

Universal Screening for Methicillin-Resistant *Staphylococcus aureus* at Hospital Admission and Nosocomial Infection in Surgical Patients

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CARRIAGE OF ANTIMICROBIAL-resistant pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) places patients at high risk of infection.^{1,2} Early identification of patients colonized with MRSA and subsequent prevention of patient-to-patient spread through infection control measures are believed to be potent interventions to control MRSA.³ In addition, rapid MRSA screening of surgical patients may decrease MRSA infections by facilitating appropriate selection of antibiotic agents for preoperative prophylaxis.⁴

Experts and policy makers, nationally and internationally, recommend universal admission screening as a means to control MRSA.^{5,6} However, no controlled trial has tested the hypothesis that rapid MRSA screening may improve patient outcome by decreasing MRSA cross-transmission and increasing the adequacy of preoperative pro-

Context Experts and policy makers have repeatedly called for universal screening at hospital admission to reduce nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infection.

Objective To determine the effect of an early MRSA detection strategy on nosocomial MRSA infection rates in surgical patients.

Design, Setting, and Patients Prospective, interventional cohort study conducted between July 2004 and May 2006 among 21 754 surgical patients at a Swiss teaching hospital using a crossover design to compare 2 MRSA control strategies (rapid screening on admission plus standard infection control measures vs standard infection control alone). Twelve surgical wards including different surgical specialties were enrolled according to a prespecified agenda, assigned to either the control or intervention group for a 9-month period, then switched over to the other group for a further 9 months.

Interventions During the rapid screening intervention periods, patients admitted to the intervention wards for more than 24 hours were screened before or on admission by rapid, multiplex polymerase chain reaction. For both intervention (n=10 844) and control (n=10 910) periods, standard infection control measures were used for patients with MRSA in all wards and consisted of contact isolation of MRSA carriers, use of dedicated material (eg, gown, gloves, mask if indicated), adjustment of perioperative antibiotic prophylaxis of MRSA carriers, computerized MRSA alert system, and topical decolonization (nasal mupirocin ointment and chlorhexidine body washing) for 5 days.

Main Outcome Measures Incidence of nosocomial MRSA infection, MRSA surgical site infection, and rates of nosocomial acquisition of MRSA.

Results Overall, 10 193 of 10 844 patients (94%) were screened during the intervention periods. Screening identified 515 MRSA-positive patients (5.1%), including 337 previously unknown MRSA carriers. Median time from screening to notification of test results was 22.5 hours (interquartile range, 12.2-28.2 hours). In the intervention periods, 93 patients (1.11 per 1000 patient-days) developed nosocomial MRSA infection compared with 76 in the control periods (0.91 per 1000 patient-days; adjusted incidence rate ratio, 1.20; 95% confidence interval, 0.85-1.69; $P=.29$). The rate of MRSA surgical site infection and nosocomial MRSA acquisition did not change significantly. Fifty-three of 93 infected patients (57%) in the intervention wards were MRSA-free on admission and developed MRSA infection during hospitalization.

Conclusion A universal, rapid MRSA admission screening strategy did not reduce nosocomial MRSA infection in a surgical department with endemic MRSA prevalence but relatively low rates of MRSA infection.

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phylaxis. This study was designed to evaluate the effect of a MRSA early detection strategy on nosocomial MRSA infections in a cohort of surgical patients at a large Swiss teaching hospital with endemic MRSA.

METHODS

Study Design and Setting

We conducted a prospective, interventional cohort study using a crossover design to compare the effect of 2 different MRSA control strategies (rapid screening plus standard infection control measures vs standard infection control alone) on the development of nosocomial MRSA infection. The study was conducted in the surgical department of the University of Geneva Hospitals (365 beds and 13 280 admissions in 2004). Twelve wards in 8 different specialties (abdominal surgery, orthopedics, urology, neurosurgery, cardiovascular surgery, thoracic surgery, plastic surgery, and solid organ transplantation) were enrolled in the study. The study population included all adult patients admitted to the surgical department for more than 24 hours. Patients admitted for ambulatory surgery were excluded, as they were considered to be at low risk of MRSA infection.⁷

Each surgical specialty was assigned to either the intervention or control study group and enrolled according to a prespecified plan encompassing 4 study phases. From July to September 2004, a baseline surveillance period without MRSA screening on admission was implemented in all wards. Intervention period 1 (October 2004–June 2005) consisted of a 9-month intervention with application of the rapid screening tool in the orthopedic, neurosurgery, plastic surgery, cardiovascular, and thoracic surgery wards, with the remaining wards serving as concurrent controls. Follow-up for MRSA infections was continued in all wards during the next 2 months (washout period). In September 2005, the wards were switched for an additional 9 months (crossover phase) to balance the effect of possible ward-related confounding variables. In intervention pe-

riod 2 (September 2005–May 2006), rapid MRSA screening was applied to patients on admission to the urology, transplant, and abdominal surgery wards and the remaining wards became controls.

