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Authors

Huang, Susan S

Rifas-Shiman, Sheryl L

Warren, David K

et al.

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Improving Methicillin-Resistant *Staphylococcus aureus* Surveillance and Reporting in Intensive Care Units

Susan S. Huang,[1,2] Sheryl L. Rifas-Shiman,[2] David K. Warren,[3] Victoria J. Fraser,[3] Michael W. Climo,[4] Edward S. Wong,[4] Sara E. Cosgrove,[5] Trish M. Perl,[5] Jean M. Pottinger,[6] Loreen A. Herwaldt,[6] John A. Jernigan,[7] Jerome L. Tokars,[7,8] Daniel J. Diekema,[6] Virginia L. Hinrichsen,[2] Deborah S. Yokoe,[1] Richard Platt,[1,2] and the Centers for Disease Control and Prevention Epicenters Program

[1]Brigham and Women's Hospital, Channing Laboratory and Infection Control Department, and [2]Department of Ambulatory Care and Prevention, Harvard Medical School, and Harvard Pilgrim Health Care, Boston, Massachusetts; [3]Washington University School of Medicine, Division of Infectious Diseases, St. Louis, Missouri; [4]Hunter Holmes McGuire Veterans Affairs Medical Center, Division of Infectious Diseases, Richmond, Virginia; [5]The Johns Hopkins Medical Institutions, Department of Hospital Epidemiology and Infection Control, Baltimore, Maryland; [6]University of Iowa Hospitals and Clinics, Program of Hospital Epidemiology, Iowa City; [7]Division of Healthcare Quality Promotion and [8]Biosense, National Center for Public Health Informatics, Centers for Disease Control and Prevention, Atlanta, Georgia

(See the editorial commentary by Talbot, on pages 314–7, and the article by Huang et al., on pages 339–46.)

Background. Routine culturing of patients in intensive care units (ICUs) for methicillin-resistant *Staphylococcus aureus* (MRSA) identifies unrecognized carriers and facilitates timely isolation. However, the benefit of surveillance in detecting prevalent and incident carriers likely varies among ICUs. In addition, many assessments underestimate the incidence of acquisition by including prevalent carriers in the at-risk population.

Methods. We performed a retrospective cohort study using accurate at-risk populations to evaluate the range of benefit of admission and weekly surveillance cultures in detecting otherwise unrecognized MRSA in 12 ICUs in 5 states.

Results. We assessed 142 ICU-months. Among the 12 ICUs, the admission prevalence of imported MRSA was 5%–21%, with admission surveillance providing 30%–135% increases in rates of detection. The monthly hospital-associated incidence was 2%–6%, with weekly surveillance providing 7%–157% increases in detection. The common practice of reporting incidence using the total number of patients or total patient-days underestimated incidence by one-third. Surgical ICUs had lower MRSA importation but higher MRSA incidence. Overall, routine surveillance prevented the misclassification of 17% (unit range, 11%–29%) of "incident" carriers, compared with clinical cultures, and increased precaution days by 18% (unit range, 11%–91%).

Conclusions. Routine surveillance significantly increases the detection of MRSA, but this benefit is not uniform across ICUs, even with high compliance and the use of correct denominators.

Studies have shown that routine active screening for methicillin-resistant *Staphylococcus aureus* (MRSA) advances the identification of carriers and implementation of infection control measures to prevent patient-to-patient transmission [1–8]. This is important, because carriage is often asymptomatic and carriers have a high risk of subsequent invasive disease. Nevertheless, the yield of screening programs is likely to vary among and within institutions, because of variability in patient populations, transmission rates, and the frequency of obtaining clinical cultures for therapeutic reasons.

