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ORIGINAL INVESTIGATION

Infection Acquisition Following Intensive Care Unit Room Privatization

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Background: Patients in intensive care units (ICUs) often acquire infections, which impose a heavy human and financial burden. The use of private rooms may reduce the acquisition of certain pathogens, but the limited evidence on this topic is inconsistent.

Methods: We compared the rates of acquisition of infectious organisms in an ICU before and after a change from multibed to single rooms. As a control, we used acquisition rates in the ICU of a nearby university teaching hospital, which contained both multibed and single rooms, during the study period. We used a statistical model to adjust for background time trends common to both hospitals.

Results: The adjusted rate of acquisition of *Clostridium difficile*, vancomycin-resistant *Enterococcus* species, and methicillin-resistant *Staphylococcus aureus* combined decreased by 54% (95% confidence interval [CI], 29%-70%) following the intervention. The methicillin-resistant *S aureus* acquisition rate fell by 47% (95% CI,1%-71%), the *C difficile* acquisition rate fell by 43% (95% CI, 7%-65%), and the yeast acquisition rate fell by 51% (95% CI, 34%-64%). Twelve common and likely exogenous organisms and exogenous/endogenous organisms had a reduction in acquisition rates after the intervention; for 6 of them, this reduction was statistically significant. No effect was observed on the acquisition rate of coagulase-negative *Staphylococcus* species, the most common endogenous organism, for which no change would be expected. The adjusted rate ratio of the average length of stay in the ICU was 10% (95% CI, 0%-19%) lower after the intervention.

Conclusion: Conversion to single rooms can substantially reduce the rate at which patients acquire infectious organisms while in the ICU.

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HEALTH CARE–ASSOCIATED infections occur in about 30% of patients in intensive care units (ICUs) and are associated with substantial morbidity and mortality.[1] In ICU patients, these infections are associated with an increased length of stay (LOS) of 8 to 9 days,[2] and the resulting additional cost from excess stay alone is estimated to be $3.5 billion per year in the United States.[3]

Isolation of ICU patients in private rooms is a common infection control recommendation intended to limit the transmission of infectious organisms to patients by facilitating infection control practices by health care workers.[4] Current guidelines on the design and construction or renovation of hospitals and other health care facilities, issued by the American Institute of Architects Academy of Architecture for Health with assistance from the US Department of Health and Human Services, recommend single-patient rooms.[5]

However, results from studies are inconclusive regarding the effect of private rooms on infection rates.[6-9] A systematic review of 8 studies found that only 3 showed a statistically significant reduction in the rate of infections in ICU patients following an intervention to change the facilities' architecture.[10]

Most previous studies were limited in their scope to specific types of bacteria or infection. Many examined methicillin-resistant *Staphylococcus aureus* (MRSA),[10] and only a few studies considered the effect of a physical intervention on vancomycin-resistant *Enterococcus* species (VRE)[11] and *Clostridium difficile*.[12]

Private rooms are believed to facilitate better infection control practices and allow for better isolation of patients from hospital-borne infectious agents.[13] A sensitive measure of transmission of bacteria and yeast is the first, or incident, acquisition of those organisms by a patient. Acquisition of an infectious organism is a necessary precursor to infection. Once

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acquired, the organism may result in colonization in the patient, with no symptoms being evident, or it may lead to symptomatic infection. The association between colonization and future infection is well demonstrated for many bacteria,[14-17] and the colonization rate is therefore clinically important.

Bacteria may be acquired from exogenous sources, such as the physical environment, other patients, or health care workers. In addition, acquisition can be from an endogenous source, such as the patient's flora. Infection control efforts such as patient isolation are directed toward preventing the transmission of exogenous bacteria. A comparison of an intervention's effect on likely exogenous vs likely endogenous colonization rates gives direct evidence of an intervention's success in achieving reduced exposure of patients to hospital-borne organisms.

