSN, MHS, Terresa Carter, Emily Evers, Janice Langford, RN, MS, Elizabeth Vaeth, Kim Holmes, RN, MS and Kathleen Shutt, MS, Maryland Emerging Infections Program; Lindsey Lesher, MPH, Jessica Nerby, MPH, Minnesota Emerging Infections Program; Anita Gellert, RN, New York Emerging Infections Program; Robert Vega, MS, Janie Tierheimer, MT (ASCP), Karen Stefonek, MPH, Michelle Barber, MS, Janet Brock, and Mark Schmidt, PhD, MPH, Oregon Emerging Infections Program; Brenda Barnes, RN, CCRP, Terri McMinn, Susan Tymensky, RN, CCRP, Melinda Eady, Tennessee Emerging Infections Program; and Jonathan Edwards, MStat, and John Jernigan, MD, MS, Division of Healthcare Quality Promotion, CDC. Those acknowledged herein received compensation for this data collection from the Emerging Infection Program of the Centers for Disease Control and Prevention.

REFERENCES

1. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care-associated infections and deaths in US hospitals, 2002. *Public Health Rep*. 2007; 122(2):160-166.
2. Hidron AI, Edwards JR, Patel J, et al; 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.
3. US Department of Health and Human Services. HHS action plan to prevent healthcare-associated infections. http://www.hhs.gov/ophs/initiatives/hai/infection.html. Accessed October 28, 2009.
4. Huang SS, Yokoe DS, Hinrichsen VL, et al. Impact of routine intensive care unit surveillance cultures and resultant barrier precautions on hospital-wide methicillin-resistant *Staphylococcus aureus* bacteremia. *Clin Infect Dis*. 2006;43(8):971-978.
5. Harbarth S, Fankhauser C, Schrenzel J, et al. Universal screening for methicillin-resistant *Staphylococcus aureus* at hospital admission and nosocomial infection in surgical patients. *JAMA*. 2008;299(10): 1149-1157.
6. Robicsek A, Beaumont JL, Paule SM, et al. Universal surveillance for methicillin-resistant *Staphylococcus aureus* in 3 affiliated hospitals. *Ann Intern Med*. 2008;148(6):409-418.
7. Chaberny IF, Schwab F, Ziesing S, Suerbaum S, Gastmeier P. Impact of routine surgical ward and intensive care unit admission surveillance cultures on hospital-wide nosocomial methicillin-resistent *Staphylococcus aureus* infections in a university hospital: an interrupted time-series analysis. *J Antimicrob Chemother*. 2008;62(6):1422-1429.
8. Ridenour G, Lampen R, Federspiel J, Kritchevsky