The range of improvement in estimates of incidence and prevalence due to routine surveillance is difficult to determine from existing literature. Several studies

were performed during MRSA outbreaks, so those results are not applicable to settings in which MRSA is endemic [9–12]. Many other studies showed that screening is advantageous in high-incidence settings, but they differed widely in patient population, screening method, and analysis [2–6, 13–15]. Most studies performed either admission-only screening, which does not assess health-care–associated transmission [1, 3, 6–7, 16], or selective screening of high-risk patients [2, 4–5, 13–15], which does not allow population assessments of the full MRSA reservoir. Fewer studies evaluated the impact of screening alone on estimates of both MRSA acquisition (incidence) and carriage (prevalence) [4, 12, 17–19]. A better understanding is needed of the range of benefit that different institutions might experience with routine surveillance.

The most informative studies of routine MRSA surveillance were conducted in France, and they showed that routine admission screening for MRSA reveals a much larger reservoir than clinical cultures alone [1, 2, 13]. There are no similar estimates in the United States that have been based on high-compliance surveillance during nonoutbreak settings. Another problem affecting numerous reports of incidence is the failure to omit already-colonized patients from the pool of patients at risk when calculating rates of acquisition [4, 5, 12, 17–20]. Rates computed in this way understate the true incidence rate by erroneously using inflated denominators. Accurate incidence measures are critical for the assessment of transmission and the evaluation of the impact of control measures within and across institutions.

We conducted a multicenter retrospective study to describe the variation in benefit of routine MRSA screening in intensive care units (ICUs) at US academic medical centers. We sought to evaluate the range in size of the MRSA reservoir, the impact of surveillance on improving estimates of incidence and prevalence among different types of ICUs, the correlation between measures based on clinical cultures alone (compared with those where surveillance is added), the magnitude of error associated with including MRSA carriers in incidence denominators, and the ICUs most likely to detect large numbers of MRSA carriers with surveillance efforts. We further evaluated the lead-time surveillance provided in advancing contact precautions and the duration of MRSA positivity in patients in ICUs.

METHODS

Description of Participating ICUs

Participating hospitals were from 5 US academic medical centers that had instituted routine nares surveillance cultures for MRSA in 12 adult ICUs as part of infection control initiatives. All centers participated in the Centers for Disease Control and Prevention (CDC) Epicenters Program and included Barnes-Jewish Hospital (St. Louis, MO), Brigham and Women's Hospital (Boston, MA), Hunter Holmes McGuire Veterans Affairs Medical Center (Richmond, VA), Johns Hopkins Medical Institutions (Baltimore, MA), and University of Iowa Hospitals and Clinics (Iowa City, IA). This study was approved by the institutional review boards of the CDC and all participating centers.

Each center provided retrospective ICU data for ∼1 year between 1 January 2002 and 31 August 2004. Outside of active surveillance cultures, there was no change in infection control practices, and there were no other special infection control programs to reduce MRSA during the study period. We collected ICU admission and discharge dates and sites of all positive MRSA clinical cultures and all surveillance cultures (positive and negative results). In addition, the date of the most recent institutional MRSA-positive culture before the ICU study period was provided for MRSA-positive patients. Last, each center completed a questionnaire about the specialty and size of participating ICUs and the methods of collecting surveillance cultures.

Data Analysis

Measuring prevalence and incidence, adjusting for at-risk populations. Univariate descriptions were provided for ICU characteristics. The percentage compliance with surveillance was calculated on the basis of nares cultures sent within 1 calendar day of the admission or weekly surveillance day. Monthly prevalence (the number of ICU patients ever known to be MRSA positive before or during that month/total number of ICU patients that month), monthly prevalence density (prevalence numerator/total monthly person-days), monthly admission prevalence (the number of patients ever known to be MRSA positive before or within 2 calendar days of admission/total number of monthly admissions), monthly incidence (the number of patients newly detected to be MRSA positive/number of patients at risk for new MRSA detection), and monthly incidence density (incidence numerator/number of person-days at risk for new MRSA detection) were calculated monthly for each unit, along with unit-specific means and SDs. Incident carriers were defined as patients with newly detected MRSA (colonization or infection) occurring at least 2 days after admission through 2 days after ICU discharge in persons without prior institutional cultures positive for MRSA (the at-risk population). ICU-specific summary measures were calculated as the mean of monthly measures.