On March 2, 2002, a new ICU with only private rooms opened at the Montreal General Hospital in Quebec, Canada, replacing the older ICU, which had rooms containing 12 patients. The presence of a second university teaching hospital under the same McGill University academic department of medicine, about 1.4 km (<1 mile) away and serving the same community, presented a valuable opportunity to examine the effect of private rooms on bacterial acquisition rates. A comparison of rates before and after the privatization, while taking other factors and trends into account, provided an opportunity to assess the effect of the intervention on acquisition rates.

METHODS

SETTING AND STUDY DESIGN

The Montreal General Hospital (intervention hospital) and the Royal Victoria Hospital (comparison hospital) are 2 McGill University hospitals serving the same Montreal region. The hospitals have a single, common infection control service with 1 director, and they share infection control policies and practices. The hospitals experienced similar trends in the rates of bacterial infection and outbreaks of *C difficile* during the study period.

The 25-bed adult ICU of the comparison hospital remained unchanged from 2000 to 2005 and had rooms with 2, 5, or 6 beds and 8 single rooms. Before the intervention, the 24-bed adult ICU at the intervention hospital consisted of 2 large rooms of 12 beds, 2 private rooms within each larger room, and a total of 4 sinks. In March 2002, the ICU at the intervention hospital was moved to a new location within the hospital with 24 beds, each in a private room containing a sink, and 2 additional sinks in an area outside the private rooms.

The patient-nurse ratio was the same in both hospitals and remained constant during the study period. This ratio was 1:1 for 30% of beds and 2:1 for 70% of beds. This ratio was maintained even through a temporary shortage in nursing staff by intermittent closure of beds. Alcohol-based hand gels were available during the study in a ratio of 1 per 2 beds in both hospitals. The products that were used were identical between the 2 hospitals.

We studied the cohorts of patients who were admitted to these 2 ICUs from 2000 to 2005.

PATIENTS AND TEST RESULTS

We measured the incidence rates of positive results of microbiologic testing for all patients in the cohort. Test results for specimens collected during the first 48 hours after ICU admission were excluded. After that time, the initial positive test result per patient per organism was counted, regardless of the specimen type. An ICU patient was considered at risk of colonization by every bacteria group that had not been identified on previous testing of the patient in question.

Organisms identified in tests that were ordered up to 48 hours after a patient was discharged from the ICU were considered as ICU-acquired. Studies that rely on data recorded in the ICU alone do not routinely include cases identified after a patient is discharged from the ICU. We therefore also performed a sensitivity analysis by including only cases that would have been captured at the ICU alone for MRSA.

INFECTIOUS ORGANISMS

Bacteria, yeast, and molds were divided into likely exogenous or endogenous sources of infection.[18-21] An organism was considered exogenous if it was likely to be transmitted to a patient through contact in the ICU with contaminated equipment, the environment, another patient, or staff. An organism was considered endogenous if it was likely to be present in the patient's flora on admission to the ICU, for example, coagulase-negative *Staphylococcus* species.

DATA

Data for the study were obtained from 3 hospital information systems. First, ICU patients were identified and admission times to the ICU were obtained from the admission-discharge-transfer database, which contained the location information during hospitalization for all patients. Every admission to a specific bed within the hospital, move to another bed, and discharge is recorded with its precise time.

Second, results of testing for microbes and yeast were obtained from the laboratory information system. All patients were screened for MRSA and VRE on ICU admission. Contacts of index cases were rescreened. The same protocol applied to both hospitals during the entire study period. Other microbiology testing was initiated upon suspicion of an infection. Stool samples were tested routinely for *C difficile* in patients with diarrhea.

Finally, information on patients' infections was obtained from the ICU information system and was used to validate our approach of using the first test result identifying an infectious organism. The ICU database is maintained by an archivist who records all infections identified for patients during an ICU stay. MRSA- and VRE-positive assays are recorded as well as *C difficile* colitis cases. For these 3 organisms, we validated cases detected using the laboratory test results against cases recorded in the ICU information system. We computed sensitivity and specificity of case detection via the laboratory test results using the ICU system as the criterion standard. The system was in place during almost the entire study period at the comparison hospital and from February 2003 at the intervention hospital.

