Original Investigation

Universal Glove and Gown Use and Acquisition of Antibiotic-Resistant Bacteria in the ICU
A Randomized Trial

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IMPORTANCE Antibiotic-resistant bacteria are associated with increased patient morbidity and mortality. It is unknown whether wearing gloves and gowns for all patient contact in the intensive care unit (ICU) decreases acquisition of antibiotic-resistant bacteria.

OBJECTIVE To assess whether wearing gloves and gowns for all patient contact in the ICU decreases acquisition of methicillin-resistant *Staphylococcus aureus* (MRSA) or vancomycin-resistant *Enterococcus* (VRE) compared with usual care.

DESIGN, SETTING, AND PARTICIPANTS Cluster-randomized trial in 20 medical and surgical ICUs in 20 US hospitals from January 4, 2012, to October 4, 2012.

INTERVENTIONS In the intervention ICUs, all health care workers were required to wear gloves and gowns for all patient contact and when entering any patient room.

MAIN OUTCOMES AND MEASURES The primary outcome was acquisition of MRSA or VRE based on surveillance cultures collected on admission and discharge from the ICU. Secondary outcomes included individual VRE acquisition, MRSA acquisition, frequency of health care worker visits, hand hygiene compliance, health care–associated infections, and adverse events.

RESULTS From the 26 180 patients included, 92 241 swabs were collected for the primary outcome. Intervention ICUs had a decrease in the primary outcome of MRSA or VRE from 21.35 acquisitions per 1000 patient-days (95% CI, 17.57 to 25.94) in the baseline period to 16.91 acquisitions per 1000 patient-days (95% CI, 14.09 to 20.28) in the study period, whereas control ICUs had a decrease in MRSA or VRE from 19.02 acquisitions per 1000 patient-days (95% CI, 14.20 to 25.49) in the baseline period to 16.29 acquisitions per 1000 patient-days (95% CI, 13.48 to 19.68) in the study period, a difference in changes that was not statistically significant (difference, −1.71 acquisitions per 1000 person-days, 95% CI, −6.15 to 2.73; $P = .57$). For key secondary outcomes, there was no difference in VRE acquisition with the intervention (difference, 0.89 acquisitions per 1000 person-days; 95% CI, −4.27 to 6.04, $P = .70$), whereas for MRSA, there were fewer acquisitions with the intervention (difference, −2.98 acquisitions per 1000 person-days; 95% CI, −5.58 to −0.38; $P = .046$). Universal glove and gown use also decreased health care worker room entry (4.28 vs 5.24 entries per hour, difference, −0.96; 95% CI, −1.71 to −0.21, $P = .02$), increased room-exit hand hygiene compliance (78.3% vs 62.9%, difference, 15.4%; 95% CI, 8.99% to 21.8%; $P = .02$) and had no statistically significant effect on rates of adverse events (58.7 events per 1000 patient days vs 74.4 events per 1000 patient days; difference, −15.7; 95% CI, −40.7 to 9.2, $P = .24$).

CONCLUSIONS AND RELEVANCE The use of gloves and gowns for all patient contact compared with usual care among patients in medical and surgical ICUs did not result in a difference in the primary outcome of acquisition of MRSA or VRE. Although there was a lower risk of MRSA acquisition alone and no difference in adverse events, these secondary outcomes require replication before reaching definitive conclusions.

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Antibiotic resistance is associated with considerable morbidity, mortality, and costs.[1,2] Methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE) are primary causes of health care-associated infections (HAIs) that are associated with worse outcomes than those caused by antibiotic-susceptible *S aureus* and *Enterococcus*.[3,4] The estimated cost of antibiotic-resistance in the United States is more than $4 billion per year.[1] Health care-associated infections are the most common complication of hospital care, affecting an estimated 1 in every 20 inpatients.[2]

Numerous studies have shown that health care workers acquire bacteria on their hands and clothing by touching patients.[5,6] Current interventions focus on hand hygiene; however, despite decades of efforts to improve hand hygiene compliance, hand hygiene compliance rates remain low.[7] The use of gloves and gowns may reduce acquisition of antibiotic-susceptible and antibiotic-resistant bacteria by health care workers and decrease subsequent transmission to other patients.

The Centers for Disease Control and Prevention (CDC) recommend use of contact precautions (wearing gloves and gowns) when caring for patients colonized or infected with antibiotic-resistant bacteria.[8] However, colonization with MRSA, VRE, or other antibiotic-resistant bacteria often is not detected, and contact precautions, therefore, are not applied. Small, nonrandomized trials suggest that wearing gloves and gowns for all patient contact may decrease acquisition of antibiotic-resistant bacteria and HAIs.[9-12] However, the use of contact precautions has also been associated with fewer health care worker-patient contacts and an increase in adverse events.[13-15]

HAI *health care–associated infection*

ICU *intensive care unit*

IHI *Institute for Healthcare Improvement*

MRSA *methicillin-resistant* Staphylococcus aureus

VRE *vancomycin-resistant* Enterococcus

We conducted a cluster randomized trial to assess whether wearing gloves and gowns for all patient contact in the intensive care unit (ICU) compared with the use of contact precautions only for patients with known antibiotic-resistant bacteria reduces colonization acquisition rates of MRSA and VRE. We hypothesized that the intervention would decrease MRSA or VRE acquisition.

Methods

Study Design

The study was a matched pair cluster randomized trial with the ICU as the level of randomization and inference. In the intervention group, health care workers wore gloves and gowns for all patient contact and when entering any patient room. In the control group, health care workers wore gloves and gowns according to CDC guidelines, ie, for patients with known antibiotic-resistant bacteria. From September 2011 to December 2011, ICUs collected baseline data on the primary outcome of MRSA or VRE acquisition. The ICUs were pair-matched based on baseline MRSA or VRE acquisition rates as a composite outcome. Within each pair, 1 ICU was randomized to the intervention and the other to the control group by the statistician (M.S.) using a computer-generated sequence.[16] The study period was January 4, 2012, to October 4, 2012. The trial was conducted in accordance with CONSORT guidelines.[17] A cluster randomized trial was necessary to answer these questions because a behavioral infection control intervention could not be studied using traditional patient-level randomization.[18,19]

Recruitment and Eligibility Criteria

We recruited medical, surgical, or combined medical-surgical ICUs for adult patients from academic and community hospitals in the United States through the Society for Healthcare Epidemiology of America (SHEA) Research Network (**Figure**).[20] The only exclusion criterion was that ICUs could not screen patients for MRSA or VRE (active surveillance culturing). Patients were eligible for inclusion in the analysis of the primary outcome if they had a negative admission culture for MRSA or VRE and a discharge culture collected (as described below).

