

ORIGINAL ARTICLE

Veterans Affairs Initiative to Prevent Methicillin-Resistant *Staphylococcus aureus* Infections

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ABSTRACT

BACKGROUND

Health care–associated infections with methicillin-resistant *Staphylococcus aureus* (MRSA) have been an increasing concern in Veterans Affairs (VA) hospitals.

METHODS

A “MRSA bundle” was implemented in 2007 in acute care VA hospitals nationwide in an effort to decrease health care–associated infections with MRSA. The bundle consisted of universal nasal surveillance for MRSA, contact precautions for patients colonized or infected with MRSA, hand hygiene, and a change in the institutional culture whereby infection control would become the responsibility of everyone who had contact with patients. Each month, personnel at each facility entered into a central database aggregate data on adherence to surveillance practice, the prevalence of MRSA colonization or infection, and health care–associated transmissions of and infections with MRSA. We assessed the effect of the MRSA bundle on health care–associated MRSA infections.

RESULTS

From October 2007, when the bundle was fully implemented, through June 2010, there were 1,934,598 admissions to or transfers or discharges from intensive care units (ICUs) and non-ICUs (ICUs, 365,139; non-ICUs, 1,569,459) and 8,318,675 patient-days (ICUs, 1,312,840; and non-ICUs, 7,005,835). During this period, the percentage of patients who were screened at admission increased from 82% to 96%, and the percentage who were screened at transfer or discharge increased from 72% to 93%. The mean (\pm SD) prevalence of MRSA colonization or infection at the time of hospital admission was 13.6 \pm 3.7%. The rates of health care–associated MRSA infections in ICUs had not changed in the 2 years before October 2007 ($P=0.50$ for trend) but declined with implementation of the bundle, from 1.64 infections per 1000 patient-days in October 2007 to 0.62 per 1000 patient-days in June 2010, a decrease of 62% ($P<0.001$ for trend). During this same period, the rates of health care–associated MRSA infections in non-ICUs fell from 0.47 per 1000 patient-days to 0.26 per 1000 patient-days, a decrease of 45% ($P<0.001$ for trend).

CONCLUSIONS

A program of universal surveillance, contact precautions, hand hygiene, and institutional culture change was associated with a decrease in health care–associated transmissions of and infections with MRSA in a large health care system.

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METHICILLIN-RESISTANT *STAPHYLOCOCCUS aureus* (MRSA) infections are a problem in the United States¹ and elsewhere. MRSA is one of the most common causes of ventilator-associated pneumonia, bloodstream infection associated with central venous catheters, and surgical-site infections.^{1,2}

In 2001, the Veterans Affairs (VA) Pittsburgh Healthcare System began working with the Pittsburgh Regional Healthcare Initiative and the Centers for Disease Control and Prevention (CDC) to eliminate health care–associated MRSA infections with the use of a “MRSA bundle.” The bundle, which was based on published guidelines, comprised universal nasal surveillance for MRSA colonization, contact precautions for patients who were carriers of MRSA, hand hygiene, and an institutional culture change whereby infection control became the responsibility of everyone who had contact with patients.³ After implementation of this approach in a pilot project, the rates of health care–associated MRSA infections were reduced by 60% on a surgical ward and by 75% in a surgical intensive care unit (ICU) within 4 years.⁴

On the basis of the success of the pilot study in the VA Pittsburgh Healthcare System, and recognizing the importance of preventing MRSA infections for all veterans, the Veterans Health Administration (VHA), a division of the Department of Veterans Affairs, issued a directive (see the Supplementary Appendix, available with the full text of this article at NEJM.org) implementing a nationwide initiative to decrease health care–associated MRSA infections in acute care facilities. In this article, we report an analysis of the effect of the MRSA Prevention Initiative during the period from October 2007, when the program was fully implemented in ICUs and non-ICUs nationwide, through June 2010.

METHODS

INTERVENTIONS

Medical centers were directed to implement the MRSA bundle in one patient care unit (preferably an ICU) beginning in March 2007 and to implement the bundle in all remaining acute care units (with the exception of mental health units) by October 1, 2007. The bundle consisted of surveillance for nasal colonization with MRSA for all patients admitted to the hospital, all patients transferred from one unit to another within the hospital, and all patients discharged from the

hospital; contact precautions for patients who were either colonized or infected with MRSA; hand hygiene; and a change in the institutional culture. The recommended approach to achieve culture change was “positive deviance”⁵ (a problem-solving approach that is based on the observation that in every community, there are certain persons or groups whose uncommon behaviors or strategies, as compared with those of their peers, enable them to find better solutions to problems). The goal of the culture change was to foster alterations in practice so that infection control and prevention would become the responsibility of everyone involved in the care of patients and thus a natural component of patient care.

PATIENTS

All patients admitted to VA acute health care facilities (except patients admitted to mental health units) were eligible to participate in the MRSA Prevention Initiative. Because this was not a research project, but rather a quality-improvement initiative, written informed consent from individual patients was not required, consistent with VA policy.⁶ Written information was available for each patient or his or her caregiver, with details about MRSA, relevant principles of infection control, the purpose and goals of the MRSA Prevention Initiative, and patients’ rights and oral assent (see the Supplementary Appendix).

