Background: Admission to intensive care unit rooms previously occupied by carriers of methicillin-resistant Staphylococcus aureus (MRSA) or vancomycin-resistant enterococci (VRE) had been found to confer a 40% increased risk of acquisition, presumably through environmental contamination. Subsequently, a cleaning intervention was shown to reduce MRSA and VRE room contamination. We now evaluate the effect of this intervention on the risk of acquiring MRSA and VRE from prior room occupants.

Methods: We conducted a retrospective cohort study of patients admitted to 10 intensive care units at a 750-bed academic medical center during the enhanced cleaning intervention (from September 1, 2006, through April 30, 2008; n=9449) vs baseline (from September 1, 2003, through April 30, 2005; n=8203) periods. The intervention consisted of targeted feedback using a black-light marker, cleaning cloths saturated with disinfectant via bucket immersion, and increased education regarding the importance of repeated bucket immersion during cleaning. Intensive care units included medical, cardiac, burn/trauma, general surgery, cardiac surgery, thoracic surgery, and neurosurgery units. We calculated the number of room stays involving the potential for MRSA and VRE acquisition and then assessed the frequency at which eligible patients were exposed to rooms in which the prior occupants had MRSA-positive or VRE-positive status.

Results: Acquisition of MRSA and VRE was lowered from 3.0% to 1.5% for MRSA and from 3.0% to 2.2% for VRE (P<.001 for both). Patients in rooms previously occupied by MRSA carriers had an increased risk of acquisition during the baseline (3.9% vs 2.9%, P=.03) but not the intervention (1.5% vs 1.5%, P=.79) period. In contrast, patients in rooms previously occupied by VRE carriers had an increased risk of acquisition during the baseline (4.5% vs 2.8%, P=.001) and intervention (3.5% vs 2.0%, P<.001) periods.

Conclusions: Enhanced intensive care unit cleaning using the intervention methods may reduce MRSA and VRE transmission. It may also eliminate the risk of MRSA acquisition due to an MRSA-positive prior room occupant.

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Environmental Cleaning Intervention and Risk of Acquiring Multidrug-Resistant Organisms From Prior Room Occupants

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education regarding the importance of repeated bucket immersion during cleaning.

Data collection and analyses were performed identically for MRSA and VRE. We obtained census information detailing ICU occupants and occupancy dates from September 1, 2006, through April 30, 2008, and from September 1, 2003, through April 30, 2005. Intensive care units included medical (n=2), cardiac, burn/trauma, general surgery, cardiac surgery (n=2), thoracic surgery, and neurosurgery (n=2) units. They routinely performed high-compliance admission and weekly MRSA and VRE screening, systematically distinguishing between imported and incident cases. For each occupant, we collected demographic and comorbidity data based on *International Classification of Diseases, Ninth Revision* codes within 1 year of ICU admission. We also collected each occupant’s pre-ICU, ICU, and post-ICU length of stay; duration of room vacancy before ICU admission; and carrier status at ICU admission and discharge.

Carrier status was obtained from infection control and microbiology laboratory records. Patients were eligible for acquiring MRSA during an ICU stay if they had no history of MRSA before room admission and no MRSA-positive culture results within 2 days of ICU admission. Identical criteria were used for VRE. Patients could contribute data from any number of room stays until MRSA or VRE acquisition occurred.

We calculated the number of room stays involving the potential for MRSA and VRE acquisition. We then assessed the frequency at which eligible patients were exposed to rooms in which the prior occupant had MRSA-positive or VRE-positive status. To evaluate the association between a prior occupant with MRSA-positive or VRE-positive status and MRSA or VRE acquisition by the next occupant, we used generalized linear mixed models in baseline, intervention, and combined models. Models controlled for the collected variables described herein and accounted for clustering by ward.

### RESULTS

A total of 8203 and 9449 patients had 11,528 and 13,359 ICU stays during baseline and intervention periods, respectively. After excluding carriers on ICU admission, the number of patients eligible for MRSA or VRE acquisition was 7629 and 7806 at baseline and 8716 and 8824 during the intervention, respectively. Patient characteristics are summarized in Table 1.