Because studies of infection control interventions are often based on changes in monthly epidemiologic measures across time, we evaluated the intra- and interunit stability of these measures. Intraunit month-to-month variability was described by the SDs of a unit's monthly measures. Interunit differences in ICU-specific measures among the 12 ICUs were evaluated using 1-way analysis of variance (ANOVA) tests that accounted for intraunit variability. Summary statistics across all ICUs were

reported as the mean and range of ICU-specific summary measures. All epidemiologic measures were based on both clinical and surveillance cultures unless otherwise stated.

Evaluating the impact of surveillance on estimates of prevalence and incidence. We compared monthly incidence and prevalence measures, with and without the inclusion of surveillance culture data, using paired t tests and tests of correlation. Patients with a positive MRSA culture (clinical or surveillance) before or within 2 days of admission to the ICU were excluded from comparisons of incidence measures with and without surveillance data. We also determined the proportion of imported MRSA that would have been attributed to hospital-associated acquisition if only clinical cultures were considered. Finally, we assessed the linear change in monthly incidence during the study period using mixed models accounting for clustering within ICUs.

Assessing types of ICUs associated with increased incidence and prevalence. We used multivariate analyses to evaluate predictors of monthly admission prevalence and monthly incidence. In particular, we evaluated whether ICU type (medical or surgical) or monthly compliance with admission screening was associated with monthly admission prevalence and whether ICU type, monthly admission rate, monthly admission prevalence, or the number of ICU beds was associated with monthly incidence. For ease of interpretation, we used a priori binary outcomes of monthly admission prevalence of >10% and a monthly incidence of >5%. Dichotomous variables associated with the outcome at $\alpha < .2$ in bivariate analyses (χ^2 tests) were entered into generalized linear mixed models (PROC GLIMMIX in SAS version 9.1; SAS Institute), along with continuous variables. Final models were determined using stepwise backward selection at $\alpha = .05$, and all models accounted for clustering within ICUs.

Assessing the impact of using incidence denominators adjusted for at-risk populations. We assessed the effect of counting prevalent carriers in incidence density denominators. We compared incidence density that excluded patient-days of patients already harboring MRSA from the denominator (1000 patient-days at risk for new MRSA detection) with incidence density denominators of 1000 total patient-days. Comparisons were made using 2-tailed paired t tests of monthly measures.

Assessing the impact of surveillance on infection control precautions. The lead time was defined as the number of ICU precaution days attributable to surveillance cultures. This was determined by selecting persons newly detected to have MRSA by a surveillance culture and summing the ICU-days between the surveillance culture date and any subsequent MRSA-positive clinical culture. In the absence of a subsequent MRSA-positive clinical culture, all ICU-days during the study period were counted as added precaution days.

Assessing the persistence of MRSA carriage. Finally, we estimated the persistence of MRSA carriage as the likelihood of MRSA positivity at the time of admission screening among patients with a history of MRSA. We plotted the likelihood of positivity by time since their last positive institutional culture.

RESULTS

Description of participating ICUs. We evaluated 142 ICU-months from 4 medical and 8 surgical ICUs (table 1). Overall, 8013 patients were admitted 9691 times to the 12 ICUs, ac-

Table 1. Characteristics of participating intensive care units (ICUs).

Unit type	Beds, no.	LOS, median, days	Monthly admissions, mean no.	Study period, months	Admissions, total no.
Medical ICUs					
General medical	16	3	86.6	12	1039
General medical	10	3	59.3	12	712
Cardiac	10	2	73.6	12	883
Medical/cardiac	16	2	84.5	10	845
Surgical ICUs					
General surgery	24	3	103.3	12	1239
General surgery	10	2	72.0	12	864
Cardiac surgery	10	2	56.4	12	677
Cardiac surgery	10	2	66.3	12	796
Thoracic surgery	10	2.5	39.0	12	468
Burn	16	6	45.9	12	551
Burn/trauma	10	2	58.8	12	706
Neurosurgery	10	2	75.9	12	911

NOTE. LOS, length of stay.

counting for 49,282 ICU patient-days. Of all patients, 43.3% were >65 years old, and 61.2% were male.