RESOURCES AND TRAINING

The VA Central Office provided funds to each facility in the United States for educational materials, laboratory equipment and supplies, and salaries for dedicated laboratory personnel and for a newly created position, the MRSA prevention coordinator. The coordinator at each facility oversaw implementation of the initiative at that facility, collected and reported data on the program at that facility, provided feedback to front-line health care workers, and dealt with local challenges. Regional and national educational and training sessions for the coordinators were conducted by the MRSA Program Office.

ACTIVE SURVEILLANCE AND CONTACT PRECAUTIONS

Training on the method of obtaining nasal swabs was provided to all MRSA prevention coordinators through the MRSA Program Office. Samples of nasal secretions were obtained with a swab from both anterior nares of patients within 24 hours after their admission to the hospital. Swabs were

also obtained from patients who were not known to be colonized or infected with MRSA when they were transferred between, or discharged from, units within each facility. The local clinical microbiology laboratory processed the swabs with the use of standard or selective chromogenic agar for the isolation of MRSA or with polymerase-chain-reaction (PCR)-based tests for rapid molecular detection of the organism. Positive results were reported to the patient's nursing unit and were recorded in the electronic health record.

Patients who were found to be colonized or infected with MRSA or who were known to have been colonized or infected with MRSA within the previous 12 months were assigned to contact precautions.⁷ These patients were cared for with contact precautions during their hospital stay and all subsequent hospitalizations. Contact precautions remained in effect until two nasal swabs and cultures of infected sites (if still present), obtained 1 week apart, were negative, provided that the patients were not receiving antibiotics for an active MRSA (or other) infection at the time of these subsequent surveillance tests. Routine MRSA decolonization was not recommended (see the Supplementary Appendix).

DEFINITIONS OF PREVALENCE, TRANSMISSION, AND HEALTH CARE-ASSOCIATED INFECTION

We calculated the facility-wide rate of colonization at admission by dividing the number of patient admissions with MRSA, as detected by nasal swabbing or clinical cultures within 48 hours after admission, by the total number of admissions to the facility. As of April 2008, all persons who had a history of colonization or infection with MRSA within the previous 12 months were also considered to be positive for MRSA at the time of admission. A clinical culture was defined as a specimen obtained from any body site, fluid, or drainage area other than specimens obtained for surveillance. If MRSA was detected in both the nasal-swab specimen and a clinical culture, the event was counted once in the category of clinical culture. Geographic variation in prevalence was examined according to the four regions of the United States (Northeast, South, Midwest, and West) defined by the Census Bureau (www.census.gov).

Patients who were negative for MRSA at the time of admission and during the 12 months before admission and were found to be colonized or infected with MRSA after they had been in a unit for more than 48 hours were considered to

have an event of MRSA transmission attributable to that unit. Patients not known to be colonized or infected with MRSA who were readmitted to the hospital within 48 hours after discharge and were found to be positive at the time of readmission were considered to have a transmission event attributable to the unit from which they had been discharged.

Health care-associated MRSA infections were defined according to guidelines of the CDC's National Healthcare Safety Network (NHSN),⁸ with the following adaptations: a diagnosis of MRSA infection required a positive culture, rather than just a clinical diagnosis by a physician, and a positive clinical culture was considered to be community-associated if it was obtained within 48 hours after admission. After 48 hours, a positive clinical culture obtained from a patient in whom infection was not present or incubating at the time of admission, as defined by NHSN criteria,⁹ was considered to be a health care-associated event. No molecular typing of the MRSA isolates was performed. A physician or other professional in infection prevention and control reviewed the patient's record to determine whether the criteria for a health care-associated infection had been met.

DATA MANAGEMENT

Beginning in October 2007, MRSA prevention coordinators at all facilities entered, for each month, aggregate data on active surveillance testing and on the prevalence and transmission of MRSA and health care-associated MRSA infections into a database that was developed and maintained by the VA Inpatient Evaluation Center (IPEC). The coordinators at all facilities also collected retrospective information on health care-associated MRSA infections detected in ICUs between October 2005 and the end of September 2007 in order to establish a baseline before implementation of the MRSA Prevention Initiative. With the exception of the category of systemic infection, data entered into the MRSA data management Web site at IPEC included all major categories of health care-associated infections surveyed by the NHSN (e.g., urinary tract infections, bloodstream infections, pneumonia, and skin and soft-tissue infections).⁸

In addition to data on health care-associated MRSA infections, MRSA prevention coordinators were asked to enter into the IPEC database, on an optional basis, data on health care-associated

infections with vancomycin-resistant enterococcus (VRE) and *Clostridium difficile* (defined according to NHSN guidelines⁸), each month from October 2007 through June 2010.

For the purpose of the dissemination of this information beyond the programmatic needs of the MRSA Prevention Initiative, the analysis was approved by the institutional review boards at the VA Pittsburgh Healthcare System and the Cincinnati VA Medical Center.

STATISTICAL ANALYSIS

We used the SAS statistical program, version 9.2 (SAS Institute), to extract monthly data on facility-level and unit-level variables from a Microsoft SQL Server 2005 Analysis Services online analytical processing cube (Microsoft) that was maintained in secure files on a server at IPEC.