The study protocol was approved by the institutional review board as a continuous quality improvement project with a waiver of informed consent. However, an information sheet entitled “An Action to Prevent Infections” was used to inform all patients or next of kin about the scope of the study and test results.

Study Intervention and MRSA Control Measures

The study intervention consisted of application of a molecular technique for early detection of MRSA carriage by rapid screening of patients admitted to the intervention wards (including both elective and emergency admissions). Standard infection control measures were used for patients with MRSA in all wards and consisted of contact isolation of identified MRSA carriers in flagged side or single rooms whenever available, use of dedicated material (gown, gloves, and, if indicated, mask), adjustment of perioperative antibiotic prophylaxis of MRSA carriers, computerized MRSA alert system, and topical decolonization (nasal mupirocin ointment and chlorhexidine body washing) of known MRSA carriers for 5 days.^{8,9} If a patient started a 5-day decolonization regimen and went to the operating room before day 5, treatment was completed after surgery. MRSA carriers who were identified only after surgical intervention also underwent decolonization for 5 days. No preemptive isolation was instituted for patients without a history of MRSA carriage.

Other Control Measures

The University of Geneva Hospitals has a history of hand hygiene observation and promotion.¹⁰⁻¹³ During the study, there was no promotion campaign in the surgical department targeting hand hygiene or other aspects of basic infec-

tion control, nor were there initiatives to alter antibacterial use or implement an antibiotic stewardship program.

Screening Process in the Intervention Wards

Admission screening for MRSA carriage was carried out for all patients admitted to the intervention wards by systematic sampling of the anterior nares and perineal region and other sites (catheter insertion sites, skin lesions, or urine) when clinically indicated.¹⁴ Specimens were collected with a sterile Dacron-tipped swab premoistened with sterile saline solution.¹⁵ If a patient had been screened at another hospital site within 3 days prior to admission to the surgical service, he/she was not rescreened on admission to the intervention ward. Eligible patients admitted through the emergency department were screened on-site 7 days per week. Patients admitted directly to a ward were screened within the first 12 hours of admission or as an outpatient during preoperative workup.

Microbiologic Procedures

We used a multiplex immunocapture-coupled quantitative polymerase chain reaction (qPCR) developed at our institution that enables a rapid diagnosis of MRSA carriage through detection of the *mecA* gene.^{14,16} Swab samples were resuspended in a buffer, then *S aureus* was immunocaptured using monoclonal antibodies coupled to magnetic beads and directed against protein A. After bacterial lysis, the presence of MRSA was assessed by a multiplex real-time qPCR assay.¹⁶ In a prior study, the test yielded a sensitivity of 96% and a specificity of 91% compared with conventional culture-based methods.¹⁷ Rapid MRSA tests were performed twice daily 6 days per week. Samples collected on Sunday were processed on Monday morning.

Outcomes and Definitions

The primary outcome measure was the overall rate of nosocomial MRSA infection per 1000 patient-days. Infection was defined as hospital acquired if it occurred more than 48 hours after

admission and less than 72 hours after discharge from the surgical service. The primary end point was assessed among patients with previously known or newly identified MRSA carriage and was measured within each surgical specialty. The rate of surgical site infection due to MRSA (per 100 procedures) constituted a secondary outcome. Surgical site infection due to MRSA was attributed to surgery if it was documented within 30 days following the surgical procedure. An additional secondary outcome was the nosocomial MRSA acquisition rate, expressed as the rate of new MRSA cases detected by clinical cultures retrieved more than 48 hours after admission in previously MRSA-free patients. For the latter end point, a case of nosocomial MRSA acquisition was defined as any patient previously not known to have MRSA colonization or infection prior to hospital admission but who subsequently had positive clinical cultures (excluding surveillance swabs) for MRSA during hospitalization. Patients with clinical cultures or surveillance swabs positive for MRSA during the first 48 hours of hospital admission were considered to have colonization on admission and were not eligible for nosocomial MRSA acquisition.