DATA ANALYSIS

To isolate the effect of the intervention from other changes and trends that took place during the study period, we took advantage of the fact that, apart from the intervention, both hospitals experienced similar trends and changes. Rather than compute 2 separate pre-post rate ratios for each hospital and then compare those ratios, we compared the 26 monthly preintervention rate ratios (monthly intervention vs comparison to adjust for time trends and other common hospital factors) with the corresponding 46 postintervention rate ratios. Thus, we used the 72 monthly rates for each organism in each hospital to calculate 72 rate ratios (intervention vs comparison hospital). We

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Table 1. Patient Populations in the ICUs Before and After Room Privatization[a]

Period Relative to March 2, 2002	Hospital Intervention		Hospital Comparison	
	Before	After	Before	After
Hospital admissions with ICU stay, No.	2732	5468	4167	6976
Mean age, y	59.6	59.4	60.1	60.9
Female sex, No. (%)	973 (35.6)	1874 (34.3)	1624 (39.0)	2690 (38.6)

[a]The approximate mix of patients remained largely constant within each intensive care unit (ICU) throughout the study period. At the intervention hospital, general medical patients accounted for 25% of admissions and 27% of patient days, nontrauma surgery patients for 30% of admissions, trauma patients for 21% of patient days, and cardiac surgery patients for 21% of admissions and 15% of patient days. At the comparison hospital, general medical patients accounted for 14% of admissions, nontrauma surgery for 37% of admissions and 33% of patient days, cardiac surgery accounted for 44% of admissions, solid organ transplantation accounted for 4% of admissions and 5% of patient days, and patients with hematology-oncology–related diagnosis accounted for 1% of admissions.

Table 2. Numbers and Rates of Initial-Positive Culture Test Results for Common Organisms

Organism	No. (Rate per 10 000 Patient Days)	
	Hospital Intervention	Hospital Comparison
Coagulase-negative *Staphylococcus* species	471 (119.0)	536 (116.2)
Enterococcus species	257 (64.9)	317 (68.7)
Yeast	245 (61.9)	594 (128.7)
Escherichia species	205 (51.8)	209 (45.3)
Klebsiella species	190 (48.0)	280 (60.7)
Staphylococcus aureus	190 (48.0)	126 (27.3)
Enterobacter species	176 (44.5)	175 (37.9)
Pseudomonas species	156 (39.4)	221 (47.9)
Haemophilus species	150 (37.9)	74 (16.0)
MRSA	141 (35.6)	62 (13.4)
Clostridium difficile	130 (32.9)	135 (29.3)
Streptococcus viridans	94 (23.8)	56 (12.1)
Corynebacterium species	87 (22.0)	106 (23.0)
Acinetobacter species	71 (17.9)	30 (6.5)
Stenotrophomonas maltophilia	61 (15.4)	78 (16.9)
Serratia species	48 (12.1)	75 (16.3)
Citrobacter species	43 (10.9)	53 (11.5)
Proteus mirabilis	33 (8.3)	73 (15.8)
Streptococcus pneumoniae	37 (9.3)	12 (2.6)
Morganella species	21 (5.3)	22 (4.8)
Group B *Streptococcus* species	21 (5.3)	14 (3.0)
Bacteroides species	17 (4.3)	30 (6.5)
Fungi	12 (3.0)	22 (4.8)
VRE	10 (2.5)	16 (3.5)
Lactobacillus species	12 (3.0)	18 (3.9)
Neisseria species	15 (3.8)	7 (1.5)
Moraxella species	9 (2.3)	22 (4.8)
Anaerobic cocci	8 (2.0)	23 (5.0)

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus* species.