Data from all facilities were pooled for the analyses. Facility-specific data were available for stratification when necessary. Adherence to active surveillance testing was reported as the percentage of eligible patients who were tested, and the rates of transmission and health care–associated infection were expressed as the number per 1000 patient-days. The rates of ventilator-associated pneumonia and bloodstream infection associated with central venous catheters were expressed as the number per 1000 device-days. All data were analyzed monthly except for data on MRSA bloodstream infections not associated with a device, pneumonias, urinary tract infections, and skin and soft-tissue infections (defined according to NHSN guidelines⁸), which were evaluated quarterly owing to the small numbers of events.

Quantitative and qualitative variables are reported with the use of descriptive statistics. Trends were examined by means of Poisson regression models, and Student's t-tests and analyses of variance with Duncan's multiple-comparisons method were used to compare groups of interest. The Durbin–Watson (*d*) statistic was used to test for the presence of autocorrelation in the rates of health care–associated infections. No strong evidence was found; therefore, data transformations were deemed to be unnecessary.

RESULTS

CHARACTERISTICS OF PATIENTS AND FACILITIES

The mean (\pm SD) age of patients admitted to VA acute care facilities during the period included in the analysis (October 2007 through June 2010)

Figure 1 (facing page). Active Surveillance Testing for Methicillin-Resistant *Staphylococcus aureus* (MRSA) among Patients Admitted to and Those Transferred or Discharged from Acute Care Veterans Affairs (VA) Medical Units Nationwide.

A “MRSA bundle,” comprising universal nasal surveillance for MRSA colonization, contact precautions for patients who were carriers of MRSA, hand hygiene, and an institutional culture change whereby infection control became the responsibility of everyone who had contact with patients, was implemented in 2007 in acute care VA hospitals nationwide. The shaded area represents the transition period between the time when all hospitals were required to have the program functional in at least one intensive care unit (ICU) (March 2007) to full implementation of the MRSA bundle in all ICUs and non-ICUs (October 2007). The period of analysis was from October 2007 through June 2010. The number of patients who were screened at admission and the number who were screened at transfer or discharge are shown in Panel A; the rates at screening at admission and at transfer or discharge are shown in Panel B. Although only 35% of patients admitted to the hospital were being screened when the MRSA Prevention Directive was issued in January 2007, this percentage rapidly increased to 82% by October 2007 and to 96% by June 2010. The surveillance rate at the time of transfer or discharge increased from 72% in October 2007 to 93% in June 2010.

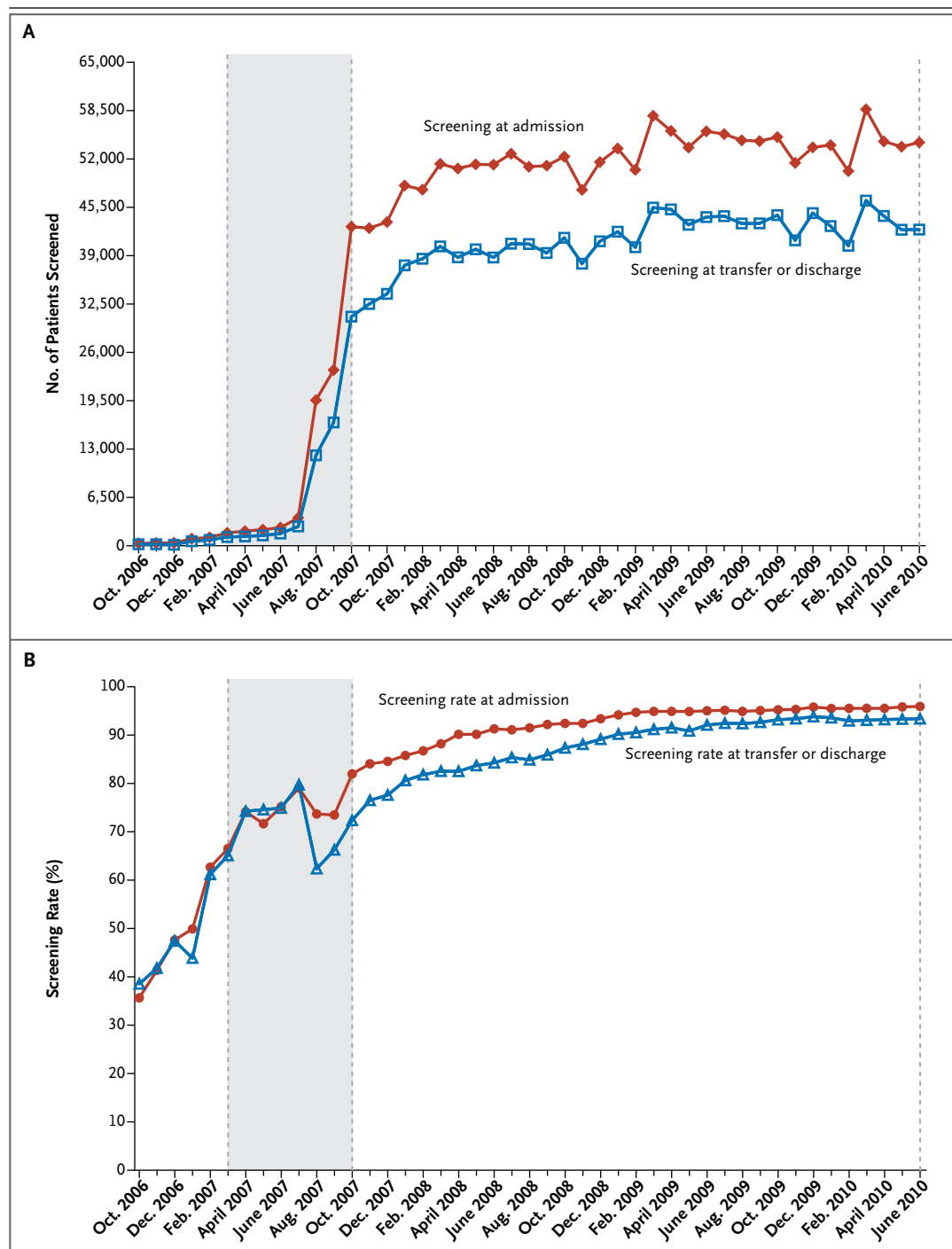
was 62.6 ± 14.4 years; 95% of the patients were men. The median length of stay was 3.0 days (interquartile range, 2.0 to 7.0).