Ethical Considerations and Institutional Review Board

The University of Maryland School of Medicine served as the central institutional review board (IRB). All participating ICUs received approval from their local IRBs, and each determined this to be a minimal-risk study and granted approval of the study along with a waiver of consent and Health Insurance Portability and Accountability Act (HIPAA) waiver.

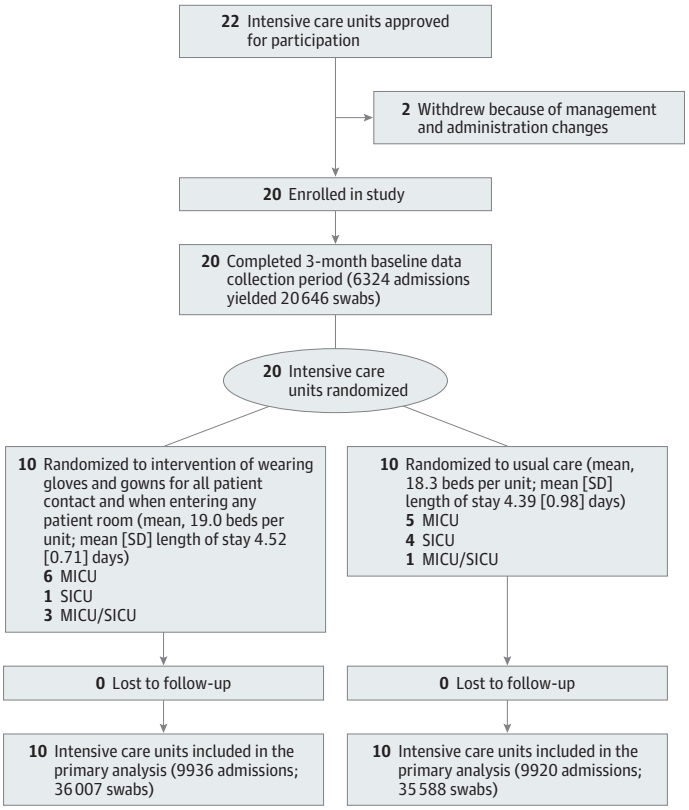
Intervention and Control Groups

The intervention occurred at the cluster level of ICU. During the study period, all health care workers (nurses, physicians, respiratory therapists, etc) in the 10 ICUs assigned to the intervention groups were required to wear gloves and gowns for all patient contact and when entering any patient room.[8,21] The 10 control ICUs followed their usual standard of care, which consisted of health care workers' following CDC contact precautions guidelines (gloves and gowns) for patients known to have infection or colonization with antibiotic-resistant bacteria such as VRE and MRSA.[8]

Ensuring Protocol Fidelity

Each site designated a study coordinator and physician champion to lead implementation. All sites were trained via webinar on proper technique for collecting and shipping cultures, and study coordinators from each site attended a study initiation meeting, where they received in-person training on all data collection requirements. Training for the Institute for Healthcare Improvement (IHI) Global Trigger Tool[22] included completion of 5 standardized cases from IHI and another 5 standardized cases from the coordinating center with feedback. To ensure that infection control and prevention staff at each ICU determined HAIs according to CDC definitions, staff were required to view standardized Microsoft Powerpoint presentations developed by the CDC on National Health Safety Network definitions and complete a test on these definitions.[23-26] Biweekly conference calls were held with site coordinators to

Figure. Study Flow Diagram



MICU indicates medical intensive care unit; SICU, surgical intensive care unit. Usual care involved following the Centers for Disease Control and Prevention recommendations of wearing gloves and gowns when working with patients with a known infection or colonization.

discuss questions, challenges, and solutions with meeting minutes and frequently asked questions with the answers distributed to sites. Additionally, all sites received at least 1 visit from study investigators. To improve admission and discharge culture compliance, sites received weekly feedback of their compliance rates compared with other sites.

Outcomes

All patients had ICU admission and ICU discharge surveillance cultures for MRSA (nasal swab) and VRE (perianal swab). The primary outcome was acquisition of either MRSA or VRE as a composite. Key secondary outcomes were MRSA and VRE acquisition as 2 separate outcomes. For each eligible patient, acquisition was defined as having an initial ICU surveillance culture that was negative for an antibiotic-resistant pathogen with a subsequent discharge surveillance culture within the same ICU admission that was positive for the same antibiotic-resistant pathogen. The ICUs did not receive results of the surveillance cultures. Specimens were shipped to and processed at the University of Maryland using a method that did not affect bacterial yield.[27] The specimens were enriched in both Enterococcosel broth and trypticase soy broth with 6.5% sodium chloride (Remel) broth and plated to bile esculin azide agar with 6 µg/mL Vancomycin agar for VRE and Spectra MRSA agar (Remel) for MRSA. Antibiotic resistance was confirmed by the detection of the resistance genes, *mecA* for MRSA and *vanA* or *vanB* for VRE by polymerase chain reaction (PCR), during the study and baseline periods.[28,29] However, due to a short amount of time between the baseline period and the randomization and notification of sites to the intervention or control group, confirmation of MRSA by PCR was not performed for the baseline period prior to site randomization assignment. Baseline MRSA rate by culture method was equal in both groups, although PCR identified more false-positive MRSA tests in the control group leading to the intervention group having a higher baseline MRSA acquisition rate.