Infection Surveillance and Data Collection

Active surveillance for nosocomial infections due to MRSA was conducted by trained infection control practitioners who visited the surgical wards at least twice a week and performed prospective surveillance of nosocomial MRSA infections using criteria established by the Centers for Disease Control and Prevention.¹⁸ We did not record infections caused by other microorganisms except for cases of polymicrobial infection that included MRSA as a pathogen. Nurses screened the data gathered from microbiology reports, medical records, and nursing charts. Active surveillance continued for patients transferred to rehabilitation, long-term care, or critical care units.

Table 1. Study Characteristics by Period of Study

Characteristics	Control Periods	Intervention Periods
Cumulative duration, mo	18 mo	18 mo
No. of admissions	10 910	10 844
Total No. of patient-days	83 120	83 757
No. of patients with surgical procedures	6072	6130
Length of stay, mean (SD), d	6.1 (1.1)	6.4 (1.3)
Bed occupancy rate, mean (SD), %	89 (19)	90 (16)
Consumption of antibiotics without MRSA activity, daily defined doses ^a	33 805	34 346
Use of alcohol-based hand rubs, L per 1000 patient-days (95% CI)	18.7 (17.7-19.8)	19.4 (18.0-20.9)
No. of previously known MRSA carriers admitted	149 ^b	178 ^b

Abbreviations: CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus*.
^aIncludes all β -lactam agents, carbapenems, fluoroquinolones, and macrolides and excludes glycopeptides, linezolid, and cotrimoxazole.
^bFor comparison of control vs intervention periods, relative risk, 1.2; 95% confidence interval, 0.97-1.49.

Postdischarge surveillance to identify MRSA surgical site infections was conducted until 30 days following the operation during regular follow-up visits at the outpatient clinic or if the patient was readmitted because of infectious complications (passive surveillance). Consultants who cared for the patients in the outpatient clinic were asked to culture any surgical site infection to exclude MRSA. Comprehensive data collection during the passive surveillance period was facilitated because the University of Geneva Hospitals are the only public hospital in the Geneva region offering primary and tertiary care.

Data elements collected for all MRSA-infected patients included patient demographics, previous hospital stay, reason for admission, underlying illness and comorbidities, exposure to invasive devices, previous antimicrobial and immunosuppressive therapy, culture results, and adherence to contact precautions. The latter was assessed during ward visits and rated "low" in the absence of sign-posting and protective equipment (eg, gowns, gloves) at room entry. We also recorded if MRSA-infected patients had received perioperative prophylaxis active against MRSA. These data were extracted from nursing charts and computerized anesthesiology records. Throughout the study, monthly use of alcohol-based hand rubs (in liters) was recorded as a surrogate marker for hand hygiene adherence.^{10,19}

Statistical Analysis

Based on MRSA surveillance information from our institution in 2003, to detect a clinically relevant reduction in the nosocomial MRSA infection rate by one-third from a prestudy incidence of 1.2 nosocomial MRSA infections per 100 admissions, a minimum of 10 428 patients was required in each study group, providing a confidence level of 95% and a power of 80%. The actual number of 21 754 patients gave the study 70% power to detect a reduction in the MRSA infection rate from 0.9% to 0.6% in the rapid detection group. Assumptions included use of a 2-tailed test with a .05 significance level and Poisson distribution of MRSA-infected patients across all wards.

Nosocomial MRSA infection and acquisition rates were calculated based on prospectively collected and validated surveillance data.⁹ Outcome measures were computed for the intervention and control groups separately and compared. We analyzed comparability of MRSA-infected patients in the control and intervention periods by χ^2 test, Fisher exact test, *t* test, or Wilcoxon rank sum test, as appropriate.

Incidence rate ratios of nosocomial MRSA infection were calculated using Poisson regression.¹⁴ To account for clustering of MRSA-infected patients within surgical subspecialties, we used the generalized estimating equation (GEE) approach.²⁰ The number of patients with nosocomial MRSA infec-

tion in a given month was the dependent variable. Only 1 MRSA infection was considered per patient per hospital stay. Intervention or control group status was the primary independent variable. The monthly number of admitted patients with previously known MRSA carriage was included in the model as an independent variable to adjust for colonization pressure.¹⁴ Moreover, we adjusted for potential confounding and secular trends by including as variables the study month, monthly use of alcohol-based hand rubs, and antibiotic selection pressure exerted by antibiotics without activity against MRSA. Antibiotic use was measured in daily defined doses, 1 daily defined dose being the standard adult daily dose of an antimicrobial agent for 1 day's treatment.²¹

To assess robustness of the results with respect to choice of statistical model, a secondary analysis was conducted using multivariable analysis of covariance for repeated-measures variables (accounting for the crossover design and the between- and withinward variance), including several continuous covariates (antibiotic use, consumption of alcohol-based hand rubs, colonization pressure). The main effect term was rapid MRSA screening. No significant period or intervention order effects were detected. The fi-

nal multivariate analysis of covariance model confirmed the absence of an intervention effect ($F=0.77$; $P=.38$) after accounting for the crossover design and adjusting for potential confounders. Thus, compared with the GEE model, none of the principal conclusions about statistical significance were altered. Only the results of the multivariate GEE Poisson analyses are presented here. All analyses were performed using Stata, version 9 (Stata Corp, College Station, Texas).