The VA has 153 hospitals nationwide. During the period included in the analysis, 196 medical, coronary care, and surgical ICUs and 428 medical, surgical, rehabilitation medicine, and spinal-cord injury units provided data to IPEC. These units represented all VA medical centers nationwide except for 3 that were exempted from participation.

There were 1,934,598 admissions to, transfers within, or discharges from these units (ICUs, 365,139; non-ICUs, 1,569,459) and 8,318,675 patient-days (ICUs, 1,312,840; non-ICUs, 7,005,835).

ACTIVE SURVEILLANCE

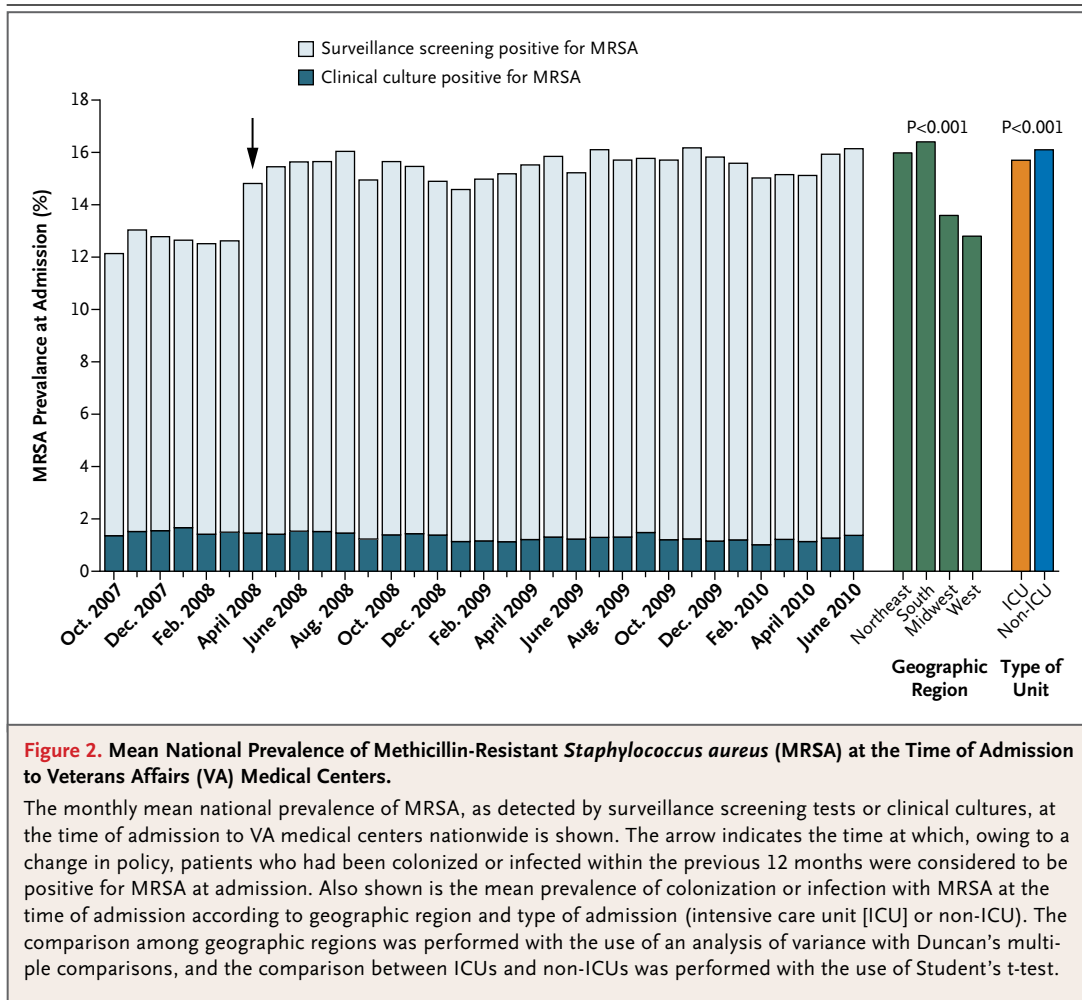
A total of 1,712,537 surveillance screening tests were obtained during the analysis period from patients who were admitted to or transferred or discharged from acute care facilities nationwide (329,903 obtained in ICUs and 1,382,634 in non-ICUs). During this period, the percentage of patients who were screened at admission increased from 82% to 96%, and the percentage who were screened at transfer or discharge increased from 72% to 93% (Fig. 1).