Overall, MRSA and VRE acquisition decreased when comparing intervention to baseline periods (Table 1). Acquisition fell from 3.0% (305 of 10,151) to 1.5% (182 of 11,849) for MRSA and from 3.0% (314 of 10,349) to 2.2% (256 of 11,871) for VRE (P<.001 for both). When evaluating acquisition by prior occupant status, patients in rooms previously occupied by MRSA carriers had an increased risk of acquisition during the baseline (3.9% vs 2.9%, P=.03) but not the intervention (1.5% vs 1.5%, P=.79) period. In contrast, patients in rooms previously occupied by VRE carriers had an increased risk of acquisition during the baseline (4.5% vs 2.8%, P=.001) and intervention (3.5% vs 2.0%, P<.001) periods.

In multivariate models evaluating predictors of acquisition, the presence of an MRSA-positive prior occupant predicted MRSA acquisition in baseline (odds ratio [OR], 1.4; P=.04) but not intervention (OR, 1.1; P=.66) models. In contrast, VRE acquisition remained associated with VRE-positive prior occupants in baseline (OR, 1.4; P=.02) and intervention (OR, 1.4; P=.04) models. Table 2 lists other variables associ-

### Table 1. Description of ICU Room Occupants and Absolute Risk of MRSA and VRE Acquisition According to Study Perioda

| Occupant | Baseline | Intervention |
|----------|----------|--------------|
| MRSA     |          |              |
| Age, median (range), y | 62 (15-103) | 62 (15-100) |
| Length of stay, median (range), d | 6 (0-227) | 6 (0-238) |
| Pre-ICU  | 3 (1-133) | 3 (1-105)    |
| ICU      | 4 (0-287) | 5 (0-239)    |
| Male sex | 4377 (57.4) | 4899 (56.2) |
| Comorbidity |          |              |
| Diabetes mellitus | 1718 (22.5) | 2545 (29.2) |
| End-stage renal disease | 389 (5.0) | 364 (4.2) |
| End-stage liver disease | 142 (1.9) | 218 (2.5) |
| Solid cancer | 1935 (25.4) | 2567 (29.5) |
| Hematologic malignant neoplasm | 385 (5.1) | 576 (6.6) |
| Immunocompromised, noncancer | 401 (5.3) | 401 (4.6) |
| ICU room stays |          |              |
| Total eligible | 10,151 (100) | 11,849 (100) |
| Prior occupant MRSA-positive | 1454 (14.3) | 1443 (12.2) |
| Acquired MRSA during ICU stay | 57 (3.9) | 21 (1.5) |
| Prior occupant MRSA-negative | 8697 (85.7) | 10,406 (87.8) |
| Acquired MRSA during ICU stay | 248 (2.9) | 161 (1.5) |

| VRE      |          |              |
|----------|----------|--------------|
| Age, median (range), y | 62 (15-103) | 62 (15-100) |
| Length of stay, median (range), d | 0 (0-137) | 0 (0-114) |
| Pre-ICU  | 3 (1-134) | 3 (1-95)     |
| ICU      | 4 (0-287) | 5 (0-239)    |
| Male sex | 4471 (57.3) | 4959 (56.2) |
| Comorbidity |          |              |
| Diabetes mellitus | 1759 (22.5) | 2599 (29.5) |
| End-stage renal disease | 390 (5.0) | 365 (4.1) |
| End-stage liver disease | 138 (1.8) | 217 (2.5) |
| Solid cancer | 1940 (24.9) | 2556 (29.0) |
| Hematologic malignant neoplasm | 375 (4.8) | 559 (6.1) |
| Immunocompromised, noncancer | 365 (4.7) | 373 (4.2) |
| ICU room stays |          |              |
| Total eligible | 10,349 (100) | 11,871 (100) |
| Prior occupant VRE-positive | 1291 (12.5) | 1446 (12.2) |
| Acquired VRE during ICU stay | 58 (4.5) | 51 (3.5) |
| Prior occupant VRE-negative | 9058 (87.5) | 10,425 (87.8) |
| Acquired VRE during ICU stay | 256 (2.8) | 205 (2.0) |

Abbreviations: ICU, intensive care unit; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant enterococci.