MRSA screening policies are described in table 2. Overall compliance was 87% with admission nares cultures and 83% with weekly cultures. All centers had policies for contact precautions and private rooms for MRSA carriers. One ICU, which treated burn patients, preemptively placed patients on contact precautions while the MRSA screen results were pending and routinely used mupirocin to decolonize MRSA carriers.

Variation in MRSA prevalence and incidence. Average monthly prevalence and incidence estimates derived from both clinical and surveillance cultures were highly varied among ICUs (table 3). MRSA prevalence varied from 9% to 24%, and admission prevalence varied 4-fold, from 5% to 21%. Incidence was lower but still varied between 2% and 6%. This interunit variation resulted in significant differences among ICUs for all measures, including prevalence ($F = 9.9$; $P < .0001$, ANOVA), admission prevalence ($F = 17.6$; $P < .0001$), and incidence ($F = 2.1$; $P = .03$).

In addition to interunit variability, there was substantial intraunit variability. The addition of surveillance-culture data revealed greater variation in all measures than was seen with clinical cultures alone. SDs (table 3) were >30% of mean monthly MRSA prevalence in one-half of ICUs and were >50% of mean monthly MRSA incidence in >90% of ICUs. Because the Poisson distribution is often used to model predictors of MRSA incidence, we assessed the distribution criterion that the variance approximates the mean of incidence estimates. In the 12 ICUs, the variance was 9–48-fold greater than the mean monthly incidence.

Variation in impact of routine surveillance. Although the use of MRSA surveillance cultures significantly increased the detection of carriers for all epidemiologic measures (table 3), this benefit differed widely among ICUs. Compared with clinical cultures alone, the proportional benefit was 18.7%–63.5% for average monthly prevalence, 29.8%–135.1% for average monthly admission prevalence, and 6.7%–156.5% for average monthly incidence.

In addition, routine surveillance prevented the misclassification of imported carriers as incident ones. Admission nares cultures identified an additional 366 patients carrying MRSA at the time of admission. Of these 366 patients, 46 (12.6%; unit range, 5.6%–21.4%) would have had their MRSA erroneously attributed to hospital acquisition on the basis of clinical cultures alone. From another vantage point, these 46 prevalent carriers represented a 16.8% (unit range, 11.1%–28.6%) misclassification rate among the 274 "incident" carriers on the basis of clinical cultures alone.

Among all ICUs, incidence decreased by 0.23% monthly ($P < .001$). This decrease was attributable to 10 ICUs for which the start of the study period coincided with the initiation of surveillance cultures (change in incidence, -0.28% monthly; $P < .001$), compared with 2 ICUs for which the study period occurred a median of 21 months after surveillance cultures had been instituted (change in incidence, 0.02% monthly; $P = .98$).

Table 2. Methicillin-resistant *Staphylococcus aureus* (MRSA) surveillance policies, by intensive care unit (ICU) type.

Unit type	Admission screen	Weekly screen	Screen if MRSA positive	Screen if on precautions	Screen both nares	Precautions pending screen results	Screening compliance,[a] %
Medical ICUs							
General medical	Y	Y	Y	Y	N	N	85
General medical	Y	Y	Y	Y	Y	N	92
Cardiac	Y	Y	Y	Y	Y	N	94
Medical/cardiac	NA[b]	Y	Y	Y	Y	N	NA[b]
Surgical ICUs							
General surgery	Y	Y	Y	Y	Y	N	79
General surgery	Y	Y	Y	Y	Y	N	87
Cardiac surgery	Y	Y	Y	Y	Y	N	90
Cardiac surgery	Y	Y	Y	Y	Y	N	94
Thoracic surgery	Y	Y	Y	Y	Y	N	93
Burn	Y	N	Y	Y	Y	Y	89
Burn/trauma	Y	Y	Y	Y	Y	N	72
Neurosurgery	Y	Y	Y	Y	Y	N	82

NOTE. N, no; NA, not applicable; Y, yes.
[a] Percentage of ICU admissions with surveillance nares cultures sent at the time of admission.
[b] MRSA screening swabs were obtained 3 times per week—Mondays, Wednesdays, and Fridays.