PREVALENCE OF MRSA COLONIZATION OR INFECTION AT ADMISSION

The mean (\pm SD) monthly prevalence of MRSA colonization or infection at admission in all medical centers during the analysis period was 13.6 \pm 3.7% (range of means across facilities, 5.4 to 28.1). The ratio of patients with MRSA colonization or infection who were identified by active

surveillance to those identified by clinical cultures alone was 10:1 (Fig. 2). The prevalence of colonization or infection at admission was higher among patients living in southern or north-eastern regions of the United States than among those living in western or midwestern regions (15.3% and 14.6%, respectively, for southern and northeastern regions vs. 11.3% and 12.5%, re-



spectively, for western and midwestern regions; $P < 0.001$). More non-ICU patients than ICU patients were colonized or infected at admission ($15.7 \pm 11.4\%$ vs. $14.5 \pm 9.1\%$, $P < 0.001$).

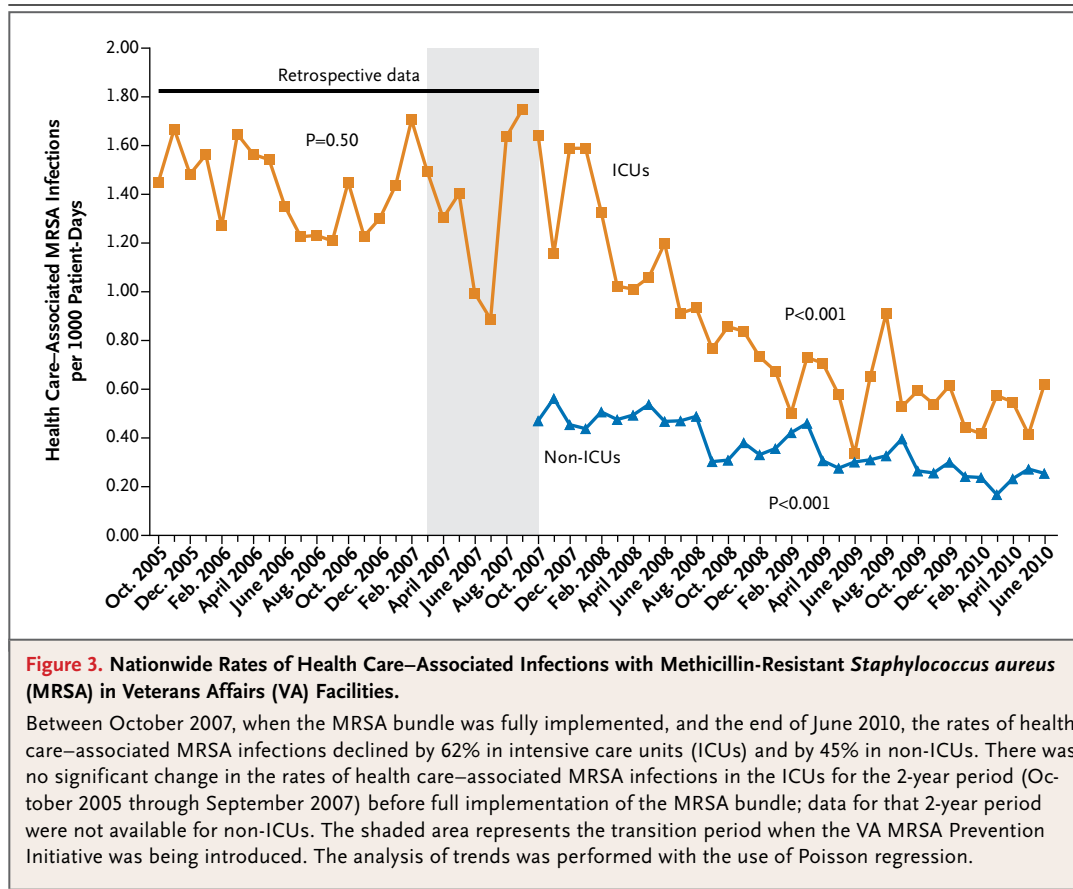
RATES OF TRANSMISSION

During the analysis period, the rate of transmission of MRSA in the ICUs was reduced from 3.02 per 1000 patient-days in October 2007 to 2.50 per 1000 patient-days in June 2010, a decrease of 17% ($P < 0.001$ for trend). During the same period, the rate of transmission in the non-ICUs was reduced from 2.54 per 1000 patient-days to 2.00 per 1000 patient-days, a decrease of 21% ($P < 0.001$ for trend).