In addition to MRSA or VRE acquisition, secondary outcomes included the following:

1. Health care–associated infections: These were recorded at the cluster level. Central line–associated bloodstream infection, catheter-associated urinary tract infection, and ventilator-associated pneumonia rates were measured in a standardized fashion at the ICU level using CDC National Healthcare Safety Network definitions.[30]

2. Adverse events: A random selection of charts was reviewed, and ICU adverse events were recorded to calculate ICU adverse event rates using the IHI Global trigger tool.[22] The trigger tool defines *adverse events* as "unintended physical injury resulting from or contributed to by medical care that requires additional monitoring, treatment, or hospitalization or that results in death." Ninety charts per ICU in both intervention and control groups were reviewed using a standardized data extraction sheet. We selected patients who had been in the study ICU for at least 24 hours and had been discharged

for 30 days. Nurse, physician, and coordinator primary clinical reviewers at each site completed chart review worksheets and patient summaries. Reviewers sent chart reviews to the coordinating center as PDFs. Two physicians (A.D.H. and D.J.M.) independently reviewed all summaries and adverse events in a blinded fashion for adequate evidence of adverse event independently and then met together for concurrence, as done previously.[31]

3. Frequency of health care worker room entry and hand hygiene compliance: Compliance with hand hygiene, glove and gown compliance, and the frequency of health care worker visits were measured by 30-minute direct observation periods on a random sample of rooms. Site study staff covertly observed health care workers. Two hours per week of observations occurred at varied times of day over the entire study period. Hand hygiene was monitored on room entry and room exit. The recording form used was based on one from the IHI.[32]

Sample Size

Initial power calculations determined that 18 ICUs were necessary to detect a 25% relative reduction in acquisition of MRSA or VRE in the intervention group vs no reduction in the control group (or relative rate ratio of 0.75) based on a presumed rate of 50 acquisitions per 1000 patient days. We calculated this rate using preliminary data from ICUs at the University of Maryland Medical Center. We enrolled 20 ICUs to account for expected attrition of 10%. These power calculations were then revised based on actual baseline-period data from this study as follows: The observed mean rate of MRSA or VRE acquisition during the baseline period was 30 new acquisitions per 1000 person-days. The monthly standard deviation in the baseline period was 15 new acquisitions per 1000 person-days and the longitudinal intraclass correlation coefficient (correlation between adjacent monthly acquisitions rates in the same ICU) was 0.38. We assumed no decrease in acquisition in ICUs assigned to standard control and a 25% relative rate reduction (which corresponds with an absolute reduction of $30 \times 0.25 = 7.5$ new acquisitions per 1000 person-days) in ICUs assigned to the intervention. We also assumed an autoregressive correlation, 9 months of follow-up during the study period, and a 25% gain in efficiency due to matching. The 20 ICUs (10 per group) were sufficient to reach 80% power to reject the null hypothesis of no difference in changes in MRSA or VRE acquisition rates between ICUs assigned to the standard control group and ICUs assigned to the intervention group using a 2-sided *t* test with 5% type I error.

Statistical Analysis

Analyses of all outcomes were conducted at the ICU level, followed the intention-to-treat approach, and accounted for the matched-pair design. All tests were 2-sided with 5% type I error. For acquisition of either MRSA or VRE and other outcomes with baseline period data, weighted paired *t* tests compared changes in rates from baseline (prerandomization) to the end of the study between the intervention and control ICUs.[16] For outcomes without baseline period data, weighted paired *t* tests compared study period rates or means between intervention and control ICUs.[16] Weighting accounted for differences in cluster sizes (eg, patient-time at risk) between ICUs with each pair weighted according to the inverse variance of the estimated effect size.[33] Testing and estimation were performed on the log scale to account for different ICU sizes[34]; estimated rates and 95% confidence intervals were obtained by exponentiating. A prespecified secondary analysis of the primary outcome and key secondary outcomes was performed, adjusting for ICU admission prevalence of MRSA or VRE. For each pair, the weight was the inverse variance of the estimated effect after adjusting for admission prevalence of MRSA or VRE. All weighted paired *t* tests had 9 degrees of freedom.[16,33,34] The statistical plan is in the Supplement.

Results

Twenty ICUs participated in the study and none withdrew. There were 26 180 patient admissions including 6324 patients during the baseline period and 19 856 patients during the study period. A total of 92 241 swabs were collected for detection of MRSA and VRE, including 20 646 swabs during the baseline period and 71 595 swabs during the study period. **Table 1** shows the characteristics of the ICUs and proportion of patients colonized at admission. During the study period, compliance with obtaining nasal cultures at admission was 95.73%; perianal cultures, 94.92%. Compliance with obtaining nasal cultures at discharge was 84.44%; perianal cultures, 85.07%. Overall, during the study period 1700 of 9920 admissions were ineligible for analysis in the control ICUs, and 1540 of 9936 admissions were ineligible for analysis in the intervention ICUs because admission or discharge cultures were not obtained. The difference in proportions of admissions that were ineligible due to missing cultures, comparing intervention with control ICUs, was not statistically significant ($P = .18$). Compliance with wearing gloves in the intervention ICUs was 86.18% (2787 of 3234) and compliance with gowns was 85.14% (2750 of 3230). In the control group, 10.52% of patients were on contact precautions. In the control ICUs, for patients on contact precautions, compliance with wearing gloves was 84.11% (556 of 661) and compliance with gowns was 81.21% (536 of 660).