fitted a logistic regression model to estimate the postintervention change in the level of these rate ratios to evaluate the effect of the intervention. The numbers of cases in the 2 hospitals combined served as the binomial denominators and the numbers of cases in the intervention hospital served as numerators, with the ratios scaled by the numbers of patient days in the contrasted hospitals. Thus, the model posited 1 rate ratio preintervention and a second rate ratio postintervention; the complement of the ratio of the 2 was taken as an estimate of the percentage reduction in the rate in the intervention hospital that was associated with the intervention. Robust confidence intervals (CIs) were constructed using the sandwich estimator.[22] We used the R (version 2.7.1) statistical software[23] for fitting the parameters of the model and for the data analysis.

We also evaluated the average number of days that a patient spent in the ICU during a hospitalization before and after the intervention. We applied a similar (linear) regression approach to the logs of the 72 (intervention vs comparison) ratios of the average LOS in the ICU during a hospitalization, comparing the ratios before and after the intervention.

The transfer to the new ICU was done overnight on March 2, 2002. The change to private rooms was hypothesized to have an immediate and a constant effect on the infection rate. To account for the possibility that the new environment was cleaner and that the cleaner environment had an effect that would fade with time, an alternative model was tested. This second model allowed the effect of the new environment to fade with time, with the incidence rate falling postintervention, and then reach a new plateau, lower than the original one. The first model assumed that any observed reduction in the incidence rate is attributable to decreased person-to-person transmission and to use of private rooms (facilitating better hand hygiene by hospital staff). The second model assumed that some of any observed reduction in the incidence rate is attributable to a temporary decreased environment to person transmission as the result of the move to a new and presumably uncontaminated environment. We tested several versions of the second model, representing several rates of environment contamination, ranging from 2 weeks to 3 months. The second model did not describe the data any better than the simple one, and so its results are not presented here.

There were no other major events during the study period, such as changes in antibiotic prescribing or infection control policies. A *C difficile* epidemic that occurred from 2003 to 2004 led to some enhancement in infection control practices, but changes were the same in both hospitals.

Models for endogenous organisms were analyzed as a negative comparison; no change in the rate of acquisition was expected as a result of the intervention. An analysis for MRSA, *C difficile*, and VRE combined was performed in addition to a separate analysis for each organism. These 3 organisms are a focus of infection control efforts and are very likely acquired from an exogenous source.

RESULTS

A total of 19 343 admissions to both ICUs contributed 85 995 patient-days at risk. The patient population within each ICU remained essentially constant before and after the intervention (**Table 1**).

In the intervention hospital, 3084 incident-positive cultures for different bacteria, yeast, and fungi were detected in the ICU during the study period, and the corresponding number in the comparison hospital was 3513. **Table 2** presents the counts and rates of incident-positive cultures for the most common organisms.

In a comparison with ICU data on patients' infections, our method of defining a case was advantageous. We captured 91% of MRSA cases noted in the ICU system, 98% of *C difficile* cases, and 100% of VRE cases. Our method captured additional cases that emerged from the

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Table 3. Number of Incident-Positive Culture Results and Rates for Selected Organisms by Year 2000-2005 and Average Length of Patient Stay at the ICU During a Hospitalization