RATES OF HEALTH CARE–ASSOCIATED INFECTION

The rate of health care–associated MRSA infection in ICUs did not change significantly from

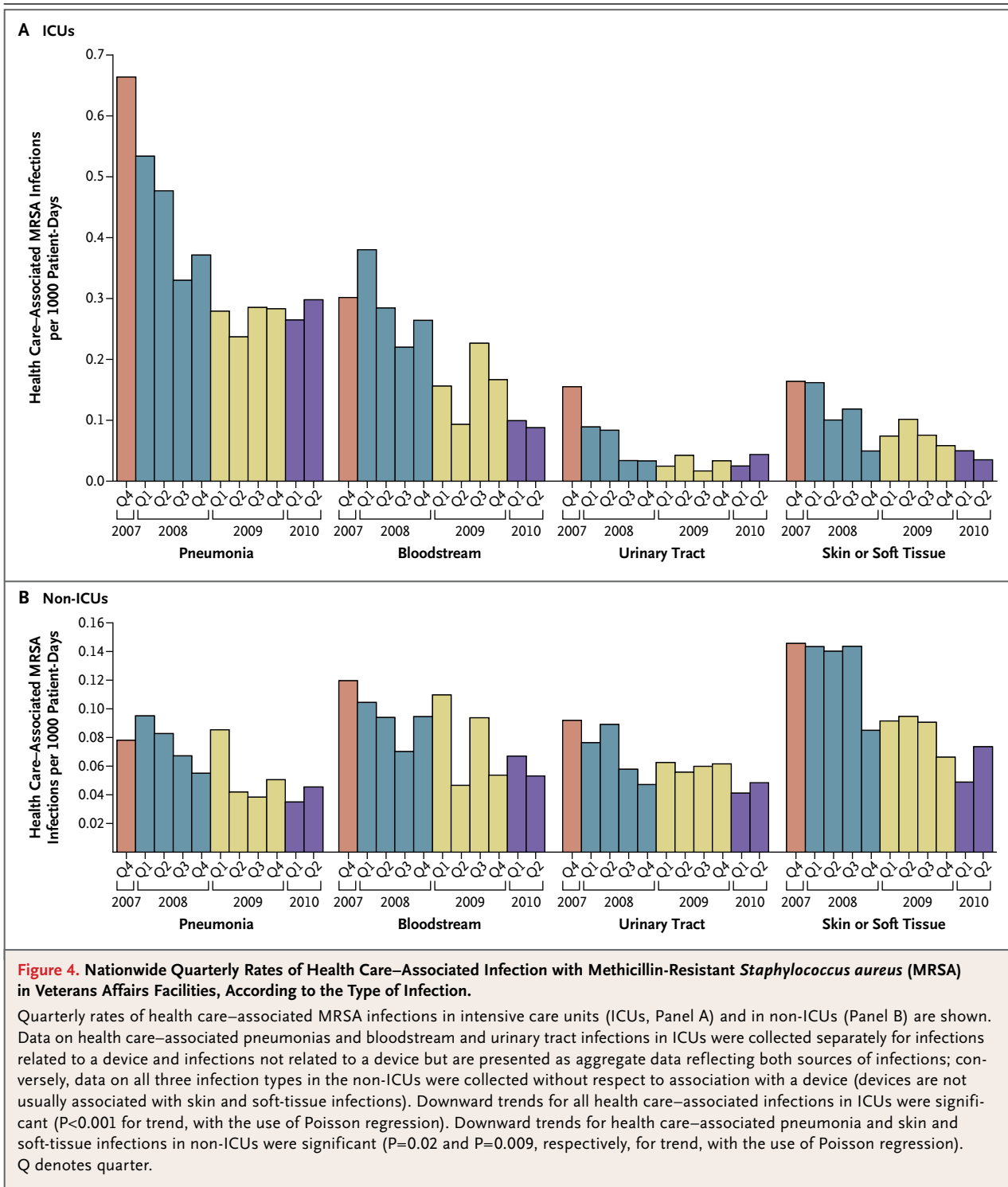
October 2005 through September 2007, which was the period before implementation of the MRSA bundle in all facilities (1.45 per 1000 patient-days in October 2005 and 1.75 per 1000 patient-days in September 2007, $P = 0.50$ for trend) but declined during the analysis period, from 1.64 per 1000 patient-days in October 2007 to 0.62 per 1000 patient-days in June 2010, a decrease of 62% ($P < 0.001$ for trend) (Fig. 3). After implementation of the MRSA bundle, there was a decline in the rate of bloodstream MRSA infection not related to a device, from 0.14 per 1000 patient-days in the fourth quarter (October through December) of 2007 to 0.03 per 1000 patient-days in the second quarter (April through June) of 2010, a decrease of 79% ($P < 0.001$ for trend). During the same period, there was a decline in the quarterly rate of bloodstream MRSA infection re-



lated to a device, from 0.16 to 0.06 per 1000 patient-days, a decrease of 62% ($P<0.001$ for trend); a decline in the quarterly rate of pneumonia not related to a device, from 0.35 to 0.22 per 1000 patient-days, a decrease of 37% ($P=0.001$ for trend); a decline in the rate of pneumonia related to a device, from 0.32 to 0.08 per 1000 patient-days, a decrease of 75% ($P<0.001$ for trend); a decline in the rate of urinary tract infection, from 0.16 to 0.04 per 1000 patient-days, a decrease of 75% ($P<0.001$ for trend); and a decline in the rate of skin and soft-tissue infections, from 0.16 to 0.04 per 1000 patient days, a decrease of 75% ($P<0.001$ for trend) (Fig. 4A).