We also used statistical process control methods to examine random variability and the temporal effect of rapid screening on nosocomial MRSA infections.^{22,23} A run chart based on Poisson distribution was constructed showing the rate of patients with nosocomial MRSA infection for each month of the study (per 1000 patient-days). The mean MRSA infection rate (center line) and the upper and lower control limits (plus/minus 3 SDs) were established as previously described.^{22,23}

RESULTS

Intervention Periods

The cohort consisted of 21 754 surgical patients. TABLE 1 compares pooled data from the control and intervention periods. The numbers of direct admissions, total patient-days, surgical procedures, bed occupancy rates, mean

length of hospital stay, and use of antibiotics and alcohol-based hand rubs were similar in the 2 periods. There were more previously known MRSA carriers admitted during the intervention periods compared with the control periods (178 vs 149 patients; relative risk, 1.2; 95% confidence interval [CI], 0.97-1.49). Total use of alcohol-based hand rub solution was similar for the control and intervention periods (18.7 L vs 19.4 L per 1000 patient-days, respectively; $P=.30$).

Screening

Overall, 10 193 of 10 844 patients (94%) were screened with the rapid molecular test during the intervention periods (TABLE 2). Six percent of patients were not screened because they were considered at very low risk of MRSA carriage according to a previously established risk index (age <50 years, no previous hospitalization, no antibiotic therapy within the last 6 months)¹⁵ or for other reasons (Table 2). A total of 1331 patients (12%) were screened during prehospitalization visits to the surgical outpatient clinic.

MRSA Detection Rates at Screening Before or at Admission

Admission screening during the intervention periods identified a total of 515

Table 2. MRSA Screening During Intervention Periods

Characteristics	Intervention Period 1: October 2004–June 2005 (n = 6483)	Intervention Period 2: September 2005–May 2006 (n = 4361)	Total (n = 10 844)
Surgical subspecialties included	Neurosurgery, orthopedics, plastic, cardiovascular, and thoracic surgery	Urology, transplant, and abdominal surgery	
Total No. of screened patients (%)	6028 (93)	4165 (96)	10 193 (94)
Screening at outpatient clinic	843	488	1331
Screening at admission	5185	3677	8862
Total No. of patients without screening (%)	455 (7)	196 (4)	651 (6)
Very low risk ^a	363	128	491
Other reasons ^b	92	68	160
MRSA-positive patients detected at			
Outpatient visit	12	14	26
Hospital admission	280	209	489
Time from screening to notification, median (IQR), h	23.1 (15.1-31.4)	22.2 (11.3-27.1)	22.5 (12.2-28.2)
MRSA result notification after surgery ^c	78	42	120

Abbreviations: IQR, interquartile range; MRSA, methicillin-resistant *Staphylococcus aureus*.

^a Considered very low risk according to previously established criteria (age <50 years, absence of hospitalization and antibiotic therapy within the last 6 months).¹⁵

^b Other reasons include time constraints due to life-threatening conditions (n = 16), refusal (n = 5), or early discharge or death (n = 139).

^c Only among patients undergoing surgery.

MRSA-positive patients among 10 193 screened patients (5.1%). Preadmission screening in the outpatient clinics and screening on admission to the surgical service detected MRSA carriage in 26 of 1331 patients (1.9%) and 489 of 8862 patients (5.5%), respectively (Table 2). The majority of patients (n=337 [65%]) had not been previously identified as MRSA carriers and would have been missed without systematic screening on admission. To detect 1 previously unidentified MRSA carrier on admission, 30 patients would have to be screened.