The effects of the intervention on the primary outcome and the key secondary outcomes are shown in **Table 2**. Intervention ICUs had a decrease in the primary outcome of MRSA or VRE from 21.35 acquisitions per 1000 patient-days (95% CI, 17.57 to 25.94) in the baseline period to 16.91 acquisitions per 1000 patient-days (95% CI, 14.09 to 20.28) in the study period, whereas control ICUs had a decrease in MRSA or VRE from 19.02 acquisitions per 1000 patient-days (95% CI, 14.20 to 25.49) in the baseline period to 16.29 acquisitions per 1000 patient-days (95% CI, 13.48 to 19.68) in the study period, a difference in changes that was not statistically significant (difference, −1.71 acquisitions per 1000 person-days; 95% CI, −6.15 to 2.73; $P = .57$). Regarding the key secondary outcome of VRE, intervention ICUs had a decrease from 15.18 acquisitions per 1000 patient-days (95% CI, 10.50 to 21.95) in the baseline period to 13.59 acquisitions per 1000 patient-days (95% CI, 10.26 to 17.99) in the study period, whereas control ICUs had a de-

Table 1. Description of Intensive Care Units During Study Period (January 4, 2012-October 4, 2012)

Pair No.	No. of Beds	ICU Type	Mean Daily Admissions	Mean ICU Length of Stay, d	Mean Patient Age, y	Female Patients, %	% (No. of Positive/Total Swabs) With Colonization at Admission (Colonization Pressure)[b]		
							MRSA	VRE	VRE or MRSA
Intervention ICUs									
1	20	MICU	3.27	5.86	59.8	51.5	14.4 (124/860)	24.4 (209/856)	32.9 (283/861)
2	24[a]	MICU	2.75	5.33	56.4	46.5	10.5 (75/717)	24.8 (175/706)	31.8 (228/717)
3	10	MICU	1.91	4.68	65.8	47.0	16.3 (94/578)	18.1 (104/576)	29.7 (172/579)
4	20	MICU	3.68	4.70	58.2	69.5	13.5 (165/1226)	15.0 (178/1191)	24.8 (306/1232)
5	18	MICU	3.67	3.79	55.3	38.2	7.96 (95/1193)	10.3 (123/1190)	16.2 (193/1194)
6	22	SICU	4.41	4.13	58.9	44.2	5.81 (73/1257)	5.10 (64/1255)	10.3 (130/1264)
7	22	MICU/SICU	3.78	4.66	64.2	49.0	10.9 (104/955)	8.88 (84/946)	17.4 (167/958)
8	24	MICU/SICU	5.73	3.48	58.7	43.6	4.84 (72/1487)	9.52 (140/1471)	13.4 (199/1488)
9	10	MICU	2.04	3.98	57.2	47.2	12.1 (67/552)	25.5 (141/552)	33.3 (184/553)
10	20	MICU/SICU	3.04	4.57	61.3	39.0	9.21 (62/673)	7.61 (50/657)	15.5 (104/673)
Mean (SD)	19.0 (5.1)		3.43 (1.12)	4.52 (0.71)	59.6 (3.32)	47.6 (8.74)	10.5 (3.68)	14.9 (7.79)	22.5 (8.92)
Control ICUs									
1	24	MICU	2.50	5.28	55.3	38.9	12.1 (111/914)	10.7 (97/911)	21.2 (194/915)
2	15	MICU/SICU	3.98	4.68	62.2	51.6	6.54 (64/979)	4.47 (43/962)	10.1 (99/983)
3	9	MICU	1.89	4.16	59.8	46.4	11.9 (61/514)	10.2 (52/512)	19.1 (98/514)
4	20	MICU	3.91	3.78	58.7	51.1	11.5 (132/1145)	17.2 (196/1137)	25.3 (290/1146)
5	20	MICU	3.09	5.06	63.9	45.9	9.95 (84/844)	24.0 (202/841)	30.4 (257/845)
6	19	SICU	2.67	6.42	58.6	41.5	7.53 (55/730)	14.9 (108/727)	19.7 (144/732)
7	10	MICU	2.08	3.21	63.7	53.0	6.04 (34/563)	5.04 (28/556)	9.93 (56/564)
8	36	SICU	8.73	3.42	62.2	43.0	4.98 (113/2267)	4.49 (101/2251)	8.94 (203/2270)
9	20	SICU	3.35	3.93	48.9	31.6	3.02 (29/959)	3.05 (29/950)	5.72 (55/961)
10	10	SICU	2.27	3.92	45.4	29.5	4.20 (23/536)	3.55 (19/535)	6.53 (35/536)
Mean (SD)	18.3 (8.1)		3.45 (1.99)	4.39 (0.98)	57.9 (6.28)	43.3 (8.09)	7.79 (3.36)	9.75 (7.05)	8.57 (15.7)

Abbreviations: ICU, intensive care unit; MICU, medical intensive care unit; SICU, surgical intenstive care unit.

[a] ICU increased from 16 to 24 beds after 3 months of the intervention.

[b] Calculated as positive admission swabs/total admission swabs.

crease in VRE from 14.37 acquisitions per 1000 patient-days (95% CI, 10.31 to 20.02) in the baseline period to 11.88 acquisitions per 1000 patient-days (95% CI, 8.65 to 16.33) in the study period, a difference in changes that was not statistically significant (difference, 0.89 VRE acquisitions per 1000 person-days; 95% CI, −4.27 to 6.04, $P = .70$). For the other key secondary outcome of MRSA, intervention ICUs had a decrease from 10.03 acquisitions per 1000 patient-days (95% CI, 8.05 to 12.50) in the baseline period to 6.00 acquisitions per 1000 patient-days (95% CI, 4.63 to 7.78) in the study period, whereas control ICUs had a decrease in MRSA from 6.98 acquisitions per 1000 patient-days (95% CI, 4.50 to 10.83) in the baseline period to 5.94 acquisitions per 1000 patient-days (95% CI, 4.59 to 7.67) in the study period, a statistically significant difference in rates of change (difference, −2.98 MRSA acquisitions per 1000 person-days; 95% CI, −5.58 to −0.38; $P = .046$). This was a 40.2% relative reduction in MRSA acquisition compared with a 15.0% reduction in control ICUs. The results did not qualitatively differ after adjusting for admission prevalence of MRSA or VRE. After adjustment, results were still not statistically significant for acquisition of MRSA or VRE ($P = .60$) and VRE ($P = .57$), and the decrease in MRSA acquisition remained significantly larger in the intervention group than in the control group ($P = .007$).