There was no significant change in the rates of ventilator-associated MRSA pneumonia or bloodstream MRSA infection associated with central venous catheters in ICUs from April 2006 through March 2007, which was the period in which programs to reduce the rate of health care–associated infections due to all pathogens

were fully implemented ($P=0.86$ for trend and $P=0.26$ for trend, respectively); however, between October 2007, when the MRSA bundle was fully implemented, and June 2010, the rate of ventilator-associated MRSA pneumonia declined from 1.17 per 1000 device-days in October 2007 to 0.33 per 1000 device-days in June 2010, a decrease of 72% ($P<0.001$ for trend), and the rate of bloodstream MRSA infection associated with central venous catheters declined from 0.46 to 0.31 per 1000 device-days, a decrease of 33% ($P<0.001$ for trend) (Fig. 5). The ratio of patient-days in the ICU on which mechanical ventilation was received to the total number of patient-days in the ICU declined from 0.29 in October 2007 to 0.25 in June 2010, a decrease of 14% ($P=0.005$ for trend); the ratio of patient-days in the ICU on which central venous catheters were used to the total number of patient-days in the ICU did not change significantly (0.46 in October 2007 and 0.44 in June 2010, $P=0.75$ for trend).



In non-ICUs, the rate of health care–associated MRSA infection fell from 0.47 per 1000 patient-days in October 2007 to 0.26 per 1000 patient-days in the last quarter (October through December) of 2007 to 0.05 per 1000 patient-days in June 2010, a decrease of 45% ($P < 0.001$ for trend) (Fig. 3). The rate of bloodstream infection declined from 0.12 per 1000 patient-days in the last quarter (October through December) of 2007 to 0.05 per 1000 patient-days

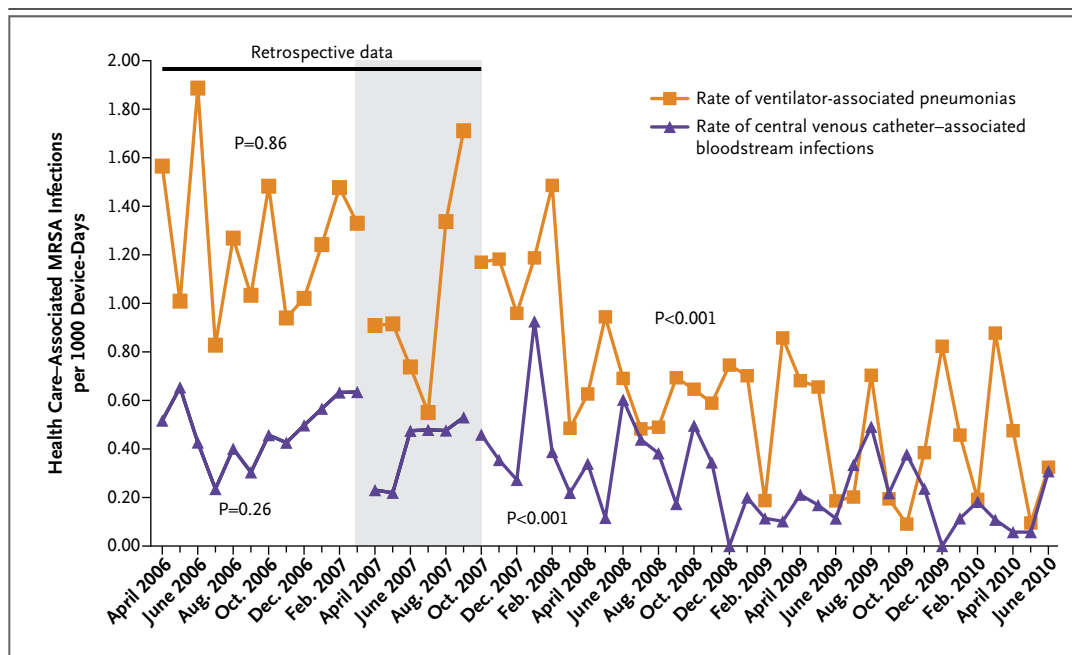


Figure 5. Nationwide Monthly Rates of Ventilator-Associated Pneumonias and Central Venous Catheter-Associated Bloodstream Infections with Methicillin-Resistant *Staphylococcus aureus* (MRSA) in Veterans Affairs (VA) Intensive Care Units.

Data are shown for the period during which bundles for these device-related health care-associated infections due to all pathogens were in place (April 2006 through March 2007), during a transition period (shaded area) when the VA MRSA Prevention Initiative was being introduced, and from October 2007 through June 2010, when the initiative was implemented in all intensive care units nationwide. P values are for trends (with the use of Poisson regression) for the respective periods and health care-associated infections. The P value for the retrospective data is only for data for the period from April 2006 to March 2007.

in the second quarter (April through June) of 2010, a decrease of 58% ($P=0.11$). During the same period, there were declines in the quarterly rates of pneumonia, from 0.08 to 0.05 per 1000 patient-days, a decrease of 38% ($P=0.02$); urinary tract infection, from 0.09 to 0.05 per 1000 patient-days, a decrease of 44% ($P=0.43$); and skin and soft-tissue infections, from 0.15 to 0.07 per 1000 patient-days, a decrease of 53% ($P=0.009$) (Fig. 4B).