Hospital, y	Avg ICU LOS, d	No. First Positives (Rate per 10 000 Patient Days)				
		C difficile	MRSA	VRE	Other	Total
Int						
2000	4.9	18 (33.6)	24 (44.9)	0	441 (824.3)	**483 (902.8)**
2001	4.7	18 (27.5)	35 (53.5)	0	513 (784.5)	**566 (865.6)**
2002	5.0	20 (29.0)	35 (50.8)	0	445 (645.4)	**500 (725.2)**
2003	4.7	23 (32.6)	21 (29.8)	2 (2.8)	509 (722.1)	**555 (787.3)**
2004	4.6	29 (43.2)	14 (20.9)	3 (4.5)	430 (640.6)	**476 (709.2)**
2005	4.9	22 (32.3)	12 (17.6)	5 (7.3)	465 (682.8)	**504 (740.1)**
Total	4.8	**130** (33.0)	**141** (35.8)	**10** (2.5)	**2803** (712.2)	**3084 (783.6)**
Comp						
2000	3.8	19 (25.3)	3 (4.0)	0	527 (701.5)	**549 (730.7)**
2001	3.9	8 (11.0)	15 (20.7)	0	491 (677.7)	**514 (709.5)**
2002	4.1	12 (15.6)	14 (18.3)	4 (5.2)	638 (831.9)	**668 (871.0)**
2003	4.2	39 (49.5)	12 (15.2)	5 (6.3)	577 (731.7)	**633 (802.7)**
2004	4.5	30 (39.7)	11 (14.6)	1 (1.3)	527 (697.6)	**569 (753.1)**
2005	4.7	27 (30.8)	7 (8.0)	6 (6.8)	540 (615.7)	**580 (661.3)**
Total	4.2	**135** (28.9)	**62** (13.3)	**16** (3.4)	**3300** (707.6)	**3513 (753.2)**

Abbreviations: Avg, average; Comp, comparison hospital; ICU, intensive care unit; Int, intervention hospital; LOS, length of stay; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus* species.

ICU, for which the test results became available only once patients were already discharged from the ICU. When not accounting for the post-ICU captured cases (which the ICU system did not capture), the specificity of our method compared with the ICU system was 96% for *C difficile*, 72% for MRSA, and 88% for VRE. Cases that emerged 48 hours after ICU discharge were, however, considered as true positives and included in the analysis.

Table 3 shows additional details about the frequency and rates of positive-culture results for selected bacteria by year. In the interval between 2002 and 2004, both hospitals experienced an epidemic of *C difficile* and an increase in the number of MRSA and VRE cases. Fifty-nine percent of MRSA cases were identified through diagnostic tests (58% in the intervention hospital and 61% at the comparison hospital) and 41% were identified through screening tests. Screening tests identified all but 1 of the VRE cases.

The average LOS in the ICU during a hospital stay increased steadily during the study period for patients at the comparison hospital (Table 3). At the intervention hospital the average LOS at the ICU fluctuated, but did not increase during the study period. The adjusted average LOS in the ICU fell by an estimated 10% (relative ratio, 0.90; 95% CI, 0%-19%) after the intervention. The decrease was borderline statistically significant.

The adjusted rate of acquisition of *C difficile*, VRE, and MRSA combined decreased after the intervention by 54% (rate ratio, 0.46; 95% CI, 29%-70%) (**Table 4**). The number of VRE cases alone was too small to obtain precise estimates, but the model for the combined data showed an additional decrease above the decrease in MRSA (47%) and *C difficile* (43%) when VRE was included. Of the other likely exogenous organisms, *Stenotrophomonas maltophilia* had a reduction that was not statistically significant, and the rate of acquisition of *Acinetobacter* species fell by 53%. The number of fungal infections was relatively small, resulting in wide CIs.

Table 4. Change in Acquisition Rates of Organisms After Privatization in the ICU

Organism	Rate Ratio (95% CI)[a]
Likely exogenous	
C difficile+MRSA+VRE	0.46 (0.30-0.71)
C difficile	0.57 (0.35-0.93)
MRSA	0.53 (0.29-0.99)
VRE	NA
Acinetobacter species	0.47 (0.24-0.92)
Stenotrophomonas maltophilia	0.48 (0.21-1.07)
Fungi-molds	1.23 (0.75-2.03)
Exogenous/endogenous	
Yeast	0.49 (0.36-0.66)
Enterococcus species	0.77 (0.56-1.06)
Enterobacter species	0.62 (0.42-0.93)
Escherichia species	0.89 (0.55-1.44)
Staphylococcus aureus	1.02 (0.67-1.54)
Pseudomonas species	1.00 (0.63-1.57)
Klebsiella species	0.62 (0.38-0.99)
Serratia species	0.77 (0.41-1.43)
Citrobacter species	1.36 (0.74-2.50)
Proteus mirabilis	0.69 (0.38-1.24)
Morganella species	0.57 (0.30-1.06)
Likely endogenous	
Coagulase-negative *Staphylococcus* species	0.96 (0.76-1.20)
Haemophilus species	0.53 (0.30-0.95)
Streptococcus viridans	1.03 (0.56-1.90)