The proportion of MRSA carriers detected on admission was similar in intervention period 1 (292/6028 [4.8%]) and intervention period 2 (223/4165

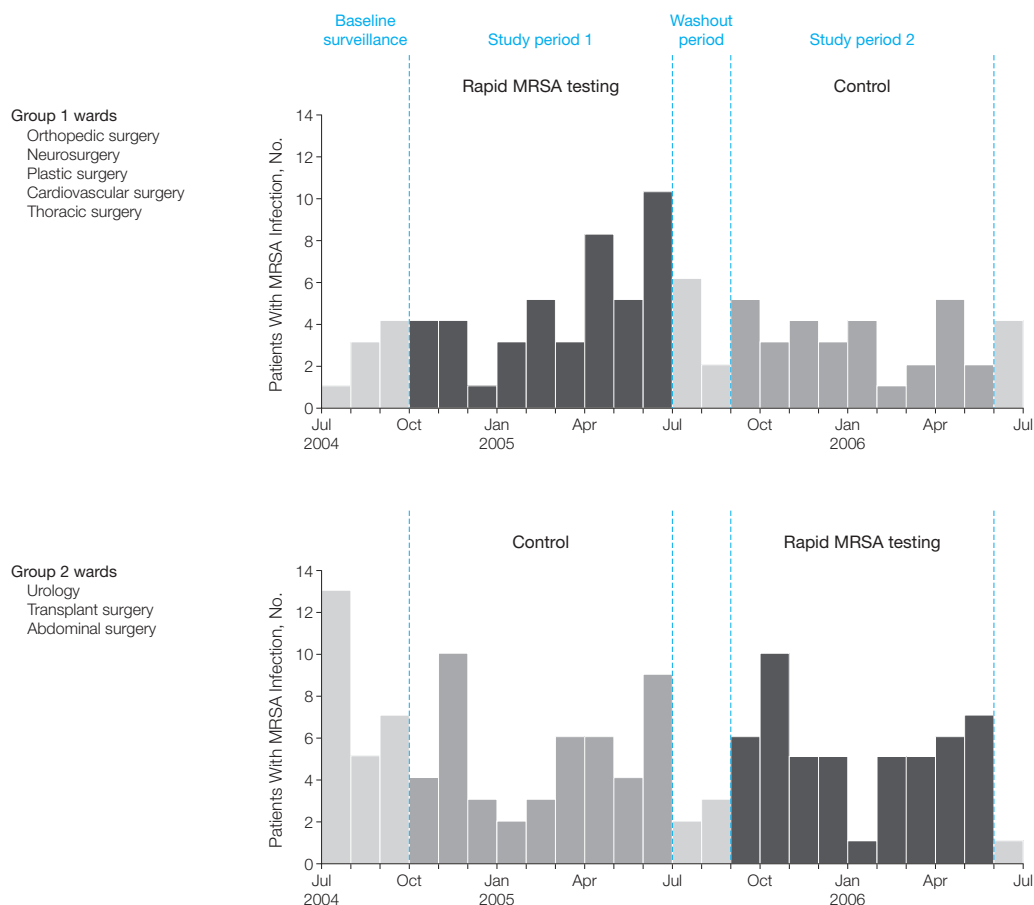
[5.3%]) (Table 2). Median time from PCR-based admission screening to notification of test results was 22.5 hours (interquartile range, 12.2-28.2 hours), including Sundays. Among 386 detected MRSA carriers undergoing surgery, 120 patients (31%) were identified only after surgical intervention because of emergency surgery and time delays in result notification. The remaining 266 patients who were identified prior to surgery received perioperative antibiotic prophylaxis active against MRSA in 115 instances (43%).

Nosocomial MRSA Infection and Acquisition Rates

FIGURE 1 shows the monthly number of patients who acquired any type of

MRSA infection, stratified by study group and period. In intervention periods 1 and 2, 169 patients acquired at least 1 nosocomial MRSA infection (incidence rate, 1.01 per 1000 patient-days). The overall rates of nosocomial surgical site and bloodstream infection due to MRSA were 1.06 per 100 surgical procedures and 0.36 per 10 000 patient-days, respectively. A total of 93 patients (1.11 per 1000 patient-days) developed nosocomial MRSA infection in the intervention periods compared with 76 patients (0.91 per 1000 patient-days) in the control periods (incidence rate ratio, 1.2; 95% CI, 0.9-1.7; $P=.21$) (TABLE 3). After adjustment for colonization pressure, use of al-

Figure 1. Incidence of MRSA Infections



Data are incident cases of any type of nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infection, stratified by period and intervention group. The total number of admissions in the control periods was 10 910 and in the intervention periods was 10 844.

cohol-based hand rubs, temporal trends, and potential clustering effects, the main outcome measure remained virtually unchanged (adjusted incidence rate ratio, 1.2; 95% CI, 0.9-1.7; $P = .29$). Table 3 shows the frequency of MRSA infections according to surgical subspecialty and the distri-

bution of infection sites, stratified by study periods. The rate of surgical site infections due to MRSA and the total nosocomial MRSA acquisition rate were not statistically different between the control and intervention periods (Table 3).