Table 2. Rates at Risk of Acquisition of Antibiotic-Resistant Bacteria per 1000 Patient-Days

	Intensive Care Units							
	Intervention			Control				
	No. of Acquisitions	Patient-Days at Risk	Mean Rate (95% CI)[a]	No. of Acquisitions	Patient-Days at Risk	Mean Rate (95% CI)[a]	Difference (95% CI)[b]	*P* Value[c]
Drug-Resistant Bacteria								
VRE or MRSA								
Study period	577	32 693.0	16.91 (14.09 to 20.28)	517	31 765.0	16.29 (13.48 to 19.68)		
Baseline	178	8684.0	21.35 (17.57 to 25.94)	176	9804.5	19.02 (14.20 to 25.49)		
Change[d]			−4.47 (−9.34 to 0.45)			−2.74 (−6.98 to 1.51)	−1.71 (−6.15 to 2.73)	.57
VRE								
Study period	411	27 765.5	13.59 (10.26 to 17.99)	337	28 340.5	11.88 (8.65 to 16.33)		
Baseline	108	7691.5	15.18 (10.50 to 21.95)	122	8818.0	14.37 (10.31 to 20.02)		
Change[d]			−1.60 (−7.18 to 3.98)			−2.48 (−5.53 to 0.56)	0.89 (−4.27 to 6.04)	.70
MRSA								
Study period	199	30 454.5	6.00 (4.63 to 7.78)	191	30 024.0	5.94 (4.59 to 7.67)		
Baseline	77	7841.0	10.03 (8.05 to 12.50)	59	9182.0	6.98 (4.50 to 10.83)		
Change[d]			−4.03 (−6.50 to −1.56)			−1.04 (−3.37 to 1.28)	−2.98 (−5.58 to −0.38)	.046

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

[a] Per 1000 patient-days at risk.

[b] Absolute difference in absolute changes $(\text{study period} - \text{baseline})_{\text{intervention ICUs}} - (\text{study period} - \text{baseline})_{\text{control ICUs}}$.

[c] From weighted paired *t* test on the log scale with 9 degrees of freedom.

[d] Absolute change, study period −baseline.

Table 3. Average Hand-Hygiene Compliance and Health Care Worker Visits per Hour

	Intensive Care Units							
	Intervention			Control				
	No. of Events	No. of Observations[a]	Mean (95% CI), %[b]	No. of Events	No. of Observations[a]	Mean (95% CI), %[b]	Mean Difference (95% CI), %[c]	*P* Value[d]
Hand-hygiene compliance, %								
Room entry	1563	2828	56.1 (47.2 to 66.7)	1644	3231	50.2 (41.4 to 60.9)	5.91 (−6.91 to 18.7)	.42
Room exit	2027	2649	78.3 (72.1 to 85.0)	2080	3266	62.9 (54.4 to 72.8)	15.4 (8.99 to 21.8)	.02
Health care–worker visits	3213	756.5	4.28 (3.95 to 4.64)	3775	716.5	5.24 (4.46 to 6.16)[e]	−0.96 (−1.71 to −0.21)	.02

[a] Observed entries and observed exits for hand-hygiene compliance, number of hours of observation for health care worker visits.

[b] Percent for hand-hygiene compliance, per hour of observation for health care worker visits.

[c] Absolute difference (intervention intensive care units [ICUs] −control ICUs).

[d] From weighted paired *t* test on the log scale with 9 degrees of freedom.

[e] In control ICUs, those patients on contact precautions had 4.78 mean visits per hour from health care workers.

Health care worker behaviors were affected by the intervention (**Table 3**). The mean number of health care worker visits per hour in the in the intervention group was 4.28 (95% CI, 3.95 to 4.64) vs 5.24 (95% CI, 4.46 to 6.16) in the control group, for a mean difference of −0.96 visits per hour (95% CI, −1.71 to −0.21; *P* = .02). Hand-hygiene compliance upon room entry did not significantly differ between the intervention and control groups (56.1% in the intervention group vs 50.2% in the control group; difference, 5.91%; 95% CI, −6.91% to 18.7%, *P* = .42), but compliance upon exit was 15.4% higher in the intervention group (78.3% vs 62.9%; 95% CI, 8.99% to 21.8%, *P* = .02).

Changes in central line-associated urinary tract infection, catheter-associated urinary tract infection, and ventilator-associated pneumonia rates did not differ significantly between the 2 groups (all *P* > .10), and ICU mortality did not significantly differ between the groups (*P* = .81; **Table 4**). The ICU adverse events were lower in the intervention group, but this was not significant (58.7 events per 1000 patient days vs 74.4 events per 1000 patient days; difference, −15.7; 95% CI, −40.7 to 9.2; *P* = .24). Preventable, nonpreventable, severe, and not severe ICU adverse events were all nonsignificantly lower in the intervention group than in the control group (all *P* >.20; Table 4).

Discussion

Our results show that health care workers wearing gloves and gowns for all ICU patient contact did not reduce the compos-

Table 4. Rates per 1000 Patient-Days at Risk of Hospital-Acquired Infections, Mortality, and Adverse Events