Abbreviations: CI, confidence interval; ICU, intensive care unit; MRSA, methicillin-resistant *Staphylococcus aureus*; NA, not available; VRE, vancomycin-resistant *Enterococcus* species.

[a] Rate ratios are estimated through logistic regression based on the split of monthly cases (see the "Data Analysis" subsection in the "Methods" section) between the 2 hospitals, before and after the intervention. Confidence intervals are based on robust standard error.

The acquisition of most of the organisms in the exogenous/endogenous group fell following the intervention (Table 4). Three organisms had statistically significant reductions in rates of acquisition: yeast, *Enterobacter*

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species, and *Klebsiella* species fell by 51%, 38%, and 38%, respectively. Acquisition of *Enterococcus* species, *Escherichia* species, and *Serratia* species fell by 23%, 11%, and 23%, respectively; these reductions were not statistically significant. The numbers of new acquisitions of *Citrobacter* species, *Proteus mirabilis*, and *Morganella* species were relatively small, resulting in wide CIs. *Staphylococcus aureus* and *Pseudomonas* species did not show any significant change in the rate of incident acquisitions.

The effect of the intervention on coagulase-negative *Staphylococcus* species, the most common organism, was not statistically significant, as expected (Table 4). Coagulase-negative *Staphylococcus* species was considered a likely endogenous organism and was tested as a negative comparison. *Streptococcus viridans*, another likely endogenous organism, also did not show a reduction in acquisition rates with the ICU intervention, but *Haemophilus* species did have a statistically significant reduction.

Our sensitivity analysis excluding MRSA cases that were captured in the 48 hours following discharge from the ICU revealed the importance of including those cases. With these cases excluded, the estimated adjusted decrease in MRSA acquisition was 31% (compared with 43% when the cases were included), and the reduction was no longer statistically significant.

COMMENT

Following the change of an ICU to all private rooms, the rate of acquisition of bacteria and yeast decreased by more than half. An ICU environment with private rooms may facilitate better infection control practices, therefore reducing the transmission of infectious organisms.

In our study, after adjustment for common outside temporal factors, *C difficile*, MRSA, yeast, *Acinetobacter* species, *Klebsiella* species, and *Enterobacter* species had significant reductions in acquisition rates. Other likely exogenous organisms, such as *S maltophilia*, *Enterococcus* species, *Escherichia* species, and *Serratia* species, had acquisition rate reductions that were not statistically significant. Yeast is the only one of these organisms (apart from MRSA, VRE, and *C difficile*) that other studies have reported to have a reduction in acquisition rate following a physical intervention.

Pseudomonas species and *S aureus* did not show any reduction in acquisition rates following the intervention, despite the fact that they are considered to be possibly exogenous. A study that used routine screening and typing for these 2 organisms found that almost all *Pseudomonas* species and *S aureus* identified in surgical ICU patients were of endogenous sources.[24] *Pseudomonas aeruginosa* is commonly isolated from patients who have been hospitalized longer than 1 week.[25] Most ICU patients spend time in hospital wards before their ICU stay. Cultures are not routinely performed in patients on admission to the ICU, which is a limitation of our data. Therefore, a possible explanation for the lack of reduction in the acquisition rates of *P aeruginosa* and *S aureus* is that many of the patients acquired those organisms before their ICU stay.