Table 3. Average monthly incidence and prevalence measures across all intensive care unit (ICUs).

Measure	Excluding surveillance		Including surveillance		Added detection with surveillance (unit range)	P^b
	Estimate, % (ICU range)	ICU SD[a]	Estimate, % (ICU range)	ICU SD[a]		
Prevalence						
Admission prevalence	8 (2.2–15.9)	1.5–5.8	11.9 (4.5–20.6)	1.9–7.5	3.9 (2.3–5.6)	<.0001
Prevalence	13.4 (6.8–19.0)	2.4–7.1	17.5 (9.2–23.5)	3.3–8.7	4.1 (2.4–6.0)	<.0001
Prevalence density/1000 patient-days	2.9 (1.5–4.4)	0.6–1.4	3.8 (2.2–5.8)	0.6–1.7	0.9 (0.4–1.4)	<.0001
Incidence[c]						
Incidence	2.6 (1.4–5.3)	1.3–4.5	3.4 (2.4–5.7)	1.7–4.6	0.8 (0.2–2.3)	<.0001
Incidence density[d]	6.7 (3.2–16.5)	2.6–10.0	8.9 (4.0–18.2)	3.1–10.1	2.2 (0.6–6.2)	<.0001

[a] SDs were calculated across all monthly estimates from a given ICU. The range across all ICUs is shown.
[b] Paired 2-tailed t test comparing monthly ICU estimates that include and exclude surveillance culture data.
[c] Similar results were found when the unit in which routine weekly surveillance was not performed was excluded (overall incidence, 2.4% without surveillance and 3.6% with surveillance [$P < .0001$]; overall incidence density, 9.3/1000 without surveillance and 7.1/1000 with surveillance [$P < .0001$]).
[d] Per 1000 patient-days at risk for newly detected MRSA.

Correlation of prevalence and incidence measures with and without surveillance data. Although monthly prevalence and incidence measures based on clinical cultures significantly underestimated values obtained with clinical and surveillance cultures, these measures were highly correlated. Correlation coefficients for monthly measures with and without surveillance cultures were as follows: admission prevalence, 0.91; prevalence, 0.92; prevalence density, 0.92; incidence, 0.87; and incidence density, 0.87.

Types of ICUs associated with elevated incidence and prevalence. In bivariate analyses of dichotomous variables, medical (vs. surgical) ICUs were associated with a monthly admission prevalence >10% ($P < .0001$). The type of ICU was not significantly associated with a monthly hospital-associated MRSA incidence >5% ($P = .16$).

In multivariate models controlling for clustering by ICU, we found that medical ICUs had 36.8-fold higher odds (95% confidence interval [CI], 4.3–319.1) of having a monthly MRSA admission prevalence >10%, compared with surgical ICUs. Compliance with monthly admission cultures was not associated with monthly admission prevalence across the range of compliance seen in this study. Predictors of monthly MRSA incidence >5% included a higher MRSA admission prevalence (odds ratio [OR], 1.1 for each percentage increase [95% CI, 1.1–1.2]) and being a surgical ICU (OR, 3.5 [95% CI, 1.2–14.7]) when we controlled for the number of ICU beds. Monthly ICU admission rates and total number of ICU beds were not predictive of a higher monthly MRSA incidence.