A total of 16 hospitals entered data on the incidence of health care-associated VRE and *C. difficile* infections in ICUs consistently during the analysis period, and 17 hospitals entered data on the incidence of these infections in non-ICUs. Poisson regression analysis for this subgroup of hospitals showed that between October 2007 and June 2010, there was a decline in the rate of health care-associated MRSA infection from 2.81 to 0.22 per 1000 patient-days in the ICUs, a decrease of 92% ($P<0.001$), and from 0.79 to 0.22

per 1000 patient-days in non-ICUs, a decrease of 72% ($P<0.001$). There was also a decline in the rate of health care-associated *C. difficile* infection in non-ICUs, from 1.44 to 0.56 per 1000 patient-days, a decrease of 61% ($P<0.001$); there was no significant change noted in the rate of health care-associated *C. difficile* infection in ICUs ($P=0.99$). During the same period, there was a significant decrease in the rates of health care-associated VRE infection in the ICUs, from 1.51 to 0.00 per 1000 patient days ($P<0.001$), and in non-ICUs, from 0.33 to 0.09 per 1000 patient-days, a decrease of 73% ($P<0.001$).

DISCUSSION

Implementation of a bundle comprising universal active surveillance, contact precautions, hand hygiene, and a change in the institutional culture was followed by significant declines in health care-associated MRSA infections in a large health

care system. These declines were sustained during the 33 months of the analysis and were greater than those reported recently in other U.S. venues.^{10,11} Investigations in smaller settings have also shown reductions in health care–associated MRSA infections when an approach similar to that of the VA was used.^{12–20}

The prevalence of MRSA carriage among VA patients at admission was 13.6%, as compared with a prevalence of 1.5% in the general U.S. population and 6.3% among patients in non-VA hospitals, as determined, in both cases, by means of universal surveillance.^{16,21} We might have seen a larger decrease in health care–associated infections if the prevalence had been lower, since there is a correlation between the prevalence of carriers and the incidence of health care–associated infections.^{22,23}

Because this VA initiative was a quality-improvement program rather than a prospectively designed trial, data are not available to evaluate the extent to which each component of the bundle may have contributed to the overall reduction in health care–associated infections. Adherence to surveillance at admission, transfer, and discharge may be a surrogate marker for adherence to the bundle.

Active surveillance identified more than 90% of MRSA carriers who would have been missed with clinical cultures alone. The sensitivity and specificity of direct plating to a chromogenic medium are similar to those of PCR, which range from about 81% to 100% and 93% to 100%, respectively.²⁴ Identifying patients who were colonized with MRSA and isolating them with contact precautions was probably important, since the environment surrounding asymptomatic carriers can be contaminated to the same extent as the environment surrounding infected patients.²⁵ Preventing transmission and subsequent colonization with MRSA reduces the risk of infection, which may occur in more than a third of recently colonized patients,^{16,26–30} and decreases the reservoir of patients who can transmit MRSA during future health care encounters.

The increase in adherence to active surveillance in the months after issuance of the VHA directive and the subsequent declines in health care–associated MRSA infections were consistent with an institutional culture change that resulted in health care workers being more aware

of health care–associated MRSA infections and increasing their adherence to hand hygiene and contact precautions. The MRSA Prevention Initiative may have also affected the rates of health care–associated *C. difficile* and VRE infections. It is known that hand hygiene reduces health care–associated infections, and contact precautions are effective in preventing the transmission of MRSA and other pathogens.^{31,32}

We do not know the extent to which concomitant infection-control initiatives may have contributed to the decrease in health care–associated MRSA infections that we observed. Guidelines were given for decolonization (see the Supplementary Appendix). Data from the national VHA Pharmacy Benefits Management database showed that, nationwide, inpatient orders for 2% mupirocin ointment, a surrogate for decolonization efforts, were reduced from 0.013 orders per unique patient in October 2007 to 0.009 orders per unique patient in April 2010, suggesting that the use of decolonization regimens did not increase during the analysis period. Recommendations for hand hygiene and transmission precautions had been in place for years, and as part of a program to improve outcomes in VA ICUs, initiatives to decrease overall rates of bloodstream infection associated with central venous catheters and ventilator-associated pneumonia were implemented in all VA ICUs as of April 2006. However, device-associated and non-device-associated MRSA infections did not decline significantly until after full implementation of the MRSA bundle in October 2007. The MRSA bundle may have had a complementary or synergistic effect when it was added to the other initiatives that were already in place.

An important approach to dealing with multi-drug-resistant bacteria is to control their spread among patients. The data from the VA suggest that proactive efforts to prevent the transmission of MRSA are associated with a reduction in health care–associated MRSA infections. Patients in acute care hospitals outside the VA system may also benefit from the implementation of an aggressive campaign to eradicate health care–associated MRSA infections that uses a strategy similar to the VA strategy, but this would need to be tested. A phased-in approach targeting high-risk patients may be reasonable initially, but optimal control of health care–associated

MRSA infections and the best ratio of cost to benefit may be realized only with universal surveillance.^{16,33} Although we did not make a formal cost-benefit assessment of the VA MRSA Prevention Initiative, others have reported that programs of active surveillance are cost-effective over a wide range of prevalence and transmission rates.^{34,35} Expanding elements of the program to long-term and ambulatory care settings may be necessary to deal with reservoirs of MRSA throughout the health care system.

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No potential conflict of interest relevant to this article was reported.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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