	Intensive Care Units							
	Intervention			Control				
	No. of Acquisitions	Patient-Days at Risk[a]	Mean Rate (95% CI)[b]	No. of Acquisitions	Patient-Days at Risk[a]	Mean Rate (95% CI)[b]	Difference (95% CI)[c]	*P* Value[d]
Hospital–Acquired Infections								
CLABSI								
Study period	39	26 347	1.20 (0.46 to 1.93)	37	22 039	1.46 (0.94 to 1.98)		
Baseline	16	9423	1.22 (0.51 to 1.93)	15	7358	1.16 (0.18 to 2.14)		
Change[e]			−0.02 (−0.76 to 0.71)			0.30 (−0.85 to 1.46)	−0.32 (−1.61 to 0.96)	.63
VAP								
Study period	34	19 216	1.00 (0.24 to 1.75)	55	19 960	1.36 (0.44 to 2.28)		
Baseline	14	7047	0.74 (0.27 to 2.03)	20	6470	0.84 (0.23 to 3.10)		
Change[e]			0.26 (−0.58 to 1.10)			0.51 (−0.44 to 1.46)	−0.25 (−1.44 to 0.93)	.68
CAUTI								
Study period	97	28 641	2.59 (1.33 to 3.86)	155	32 181	4.03 (2.99 to 5.07)		
Baseline	34	9096	1.88 (0.36 to 3.42)	38	10 674	2.36 (0.99 to 3.73)		
Change[e]			0.71 (−0.38 to 1.80)			1.67 (0.57 to 2.76)	−0.96 (−2.13 to 0.22)	.14
Adverse events								
All	266	4585	58.7 (45.8 to 75.2)	369	4846	74.4 (57.9 to 95.6)	−15.7 (−40.7 to 9.2)	.24
Preventable	134	4585	29.0 (20.0 to 42.1)	156	4846	30.4 (21.7 to 42.7)	−1.4 (−19.4 to 16.6)	.88
Nonpreventable	132	4585	33.0 (24.3 to 45.0)	213	4846	43.3 (31.0 to 60.4)	−10.3 (−27.3 to 6.8)	.40
Severe	163	4585	36.5 (25.2 to 52.8)	245	4846	48.1 (35.7 to 64.6)	−11.6 (−32.4 to 9.2)	.31
Not severe	103	4585	23.6 (15.7 to 35.5)	124	4846	25.0 (18.9 to 33.2)	−1.4 (−13.1 to 10.3)	.82
ICU mortality	881	41 190	21.2 (16.4 to 27.5)	811	40 532	19.9 (13.7 to 28.8)	1.3 (−9.3 to 12.0)	.81

Abbreviations: CAUTI, catheter-associated urinary tract infection; CLABSI, central line–associated bloodstream infection; ICU, intensive care unit; VAP, ventilator-associated pneumonia.

[a] ICU patient days for adverse events, and mortality; central line days for CLABSI; ventilator days for VAP; catheter days for CAUTI.

[b] Per 1000 patient-days at risk.

[c] For hospital-acquired infections: absolute difference in absolute changes $(\text{study period} - \text{baseline})_{\text{intervention ICUs}} - (\text{study period} - \text{baseline})_{\text{control ICUs}}$; for adverse events and mortality: absolute difference (intervention ICUs −Intervention ICUs).

[d] From paired *t* test with 9 degrees of freedom.

[e] Absolute change, study period −baseline.

ite primary outcome of VRE or MRSA acquisition. Regarding key secondary outcomes, the intervention did not reduce VRE acquisition, but it did reduce MRSA acquisition. Better hand hygiene compliance on room exit occurred in the intervention ICUs. The intervention led to fewer health care worker-patient visits and did not increase the frequency of adverse events.

To the best of our knowledge, this study is the first cluster randomized trial to assess the potential benefit of universal glove and gown use. Other smaller studies suggest that this intervention may have benefits. A quasiexperimental study conducted in response to an *Acinetobacter baumannii* outbreak found that universal glove and gown use in a medical ICU was associated with a decrease in MRSA and VRE acquisition.[9] In a single-center trial of 70 pediatric patients, fewer infections occurred when health care workers were randomized to use gloves and gowns on individual patients.[10]

The decrease in our key secondary outcomes of MRSA acquisition rates but not in VRE acquisition rates was surprising and should be considered hypothesis generating given the negative primary outcome. Interventions may have differing effects on specific antibiotic-resistant bacteria. For example, chlorhexidine bathing was shown to decrease VRE acquisition but not MRSA acquisition.[19] Also, different bacteria have shown differential methods of transmission.[35,36] The lack of effect on VRE may represent the effect of antibiotic selective pressure on the intestinal microbiome and the potential underdetection of VRE on admission surveillance culture.[35] In other words, patients thought to acquire VRE may have had low, undetectable levels at admission that increased to the level of detection with antibiotic use before discharge. The effect of universal glove and gown use on other pathogens such as carbapenem-resistant Enterobacteriaceae is not known. One plausible explanation for the observed reduction in MRSA is that intervention ICUs had a greater decrease in MRSA owing to regression to the mean. However, intervention ICUs also had higher admission prevalence of MRSA (colonization pressure), a known risk factor for MRSA transmission in ICUs, suggesting that the higher acquisition rates may not be aberrant but rather accurately reflect endemic rates in those ICUs. Comparing changes in rates and secondarily adjusting for admission prevalence helped to partially overcome this baseline imbalance. Nevertheless, replication is warranted.

Twenty to fifty percent of patients hospitalized in ICUs who are colonized with antibiotic-resistant bacteria develop infection with the same organism.[36,37] We previously demonstrated that 19% of patients who carried MRSA when admitted subsequently developed CDC-defined infection with MRSA

on the same admission.[37] In the current study, we did not find an effect on overall HAI rates, but the study was not powered for this rare outcome.

We found that the use of gloves and gowns led to fewer health care worker visits and greater hand hygiene on exit. This was found both in the intervention group and in those patients on contact precautions in the control group. We did not find a corresponding difference in adverse events between control and intervention patients. In fact, we observed fewer adverse events in the intervention group, although this was not statistically significant. Our findings are consistent with reports that contact precautions are associated with less health care worker-patient contact and better hand hygiene.[13] However, the finding of no difference in adverse events contrasts with at least 1 retrospective study reporting more falls, pressure ulcers, and electrolyte disturbances in patients on contact precautions.[15] Our results suggest that the changes in health care worker behavior may not increase adverse events when contact precautions or universal glove and gown use are implemented.

It is important to place our study in context with other similar intervention studies aiming to decrease transmission of MRSA and VRE. Climo et al[19] showed that chlorhexidine bathing decreased VRE acquisition in ICU patients. Huang et al[38] found that universal chlorhexidine bathing and intranasal mupirocin reduced MRSA clinical cultures in ICU patients. However, the use of chlorhexidine or mupirocin may increase bacterial resistance and thus could have long-term adverse effects.[39,40] Many experts advocate active surveillance and some states have mandated active MRSA surveillance but the efficacy of this practice has not been established.[18,36] Universal glove and gown use will not increase antimicrobial resistance and could eliminate costs of active surveillance, chlorhexidine, and mupirocin.