Impact of using incidence denominators adjusted for at-risk populations. In evaluating the mean monthly incidence density, the use of total patient-days as the denominator underestimated the true incidence density by 32.6% (6.0 vs. 8.9 cases/1000 patient-days at risk; $P < .0001$). Similar to paired t test results, linear regression analysis found that incidence den-

sity estimates using total patient-days as the denominator resulted in a 35.0% underestimation when compared with incidence density using patient-days at risk as the denominator (figure 1). Similar discrepancies were observed for mean monthly incidence when excluding versus including prevalent carriers from the denominator (3.4% of patients at risk vs. 3.0% of total patients; $P < .0001$).
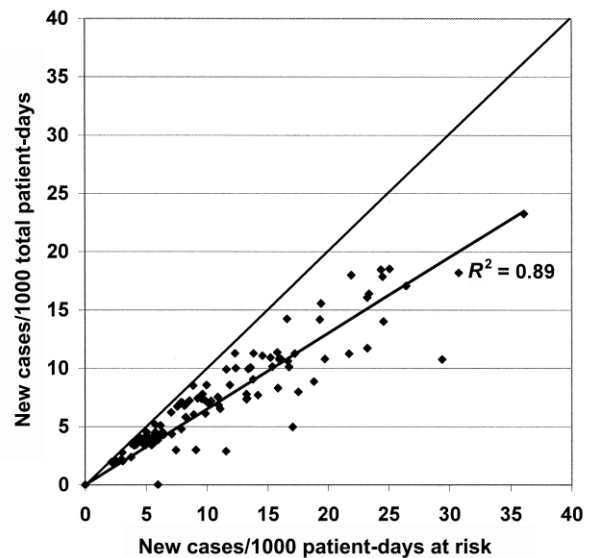

Figure 1. Graph depicting the divergence of methicillin-resistant *Staphylococcus aureus* (MRSA) incidence density estimates when comparing measures using total patient-days with patient-days at risk denominators. Denominators using patient-days at risk limit patient-days to those belonging to patients in whom MRSA has yet to be found (those eligible to become a carrier). The upper line shows the hypothetical case in which the 2 measures give identical results. The lower line is a regression line based on monthly data from the 12 intensive care units ($P < .0001$). The lines increasingly diverge as MRSA incidence density increases.

Impact of surveillance on infection control precautions.
Of 49,282 ICU patient-days, 11,078 (22.5%) were spent in contact isolation because of MRSA. In the absence of surveillance cultures, 9356 contact isolation days would have been implemented because of MRSA-positive clinical cultures obtained before and during the study period. Therefore, admission and weekly surveillance cultures resulted in 1722 additional ICU patient-days (350 persons) of contact precautions. There was an 18.4% overall increase in precaution days; however, institutional increases ranged widely, from 10.7% to 91.2%. Among the 105 patients initially identified by surveillance cultures who had subsequent MRSA-positive clinical cultures, the average lead time was 6.7 ICU patient-days. Nevertheless, only 30.0% of patients identified through surveillance cultures had a subsequent clinical culture positive for MRSA during their ICU stay. These patients accounted for only one-third (35.1%) of the lead time gained by surveillance cultures. When surveillance data were ignored, there was an average of 65.9 ICU precaution days/ICU-month. Surveillance cultures added an average of 12.0 (range, 6.6–28.3) additional precaution days/ICU-month. Additional precaution days that occurred after transfer to other unit areas or hospital readmission to a nonparticipating unit were not included.

Persistence of MRSA carriage.   Duration of carriage was evaluated among patients with an institutional MRSA-positive culture before admission to the ICU ($n = 592$). Figure 2 depicts the likelihood of a positive ICU admission surveillance culture for MRSA, based on the time since the last known positive MRSA culture. The majority of patients admitted within 150

days of their last positive MRSA culture tested positive for MRSA. Among patients admitted >300 days since their last positive MRSA culture, 29.3% were still positive for MRSA on screening surveillance cultures.

DISCUSSION

ICUs are high-risk units for the importation and acquisition of MRSA. The high compliance with admission and weekly nares cultures in several ICUs in nonoutbreak settings enabled us to examine the range of increased accuracy in the prevalence and incidence derived from improved MRSA detection. We found that the size of the MRSA reservoir varied widely among the ICUs studied, although all were in tertiary-care centers.

Although admission surveillance cultures increased the detection of MRSA imported into study ICUs by an overall average of nearly 50%, their impact varied across ICUs, from a modest improvement to more than doubling the number of detected carriers. The average improvement in identifying imported carriers was approximately one-half the improvement reported in previous non-US studies [1, 2, 6, 13]. Differences among our ICUs or between our results and data from other nations may reflect differences in physician propensities for requesting clinical cultures at the time of ICU admission. These differences likely exist at the ICU, institutional, and national levels.