Table 3. Rates of Nosocomial MRSA Infection and Acquisition

Characteristics	Control Periods (n = 10910)	Intervention Periods (n = 10844)	Incidence Rate Ratio (95% Confidence Interval)
Patients with any type of nosocomial MRSA infection, No. (%)	76 (0.7)	93 (0.9)	
Total incidence per 1000 patient-days	0.91	1.11	1.2 (0.9-1.7)
Ward of infected patients by subspecialty, No.			
Orthopedics	18	27	
Cardiovascular and thoracic surgery	9	6	
Neurosurgery	2	2	
Abdominal surgery	32	38	
Urology	13	12	
Other	2	8	
Total No. of MRSA infections ^a	88	103	
Sites of MRSA infection, No. ^a			
Surgical	60	70	
Urinary tract	10	14	
Respiratory tract	6	2	
Bacteremia	2	4	
Other	10	13	
Rate of surgical site infections due to MRSA/surgical interventions × 100	0.99	1.14	1.2 (0.8-1.7)
Patients with nosocomial MRSA acquisition ^b	132	142	
Incidence of nosocomial MRSA acquisition per 1000 patient-days	1.59	1.69	1.1 (0.8-1.4)

Abbreviation: MRSA, methicillin-resistant *Staphylococcus aureus*.

^aPatients may have had multiple sites of infection.

^bIncludes MRSA colonization or infection, identified in any type of clinical isolate, without screening specimens, in patients previously free of MRSA. Patients with previously known MRSA colonization or infection were excluded.

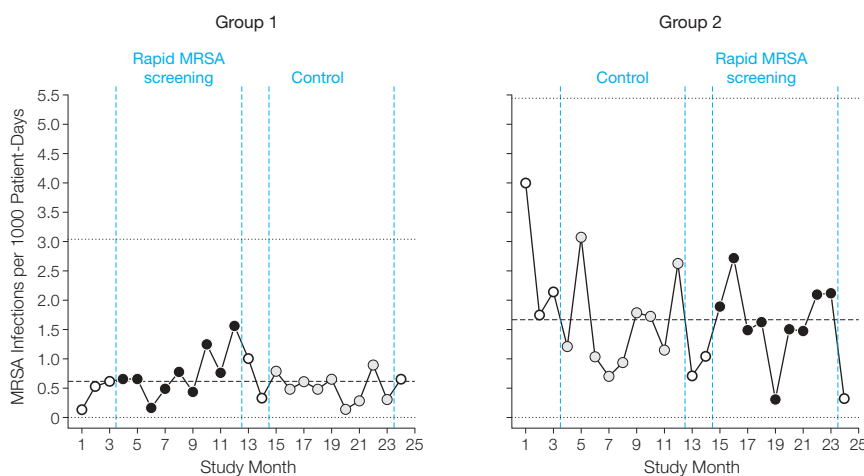
FIGURE 2 shows the monthly rate (per 1000 patient-days) of patients who developed MRSA infection in the surgical service with control limits representing 3 SDs from the mean (center line). In intervention period 1, an increasing trend of MRSA infections was observed among intervention wards, whereas in intervention period 2, data points were equally distributed above and below the mean, indicating no specific effect of MRSA screening.

Characteristics of MRSA-Infected Patients

TABLE 4 shows clinical and demographic characteristics of MRSA-infected patients detected during the control and intervention periods. Among the 93 patients who developed any type of nosocomial MRSA infection during the intervention periods, 23 (25%) had previously known MRSA carriage and 17 (18%) had been identified by admission screening. The 53 remaining patients (57%) who acquired MRSA infection during hospitalization had a negative MRSA screening result on admission (Table 4). Thus, during the intervention periods, 17 (5%) of 337 patients newly identified as MRSA-positive on admission screening, 23 (13%) of 178 previously known carriers, and 53 (0.5%) of 9678 patients found to be negative on admission developed MRSA infection during hospitalization. None of the 26 MRSA carriers detected during outpatient visits developed MRSA infection; all had received decolonization treatment and adequate prophylaxis.

Among 70 patients who developed a MRSA surgical site infection during the intervention periods, 41 patients (59%) had no evidence of MRSA prior to surgery. Among the 29 remaining patients identified as MRSA-positive be-

Figure 2. Statistical Process Control Chart



Statistical process control chart shows the nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infection rate for each month of the study. The upper and lower control limits (dotted lines) represent 3 SDs from the mean (dashed line).

fore operation, 19 (66%) received perioperative prophylaxis active against MRSA and 12 (41%) received more than 1 day of topical decolonization treatment. The rates of adequate prophylaxis (15%) and decolonization treatment (7%) were lower during the control periods because only 15 of 60 patients (25%) who later developed MRSA surgical site infection were known carriers prior to surgery (Table 4).