The rates of coagulase-negative *Staphylococcus* species and *S viridans* were not affected by the intervention, as expected. However, *Haemophilus* species, which were also considered as likely endogenous organisms, decreased significantly. A possible explanation lies in the rate of detection and the lack of screening for all organisms, which is a limitation of the data. *Haemophilus* species are identified in cultures of the respiratory system. A decrease in testing because of fewer cases of suspected infections will result in a decrease in the detection of endogenous *Haemophilus* species.

The observed decrease in LOS in the ICU is consistent with knowledge that infections in ICU patients increase the average ICU and hospital LOS.[2] Acquisition of an organism is on the causal pathway to increased LOS, but there are many other important factors affecting LOS. Acquisition, as a more direct outcome than LOS, had a stronger correlation with the intervention. In addition, the results of the sensitivity analysis of exclusion of post-ICU cases suggest that part of the benefit from reduced acquisition will take effect after the ICU stay. On the other hand, we do not have overwhelming evidence to suggest that a significant decrease in LOS occurred as a result of the intervention. The data are "noisy" and could also be consistent with a small temporal trend. A larger study is needed to measure with adequate precision the effect of such an intervention on LOS.

Many previous studies were based on ICU-identified cases of acquisition alone. In our sensitivity analysis, excluding likely ICU-acquired MRSA cases that were detected within 48 hours of ICU discharge resulted in a change in the MRSA acquisition rate that was not significant. This observation may explain why some previous studies that were focused on the rates of MRSA alone failed to show any significant decrease of rates as a result of a physical intervention.

The use of acquisition rather than infection as an outcome measure is a potential limitation of the study. However, using acquisition is a sensitive method for detecting transmission of bacteria to patients, and reducing this transmission is the target of most physical interventions. Studies that rely on infection rates also are limited by imprecision in the timing of the outcome. The interval between the acquisition and colonization of a patient by a specific pathogen and the development of an infection depends on factors independent of transmission.

In view of the epidemic that affected both hospitals in the postintervention period, the unpredictable nature of such events, and the difficulty in adequately reflecting the volatility in the statistical standard errors, a much longer series would have been desirable. However, data before 2000 were not available. Recently, the 2 hospitals instituted even greater cooperation and joint management by transferring patients to the other ICU when one is full, thereby precluding any chance to extend the data series. Despite these real-world limitations and despite the noise, the patterns in the **Figure** are clear.

The transfer to the new ICU was done overnight, with all the old equipment and beds moved to the new location. We assume that this is the reason that the effect of