In addition, we found that increased detection of ICU transmission attributable to weekly surveillance cultures was minimal in some ICUs but was marked in others. It is possible that
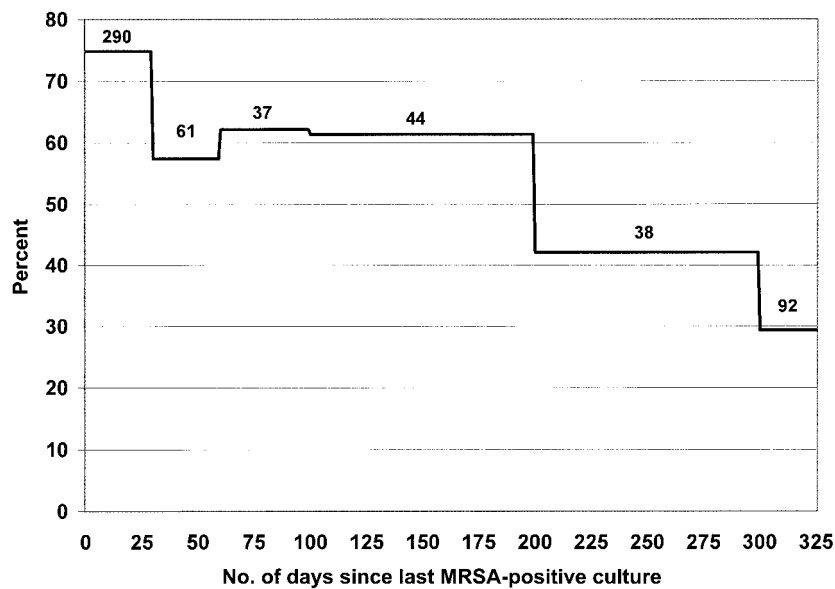

Figure 2.   Graph depicting the likelihood of a positive admission surveillance culture for methicillin-resistant *Staphylococcus aureus* (MRSA) according to the no. of days since the most recent MRSA-positive culture. Percentage positivity at admission was calculated at 30, 60, 100, 200, 300, and >300 days. The no. of patients represented in each interval is shown. A total of 562 patients are represented.

low measures of incidence reflect decreased transmission due to active surveillance and advanced barrier precautions [19]. Alternatively, it could be in response to varying MRSA importation or other sources of inter- or intraunit endemic variation [21, 22].

The threshold prevalence of MRSA carriage at which the prompt detection and isolation of carriers reliably reduces hospital-associated transmission and is economically justified has not been fully established. In fact, this threshold is likely to differ on the basis of patient population, staff practices, and attention to hand hygiene and contact precautions. Thus, the best practices may vary among and within institutions. In the present study, surveillance resulted in a significant decrease in monthly incidence of MRSA over time in ICUs in which surveillance had been newly instituted. The lack of a significant decrease in incidence in ICUs in which surveillance had been in place for some time may reflect a plateau effect where the maximum reduction in incidence had already been achieved. Factors that should influence the decision to perform routine surveillance include the prevalence of MRSA carriage at the time of admission to a hospital unit, the rate of transmission in the setting of other ongoing infection control programs, the costs of the surveillance program, the expected decrease in hospital-associated transmission, and the impact on economics and patient care of preventing acquisition and subsequent invasive disease.

In assessing which units might benefit most from intensive screening, we found that higher measures based on clinical cultures alone correlated with higher measures after active surveillance for both importation (admission prevalence) and incidence. This suggests that estimates in the absence of screening may be one useful indicator of incidence and prevalence measures after improvement gained by an intensive screening program. Not unexpectedly, ICUs importing a high number of carriers were more likely to have high levels of MRSA transmission, after adjustment for medical or surgical ICU type.