This study had several limitations. First, we were unable to blind ICUs to intervention status. Although adverse events were coded in a blinded fashion, other outcomes could have been influenced by a lack of blinding. Second, the mechanism of the intervention's effect is not completely clear. Universal glove and gown use increased hand hygiene on room exit and decreased health care worker-patient visits. Fewer visits with better hand hygiene may explain some of the effect on MRSA acquisition. Third, we did not have adequate power to detect relatively large differences in adverse events as measured by the IHI trigger tool. However, we observed fewer adverse events in the intervention group.

Our study also had many strengths. The cluster randomized design provides stronger evidence than most studies currently used to support infection control interventions, and the primary outcome measurement of MRSA or VRE acquisition was more objective than clinical culture positivity as used in other studies.[41] In addition, all ICUs enrolled completed the study, which is rare in a study of this size, and compliance with the intervention was high, which demonstrates the feasibility of implementing and sustaining the intervention. Moreover, our results represent a broad set of hospitals because the study was conducted in medical, surgical, and medical-surgical ICUs varying in size from 9 to 36 beds and located across the United States in rural, urban, academic, and nonacademic settings.

Conclusion

The use of gloves and gowns for all patient contact compared with usual care among patients in medical and surgical ICUs did not result in a difference in the primary outcome of acquisition of MRSA or VRE. Although there was a lower risk of MRSA acquisition alone and no difference in adverse events, these secondary outcomes require replication before reaching definitive conclusions.

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REFERENCES

1. Talbot GH, Bradley J, Edwards JE Jr, Gilbert D, Scheld M, Bartlett JG; Antimicrobial Availability Task Force of the Infectious Diseases Society of America. Bad bugs need drugs: an update on the development pipeline from the Antimicrobial Availability Task Force of the Infectious Diseases Society of America. *Clin Infect Dis*. 2006;42(5):657-668. doi:10.1086/499819.

2. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care–associated infections and deaths in US hospitals, 2002. *Public Health Rep*. 2007;122(2):160-166.

3. Cosgrove SE, Sakoulas G, Perencevich EN, Schwaber MJ, Karchmer AW, Carmeli Y. Comparison of mortality associated with methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* bacteremia: a meta-analysis. *Clin Infect Dis*. 2003;36(1):53-59. doi:10.1086/345476.

4. DiazGranados CA, Jernigan JA. Impact of vancomycin resistance on mortality among patients with neutropenia and enterococcal bloodstream infection. *J Infect Dis*. 2005;191(4):588-595. doi:10.1086/427512.

5. Morgan DJ, Rogawski E, Thom KA, et al. Transfer of multidrug-resistant bacteria to healthcare workers' gloves and gowns after patient contact increases with environmental contamination. *Crit Care Med*. 2012;40(4):1045-1051. doi:10.1097/CCM.0b013e31823bc7c8.

6. Hayden MK, Blom DW, Lyle EA, Moore CG, Weinstein RA. Risk of hand or glove contamination after contact with patients colonized with vancomycin-resistant *Enterococcus* or the colonized patients' environment. *Infect Control Hosp Epidemiol*. 2008;29(2):149-154. doi:10.1086/524331.

7. Boyce JM, Pittet D; Healthcare Infection Control Practices Advisory Committee: HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *MMWR Recomm Rep*. 2002;51(RR-16):1-45.

8. Siegel JD, Rhinehart E, Jackson M, Chiarello L; Health Care Infection Control Practices Advisory Committee. 2007 guideline for isolation precautions: Preventing transmission of infectious agents in health care settings. *Am J Infect Control*. 2007;35(10)(suppl 2):S65-S164. doi:10.1016/j.ajic.2007.10.007.

9. Wright MO, Hebden JN, Harris AD, et al. Aggressive control measures for resistant *Acinetobacter baumannii* and the impact on acquisition of methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococcus* in a medical intensive care unit. *Infect Control Hosp Epidemiol*. 2004;25(2):167-168. doi:10.1086/502370.

10. Klein BS, Perloff WH, Maki DG. Reduction of nosocomial infection during pediatric intensive care by protective isolation. *N Engl J Med*. 1989;320(26):1714-1721.

11. Safdar N, Marx J, Meyer NA, Maki DG. Effectiveness of preemptive barrier precautions in controlling nosocomial colonization and infection by methicillin-resistant *Staphylococcus aureus* in a burn unit. *Am J Infect Control*. 2006;34(8):476-483. doi:10.1016/j.ajic.2006.01.011.

12. Yin J, Schweizer ML, Herwaldt LA, Pottinger JM, Perencevich EN. Benefits of universal gloving on hospital-acquired infections in acute care pediatric units. *Pediatrics*. 2013;131(5):e1515-20. doi:10.1542/peds.2012-3389.

13. Morgan DJ, Pineles LL, Shardell M, et al. The effect of contact precautions on healthcare worker activity in acute care hospitals. *Infect Control Hosp Epidemiol*. 2013;34(1):69-73.

14. Morgan DJ, Diekema DJ, Sepkowitz K, Perencevich EN. Adverse outcomes associated with Contact Precautions: a review of the literature. *Am J Infect Control*. 2009;37(2):85-93. doi:10.1016/j.ajic.2008.04.257.

15. Stelfox HT, Bates DW, Redelmeier DA. Safety of patients isolated for infection control. *JAMA*. 2003;290(14):1899-1905. doi:10.1001/jama.290.14.1899.

16. Donner A, Klar N. *Design and Analysis of Cluster Randomization Trials in Health Research*. London, England: Arnold Publishing; 2000.

17. Campbell MK, Piaggio G, Elbourne DR, Altman DG; CONSORT Group. Consort 2010 statement: extension to cluster randomised trials. *BMJ*. 2012;345:e5661. doi:10.1136/bmj.e5661.

18. Huskins WC, Huckabee CM, O'Grady NP, et al; STAR*ICU Trial Investigators. Intervention to reduce transmission of resistant bacteria in intensive care. *N Engl J Med*. 2011;364(15):1407-1418. doi:10.1056/NEJMoa1000373.

19. Climo MW, Yokoe DS, Warren DK, et al. Effect of daily chlorhexidine bathing on hospital-acquired infection. *N Engl J Med*. 2013;368(6):533-542. doi:10.1056/NEJMoa1113849.