COMMENT

The present study is, to our knowledge, the largest controlled evaluation of the effect of MRSA screening on admission in patients undergoing surgery. Despite a large-scale screening campaign with use of a rapid molecular test, high adherence to screening, and identification of 337 previously unknown MRSA carriers, the incidence of nosocomial MRSA infections did not decrease during the intervention periods. There are several possible explanations for this worrisome finding.

First, overall MRSA infection rates at our center were relatively low for a surgical department at a tertiary care hospital with endemic MRSA prevalence. Recently, published data from the United Kingdom indicated that the MRSA bacteremia rate in most surgical specialties varies between 0.5 and 1.5 cases per 10 000 patient-days, whereas it was 0.36 cases per 10 000 patient-days in our surgical department.²⁷ This made a significant intervention effect less likely.²⁸

Second, 53 of 93 infected patients (57%) were MRSA-free on admission and acquired MRSA infection during hospitalization, demonstrating the limited value of screening on admission for patients hospitalized for extended periods in surgical services that do not perform weekly surveillance cultures.²⁹ Moreover, these data confirm the hypothesis raised by others that postoperative transmission may play an important role in the cause of MRSA infection.^{7,30}

Third, although we used a rapid molecular test, the positive results for 31%

of patients were only available after surgery because of a high proportion of emergency surgeries and time delays in notification of results. Likewise, 34% of patients with MRSA surgical site infection who could have benefited from antibiotic prophylaxis covering MRSA

did not receive this regimen. Especially in abdominal surgery, surgeons were reluctant to add vancomycin to the standard prophylactic regimen. In contrast, no MRSA infection developed in patients undergoing elective procedures who were found to be MRSA-

Table 4. Characteristics of Patients With Nosocomial MRSA Infection^a

Characteristics	Control Periods	Intervention Periods	P Value
MRSA-infected patients, No.	76	93	
Age, mean (SD), y	67 (16)	68 (17)	.65
Women	30 (39)	41 (44)	.55
Emergency admission	51 (67)	64 (69)	.81
Previous hospital stay	50 (66)	55 (59)	.38
Absence of comorbidities	14 (18)	19 (20)	.74
Rapidly or ultimately fatal disease (McCabe score ²⁴)	22 (29)	35 (38)	.23
Diabetes mellitus	27 (36)	29 (31)	.55
Chronic obstructive pulmonary disease	8 (11)	10 (11)	.96
Previous antibiotic exposure in past 6 mo	29 (38)	34 (37)	.83
Intensive care unit stay >24 h	23 (30)	35 (38)	.32
Central venous catheter >24 h	17 (22)	26 (28)	.41
Urinary catheter >24 h	57 (75)	62 (67)	.24
Surgery-related factors			
Patients undergoing surgery	69 (91)	86 (92)	.69
Duration of operation >75th percentile ²⁵	33 (48)	45 (52)	.58
Atmeier class of contamination (clean or clean-contaminated) ²⁶	40 (58)	43 (50)	.32
ASA physical status class ^b			.67
1	1 (1)	2 (2)	
2	22 (32)	29 (34)	
3	40 (58)	50 (58)	
4	6 (9)	5 (6)	
Infection control measures			
Duration of contact isolation, median (IQR), d	8 (0-27)	15 (6-38)	.02
Low adherence to contact precautions ^c	8 (11)	5 (5)	.21
Patients with any type of nosocomial MRSA infection, No.			
Time to develop nosocomial MRSA infection, median (IQR), d	13 (7-24)	15 (8-31)	.25
Previously known MRSA carriers	18 (24)	23 (25)	.87
Newly identified MRSA carriers	58 (76)	70 (75)	.87
Newly identified by outpatient screening prior to admission	NA	0	
Newly identified by screening on admission	NA	17	
Newly identified by clinical isolate during hospitalization	58	53	
Patients with MRSA surgical site infection, No.			
Identified as MRSA-positive prior to surgery	15 (25)	29 (41)	.05
Received perioperative prophylaxis active against MRSA	9 (15)	19 (27)	.09
Received >1 d of decolonization treatment before surgery	4 (7)	12 (17)	.07

Abbreviations: IQR, interquartile range; MRSA, methicillin-resistant *Staphylococcus aureus*; NA, not applicable.

^aData are expressed as No. (%) unless otherwise indicated.