We found that type of ICU was also a useful predictor of MRSA importation and transmission. Medical ICUs had a significantly higher MRSA importation rate than surgical ICUs, in contrast to the findings of Lucet et al. [1]. Furthermore, despite lower importation, hospital-associated transmission was significantly higher in surgical ICUs. This may be due to the presence of wounds and surgical incisions, which predispose to MRSA acquisition [23–26] and increased environmental contamination [27]. In addition, there may be differences in physician and nursing practices in surgical units, compared with those in medical units. Heightened vigilance in surgical ICUs may be needed to prevent transmission, despite the lower prevalence of MRSA.

When a sufficient MRSA reservoir exists for percentages to be meaningful, there are many advantages to routine surveil-lance. In our study, 70% of MRSA carriers who were newly identified by surveillance cultures had no subsequent MRSA-positive clinical culture within the study period. This should not be misinterpreted as a low risk for subsequent infection, which we know is not the case [28–31]; rather, it emphasizes that a substantial lead time can be gained by surveillance cultures. This lead time with contact precautions improves patient safety by reducing transmission to other patients and substantially improves the estimates of incidence and prevalence necessary for infection control decision-making.

Surveillance cultures also prevented imported carriage from being erroneously ascribed to hospital-associated ICU transmission. This occurred when imported carriers were first detected by clinical cultures obtained >48 h after admission to the ICU. In the present study, misclassification would have affected 17% of reportedly hospital-associated acquisition if surveillance cultures had been ignored. In the absence of routine surveillance, hospital resources could be needlessly expended in investigating pseudo-outbreaks caused by misclassified imported MRSA carriage. Finally, surveillance cultures can identify patients who might benefit from decolonization to reduce the 30% risk of later invasive disease [28–31].

Importantly, comprehensive knowledge of the MRSA reservoir enabled us to calculate appropriate incidence denominators that included only persons eligible to acquire colonization (i.e., those not already colonized). The use of incorrect denominators, such as total patients or total patient-days, underestimated incidence by one-third. These commonly used incorrect denominators could produce large proportional errors and result in erroneous conclusions for hospital infection control programs or research studies. Of the numerous studies of weekly surveillance in the absence of other intervention, we found very few studies that used accurate denominators for comparison [17, 19].

The present study highlights another common source of error in interpreting active surveillance data: month-to-month variability in all epidemiologic MRSA measures, which can lead to erroneous conclusions if short-term variability is misinterpreted as a significant trend [22, 32]. These fluctuations occur because of transmissibility and because small numbers of patients importing MRSA can have a large impact in units with small numbers of beds [32]. This variability means that meaningful conclusions about the impact of prevention measures often require prolonged periods to demonstrate durable changes, rather than transient chance phenomena. For similar reasons, analyses of multiple ICU interventions need to account for the clustering of incident carriers within a given unit.

There are several limitations to the present study. First, our findings are limited to ICUs from tertiary-care academic centers. However, given this restriction, the actual distribution of contributions from surveillance programs is likely even wider

than we observed. Second, the potential value of surveillance is also underestimated, given that nares cultures identify only 83%–98% of MRSA carriers [25, 33, 34] and because surveillance cultures were performed only at the time of admission and weekly thereafter. More-sensitive surveillance systems would improve the benefit, although not necessarily sufficiently to justify their cost. Third, we did not perform genetic typing of MRSA strains to support whether isolates were imported or acquired from circulating strains in a study ICU.

In summary, we show that routine surveillance for MRSA in many ICUs resulted in numerous advantages for the appropriate evaluation of this pathogen. Routine surveillance significantly advanced the institution of contact precautions and greatly improved estimates of the MRSA reservoir. Admission surveillance prevented the misclassification of imported carriers as incident ones, and weekly surveillance increased identification of hospital-associated acquisition. Furthermore, added detection through surveillance enabled the accurate calculation of incidence—a necessity for the assessment of intervention effects. Nevertheless, not all ICUs benefited from active surveillance, and the intensity of labor of routine screening may not be warranted in ICUs that do not demonstrate substantial gain.

Acknowledgment

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