20. Morgan DJ, Meddings J, Saint S, et al; SHEA Research Network. Does nonpayment for hospital-acquired catheter-associated urinary tract infections lead to overtesting and increased antimicrobial prescribing? *Clin Infect Dis*. 2012;55(7):923-929. doi:10.1093/cid/cis556.

21. Siegel JD, Rhinehart E, Jackson M, Chiarello L; Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in health care settings, 2006. *Am J Infect Control*. 2007;35(10)(suppl 2):S165-S193. doi:10.1016/j.ajic.2007.10.006.

22. Griffin F, Resar R. *IHI Global Trigger Tool for Measuring Adverse Events*. Second ed. Institute for Healthcare Improvement Innovation Series White Paper; 2009. http://www.ihi.org/knowledge/pages/IHIWhitePapers/IHIGlobalTriggerToolWhitePaper.aspx. Updated August 13, 2013; Accessed September 12, 2013.

23. Wright M, Hebden JN, Allen-Bridson K, Morrell GC, Horan T. Health care–associated infections studies project: case 4. *Am J Infect Control*. 2011;39(1):64-65. doi:10.1016/j.ajic.2010.12.001.

24. Wright MO, Hebden JN, Allen-Bridson K, Morrell GC, Horan T. Health care–associated infections studies project: case 3. *Am J Infect Control*. 2010;38(8):642-643. doi:10.1016/j.ajic.2010.07.001.

25. Wright MO, Hebden JN, Allen-Bridson K, Morrell GC, Horan T. Healthcare–associated infections studies project: an *American Journal of Infection Control* and National Healthcare Safety Network data quality collaboration. *Am J Infect Control*. 2010;38(5):416-418.

26. Wright MO, Hebden JN, Allen-Bridson K, Morrell GC, Horan T. Health care-associated infections studies project: case 2. *Am J Infect Control*. 2010;38(7):557-558. doi:10.1016/j.ajic.2010.06.003.

27. Robinson GL, Harris AD, Morgan DJ, Pineles L, Belton BM, Johnson JK; Benefits of Universal Gloving and Gowning (BUGG) Study Group. Survival of methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococcus spp* for an extended period of transport. *J Clin Microbiol*. 2012;50(7):2466-2468. doi:10.1128/JCM.00911-12.

28. Richter SS, Heilmann KP, Dohrn CL, et al. Activity of ceftaroline and epidemiologic trends in *Staphylococcus aureus* isolates collected from 43 medical centers in the United States in 2009. *Antimicrob Agents Chemother*. 2011;55(9):4154-4160. doi:10.1128/AAC.00315-11.

29. Bell JM, Paton JC, Turnidge J. Emergence of vancomycin-resistant enterococci in Australia: phenotypic and genotypic characteristics of isolates. *J Clin Microbiol*. 1998;36(8):2187-2190.

30. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control*. 2008;36(5):309-332. doi:10.1016/j.ajic.2008.03.002.

31. Landrigan CP, Parry GJ, Bones CB, Hackbarth AD, Goldmann DA, Sharek PJ. Temporal trends in rates of patient harm resulting from medical care. *N Engl J Med*. 2010;363(22):2124-2134. doi:10.1056/NEJMsa1004404.

32. Institute for Healthcare Improvement. How-to guide: Improving hand hygiene. http://www.ihi.org/knowledge/Pages/Tools/HowtoGuideImprovingHandHygiene.aspx. Updated July 8, 2011. Accessed September 12, 2013.

33. Thompson SG, Pyke SD, Hardy RJ. The design and analysis of paired cluster randomized trials: an application of meta-analysis techniques. *Stat Med*. 1997;16(18):2063-2079.

34. Brookmeyer R, Chen YQ. Person-time analysis of paired community intervention trials when the number of communities is small. *Stat Med*. 1998;17(18):2121-2132.

35. Ho J, Tambyah PA, Paterson DL. Multiresistant gram-negative infections: a global perspective. *Curr Opin Infect Dis*. 2010;23(6):546-553. doi:10.1097/QCO.0b013e32833f0d3e.

36. Yokoe DS, Mermel LA, Anderson DJ, et al. A compendium of strategies to prevent healthcare-associated infections in acute care hospitals. *Infect Control Hosp Epidemiol*. 2008;29(S1)(suppl 1):S12-S21.

37. Harris AD, Furuno JP, Roghmann MC, et al. Targeted surveillance of methicillin-resistant *Staphylococcus aureus* and its potential use to guide empiric antibiotic therapy. *Antimicrob Agents Chemother*. 2010;54(8):3143-3148. doi:10.1128/AAC.01590-09.

38. Huang SS, Septimus E, Kleinman K, et al; CDC Prevention Epicenters Program; AHRQ DECIDE Network and Healthcare-Associated Infections Program. Targeted versus universal decolonization to prevent ICU infection. *N Engl J Med*. 2013;368(24):2255-2265. doi:10.1056/NEJMoa1207290.

39. McGann P, Kwak YI, Summers A, Cummings JF, Waterman PE, Lesho EP. Detection of qacA/B in clinical isolates of methicillin-resistant *Staphylococcus aureus* from a regional healthcare network in the eastern United States. *Infect Control Hosp Epidemiol*. 2011;32(11):1116-1119. doi:10.1086/662380.

40. Lee AS, Macedo-Vinas M, François P, et al. Impact of combined low-level mupirocin and genotypic chlorhexidine resistance on persistent methicillin-resistant *Staphylococcus aureus* carriage after decolonization therapy: a case-control study. *Clin Infect Dis*. 2011;52(12):1422-1430. doi:10.1093/cid/cir233.

41. Feng PJ, Kallen AJ, Ellingson K, Muder R, Jain R, Jernigan JA. Clinical incidence of methicillin-resistant *Staphylococcus aureus* (MRSA) colonization or infection as a proxy measure for MRSA transmission in acute care hospitals. *Infect Control Hosp Epidemiol*. 2011;32(1):20-25. doi:10.1086/657668.