^bThe American Society of Anesthesiologists (ASA) physical status classification is as follows: class 1, a healthy patient; class 2, a patient with mild systemic disease; class 3, a patient with severe systemic disease; class 4, a patient with severe systemic disease that is a constant threat.

^cAdherence was rated as low in cases of absence of sign-posting and protective equipment at room entry.

positive during their outpatient visit and received adequate prophylaxis and decolonization.

Fourth, during the intervention periods, more previously known MRSA carriers were admitted, suggesting higher colonization pressure and limiting the availability of isolation rooms. However, adjustment for this variable did not change the results. Moreover, overall adherence to hand hygiene and contact precautions was good throughout the study.

Our study design had limitations. Individual wards were not randomly assigned to the study interventions. It was impossible to randomize the 6 orthopedic and abdominal surgery wards to different study groups because patients had to be screened in the outpatient clinic or the emergency department without knowing a priori which specific ward they would be admitted to after surgery. Nevertheless, by using a crossover design, we minimized the influence of unmeasured confounders. The trial was not designed to detect true MRSA cross-transmission rates. Screening 21 000 patients on discharge would have represented a logistic challenge beyond available resources. Because of the large sample size, we were also able to perform only passive postdischarge surveillance of MRSA surgical site infections. This lack of systematic telephone contact with all operated patients could have missed superficial MRSA surgical site infections. Yet, a systematic misclassification bias favoring 1 of the 2 study groups is unlikely, considering the crossover design. Finally, we did not perform conventional cultures to confirm positive results of the molecular tests, leading to possible detection bias.³¹ However, it is unlikely that false-positive screening results would have distorted the primary outcome measure.

Experts have repeatedly called for widespread MRSA screening to reduce the high MRSA rates in hospitals across Europe and North America, an approach that has been part of the "search-and-destroy" strategy success-

fully implemented in countries with low MRSA prevalence.^{32,33} Although targeted active surveillance has been proven useful during outbreaks or in high-risk populations such as intensive care units,^{14,34} the reduction of endemic MRSA through universal active surveillance cultures remains subject to great controversy.^{6,35,36} Recently, several US states have introduced legislative mandates for use of active surveillance cultures as routine screening for MRSA.⁵ Although some studies have suggested that active surveillance cultures can decrease nosocomial MRSA infections in surgical patients,³⁷⁻⁴¹ other evidence suggests that MRSA screening without a focused effort to modify other important factors, including human behavior, basic infection control practices, and cohorting of patients and health care workers, has, at best, only a moderate effect on MRSA infection rates.^{14,42}

In this study, the almost universal adoption of active surveillance cultures on admission, with good adherence to standard and contact precautions, failed to reduce nosocomial MRSA transmission, suggesting that isolated introduction of active surveillance (including rapid testing) may not be sufficient to decrease nosocomial MRSA transmission and surgical site infections. It remains to be seen whether a strategy combining early detection, preemptive isolation, and intense promotion of basic infection control measures might be more successful.

Although we did not conduct any refined economic analysis, our intervention was not cost-beneficial from the hospital perspective. Considering the costs of our intervention and the extra expenses generated by infection control practitioners' time, laboratory material, and need for additional isolation capacities, we recommend further cost-effectiveness analyses to demonstrate that universal MRSA screening policies are offset by patient or societal benefits.³¹

Overall, our real-life trial did not show an added benefit for widespread

rapid screening on admission compared with standard MRSA control alone in preventing nosocomial MRSA infections in a large surgical department. To increase effectiveness, MRSA screening could be targeted to surgical patients who undergo elective procedures with a high risk of MRSA infection. In such cases, earlier identification would allow sufficient time for optimal preoperative handling, including preoperative decontamination and adjustment of surgical prophylaxis. Finally, we suggest that surgical services and infection control teams should carefully assess their local MRSA epidemiology and patient profiles before introducing a universal screening policy.

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Study concept and design: Harbarth, Schrenzel, Christenson, Pittet.

Acquisition of data: Harbarth, Fankhauser, Schrenzel, Christenson, Gervaz, Bandiera-Clerc, Renzi, Vernaz. **Analysis and interpretation of data:** Harbarth, Fankhauser, Schrenzel, Sax, Pittet.

Drafting of the manuscript: Harbarth, Sax, Pittet.

Critical revision of the manuscript for important intellectual content: Harbarth, Fankhauser, Schrenzel, Christenson, Gervaz, Bandiera-Clerc, Renzi, Vernaz, Sax, Pittet.

Statistical analysis: Harbarth, Fankhauser, Pittet.

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