*Patients may be represented more than once because of multiple ICU admissions. Data are given as number (%) unless otherwise indicated.*
The increased risk of MRSA and VRE acquisition attributable to the carrier status of prior room occupants, as previously observed by some of us, led to an intervention that improved ICU cleaning and reduced MRSA and VRE room contamination. The cleaning intervention significantly reduced overall MRSA acquisition by 49% and VRE acquisition by 29%. However, the cleaning intervention had differential effects on the risk of VRE acquisition due to the positive carrier status of prior room occupants. It eliminated the increased acquisition risk from MRSA-positive prior occupants but did not erase the increased acquisition risk associated with VRE-positive prior occupants.

Whereas enhanced ICU cleaning appears to be effective in decreasing MRSA and VRE transmission, it may be more effective in reducing transmission of MRSA compared with VRE. Reasons for this difference may include the generally higher burden of VRE contamination and evidence that room contamination may be a major factor in VRE transmission. Other authors have found that 12% to 14% of rooms previously occupied by VRE carriers had residual contamination even after environmental cleaning. In addition, VRE contamination has been shown to persist through 3 standard room cleanings, even with bucket-based cloth-immersion cleaning.

Study limitations include the lack of data regarding antibiotic use. Antibiotic exposure is associated with increased VRE shedding among carriers and increased VRE acquisition among patients exposed to carriers. Nevertheless, these and other unmeasured factors are unlikely to be differentially distributed by prior occupant status. Bed and nursing assignments are made independent of prior occupant carrier status.

In summary, we show that enhanced ICU cleaning involving targeted feedback using a black-light marker, disinfectant-saturated cleaning cloths, and increased education regarding best-practice cleaning methods may reduce MRSA and VRE transmission and eliminate the risk of MRSA acquisition due to an MRSA-positive prior room occupant. Recent studies have particularly highlighted the black-light marker component of this campaign for its superior role in providing feedback compared with routine visual inspection. However, additional studies are needed to evaluate the differential effect of enhanced cleaning on MRSA vs VRE. This may be particularly relevant for hospitals with high VRE prevalence where the burden of VRE con-

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Table 2. Predictors of MRSA and VRE Acquisition

| Model | MRSA | VRE |
|-------|------|-----|
|       | Odds Ratio (95% Confidence Interval) | Odds Ratio (95% Confidence Interval) | P Value |
|       |      |      |      |
| MRSA  |      |      |      |
| Pre-ICU length of stay | 1.2 (1.1-1.3) | 1.4 (1.3-1.6) | <.001 |
| Duration of room vacancy between occupants | 0.9 (0.8-1.0) | 1.1 (1.0-1.2) | .03 |
| Age per decade increase | 1.1 (1.0-1.2) | 1.3 (1.1-1.6) | <.001 |
| End-stage liver disease | 1.8 (1.2-2.9) | 1.5 (1.1-2.0) | .008 |
| Prior occupant status and intervention interaction |      |      |      |
| Baseline |      |      |      |
| MRSA-negative | 1 [Reference] | VRE-negative | 1 [Reference] |
| MRSA-positive | 1.3 (1.0-1.8) | VRE-positive | 1.4 (1.0-1.8) | .04 |
| Intervention |      |      |      |
| MRSA-negative | 0.6 (0.5-0.7) | VRE-negative | 0.6 (0.5-0.8) | <.001 |
| MRSA-positive | 0.5 (0.3-0.8) | VRE-positive | 0.9 (0.6-1.2) | .35 |

Abbreviations: See Table 1.

*Adjusted for age, sex, comorbidities, pre-ICU length of stay, prior occupant length of stay, duration of room vacancy before occupancy, and clustering by ICU ward. Measured comorbidities included diabetes mellitus, end-stage renal disease, end-stage liver disease, solid cancer, immunocompromised noncancer, and hematologic malignant neoplasm.
tamination may demand more rigorous cleaning methods.

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