S, Wong E, Climo M. Selective use of intranasal mupirocin and chlorhexidine bathing and the incidence of methicillin-resistant *Staphylococcus aureus* colonization and infection among intensive care unit patients. *Infect Control Hosp Epidemiol*. 2007;28(10):1155-1161.
9. Muder RR, Cunningham C, McCray E, et al. Implementation of an industrial systems-engineering approach to reduce the incidence of methicillin-resistant *Staphylococcus aureus* infections. *Infect Control Hosp Epidemiol*. 2008;29(8):702-708.
10. Burton DC, Edwards JR, Horan TC, Jernigan JA, Fridkin SK. Methicillin-resistant *Staphylococcus aureus* central line-associated bloodstream infections in US intensive care units, 1997-2007. *JAMA*. 2009; 301(7):727-736.
11. Liebowitz LD. MRSA burden and interventions. *Int J Antimicrob Agents*. 2009;34(S3)(suppl 3): S11-S13.
12. Pearson A, Chronias A, Murray M. Voluntary and mandatory surveillance for methicillin-resistant *Staphylococcus aureus* (MRSA) and methicillin-susceptible *S aureus* (MSSA) bacteraemia in England. *J Antimicrob Chemother*. 2009;64(suppl 1):i11-i17.
13. Klevens RM, Morrison MA, Nadle J, et al; Active Bacterial Core surveillance (ABCs) MRSA Investigators. Invasive methicillin-resistant *Staphylococcus aureus* infections in the United States. *JAMA*. 2007;298 (15):1763-1771.
14. Cohen AL, Calfee D, Fridkin SK, et al; Society for Healthcare Epidemiology of America and the Healthcare Infection Control Practices Advisory Committee. Recommendations for metrics for multidrug-resistant organisms in healthcare settings: SHEA/HICPAC Position paper. *Infect Control Hosp Epidemiol*. 2008;29(10):901-913.
15. Centers for Disease Control and Prevention (CDC). Invasive methicillin-resistant *Staphylococcus aureus* infections among dialysis patients—United States, 2005. *MMWR Morb Mortal Wkly Rep*. 2007;56(9):197-199.
16. Siegel JD, Rhinehart E, Jackson M, Chiarello L; the Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in healthcare settings, 2006. http://www.cdc.gov/ncidod/dhqp/pdf/ar/MDROGuideline2006.pdf. Accessed October 28, 2009.
17. Calfee DP, Salgado CD, Classen D, et al. Strategies to prevent transmission of methicillin-resistant *Staphylococcus aureus* in acute care hospitals. *Infect Control Hosp Epidemiol*. 2008;29(suppl 1):S62-S80.
18. Robicsek A, Beaumont JL, Thomson RB Jr, Govindarajan G, Peterson LR. Topical therapy for methicillin-resistant *Staphylococcus aureus* colonization: impact on infection risk. *Infect Control Hosp Epidemiol*. 2009;30(7):623-632.
19. Centers for Disease Control and Prevention (CDC). Reduction in central line-associated bloodstream infections among patients in intensive care units—Pennsylvania, April 2001-March 2005. *MMWR Morb Mortal Wkly Rep*. 2005;54(40): 1013-1016.
20. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med*. 2006; 355(26):2725-2732.
21. DeFrances CJ, Cullen KA, Kozak LJ. National hospital discharge survey: 2005 annual summary with detailed diagnosis and procedure data. *Vital Health Stat 13*. 2007;(165):1-209.
22. DeFrances CJ, Lucas CA, Buie VC, Golosinskiy A. *2006 National Hospital Discharge Survey*. Hyattsville, MD: National Center for Health Statistics; 2008. Report 5.
23. King MD, Humphrey BJ, Wang YF, Kourbatova EV, Ray SM, Blumberg HM. Emergence of community-acquired methicillin-resistant *Staphylococcus aureus* USA 300 clone as the predominant cause of skin and soft-tissue infections. *Ann Intern Med*. 2006;144 (5):309-317.
24. Moran GJ, Krishnadasan A, Gorwitz RJ, et al; EMERGEncy ID Net Study Group. Methicillin-resistant *S aureus* infections among patients in the emergency department. *N Engl J Med*. 2006;355 (7):666-674.
25. Seybold U, Kourbatova EV, Johnson JG, et al. Emergence of community-associated methicillin-resistant *Staphylococcus aureus* USA300 genotype as a major cause of health care–associated blood stream infections. *Clin Infect Dis*. 2006;42(5):647-656.
26. Limbago B, Fosheim GE, Schoonover V, et al; Active Bacterial Core surveillance MRSA Investigators. Characterization of methicillin-resistant *Staphylococcus aureus* isolates collected in 2005 and 2006 from patients with invasive disease: a population-based analysis. *J Clin Microbiol*. 2009;47(5):1344-1351.
27. Liu C, Graber CJ, Karr M, et al. A population-based study of the incidence and molecular epidemiology of methicillin-resistant *Staphylococcus aureus* disease in San Francisco, 2004-2005. *Clin Infect Dis*. 2008;46(11):1637-1646.
28. Centers for Disease Control and Prevention. Active Bacterial Core Surveillance Reports. http://www.cdc.gov/abcs/reports-findings/surv-reports.html. Accessed June 23, 2010.
29. Carrillo-Marquez MA, Hulten KG, Hammerman W, Mason EO, Kaplan SL. USA300 is the predominate genotype causing *Staphylococcus aureus* septic arthritis in children. *Pediatr Infect Dis J*. 2009;28 (12):1076-1080.
30. Enayet I, Nazeri A, Johnson LB, Riederer K, Pawlak J, Saravolatz LD. Community-associated methicillin-resistant *Staphylococcus aureus* causing chronic pneumonia. *Clin Infect Dis*. 2006;42(7):e57-e60.
31. Kallen AJ, Brunkard J, Moore Z, et al. *Staphylococcus aureus* community-acquired pneumonia during the 2006 to 2007 influenza season. *Ann Emerg Med*. 2009;53(3):358-365.

True morality consists not in following the beaten track, but in finding out the true path for ourselves and fearlessly following it.

—Mohandis K. Gandhi (1869-1948)