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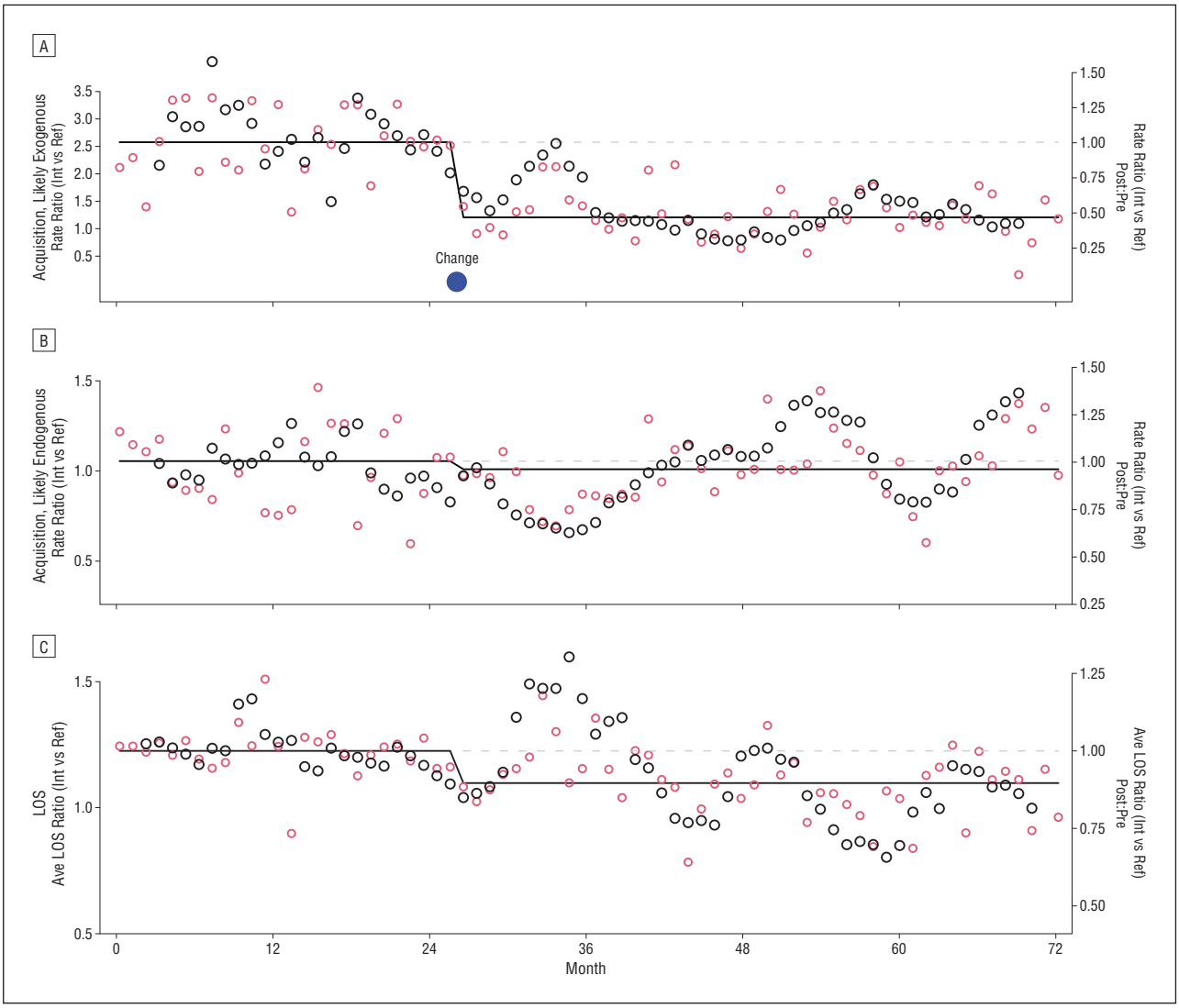

Figure. Monthly contrasts of event rates and length of stay (LOS) in the intervention (Int) vs comparison (Ref) hospitals preintervention (Pre) and postintervention (Post). Black circles represent ratios within each month; brighter (red) circles represent the fitted residuals. On the left is the axis of the ratios; on the right, the magnitude of the change in the average (Ave) ratios pre-post intervention. A, Monthly ratios of acquisition rates of likely exogenous organisms. B, Monthly ratios of acquisition rates of likely endogenous organisms. C, Monthly ratios of average LOS.

the new facility remained constant after the move, without any additional effect of the newness of the facility that would be expected to wane with time.

The older ICU had a small number of sinks, and they were not easily accessible. The new ICU environment might have resulted in improved infection control practices, as it is hypothesized that single rooms facilitate more frequent hand washing by health care workers and are easier to clean.[13,26] Single rooms also reduce the number of patient transfers among rooms. Further research is needed to determine the mechanisms through which the transmission is reduced. Better knowledge on the routes of transmission could assist in developing improved infection control policies.

The drastic improvement in the physical facility of the ICU from common rooms to private rooms yielded a dramatic reduction in the transmission of bacteria and yeast. Our approach of looking at all potentially exogenous bacteria and our modeling approach that adjusted for background time trends and other factors allowed for a comprehensive demonstration of this improvement. The effect of a physical intervention in other settings may vary depending on many local characteristics. This study demonstrates the potential benefit of single rooms in reducing the transmission of infections in ICU settings.

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