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Frequent Multidrug-Resistant *Acinetobacter baumannii* Contamination of Gloves, Gowns, and Hands of Healthcare Workers

Daniel J. Morgan, MD, **Stephen Y. Liang, MD**, **Catherine L. Smith, MD**, **J. Kristie Johnson, PhD**, **Anthony D. Harris, MD, MPH**, **Jon P. Furuno, PhD**, **Kerri A. Thom, MD, MS**, **Graham M. Snyder, MD**, **Hannah R. Day, MS**, and **Eli N. Perencevich, MD, MS**
Departments of Epidemiology and Preventive Medicine (D.J.M., A.D.H., J.P.F., K.A.T., H.D., E.N.P.), Medicine (S.Y.L., C.L.S., G.M.S.), and Pathology (J.K.J.), University of Maryland, Baltimore

Abstract

BACKGROUND—Multidrug-resistant (MDR) gram-negative bacilli are important nosocomial pathogens.

OBJECTIVE—To determine the incidence of transmission of MDR *Acinetobacter baumannii* and *Pseudomonas aeruginosa* from patients to healthcare workers (HCWs) during routine patient care.

DESIGN—Prospective cohort study.

SETTING—Medical and surgical intensive care units.

METHODS—We observed HCWs who entered the rooms of patients colonized with MDR *A. baumannii* or colonized with both MDR *A. baumannii* and MDR *P. aeruginosa*. We examined their hands before room entry, their disposable gloves and/or gowns upon completion of patient care, and their hands after removal of gloves and/or gowns and before hand hygiene.

RESULTS—Sixty-five interactions occurred with patients colonized with MDR *A. baumannii* and 134 with patients colonized with both MDR *A. baumannii* and MDR *P. aeruginosa*. Of 199 interactions between HCWs and patients colonized with MDR *A. baumannii*, 77 (38.7% [95% confidence interval {CI}, 31.9%–45.5%]) resulted in HCW contamination of gloves and/or gowns, and 9 (4.5% [95% CI, 1.6%–7.4%]) resulted in contamination of HCW hands after glove removal before hand hygiene. Of 134 interactions with patients colonized with MDR *P. aeruginosa*, 11 (8.2% [95% CI, 3.6%–12.9%]) resulted in HCW contamination of gloves and/or gowns, and 1 resulted in HCW contamination of hands. Independent risk factors for contamination with MDR *A. baumannii* were manipulation of wound dressing (adjusted odds ratio [aOR], 25.9 [95% CI, 3.1–208.8]), manipulation of artificial airway (aOR, 2.1 [95% CI, 1.1–4.0]), time in room longer than 5 minutes (aOR, 4.3 [95% CI, 2.0–9.1]), being a physician or nurse practitioner (aOR, 7.4 [95% CI, 1.6–35.2]), and being a nurse (aOR, 2.3 [95% CI, 1.1–4.8]).

Address reprint requests to Daniel J. Morgan, MD, Department of Epidemiology and Preventive Medicine, University of Maryland, Baltimore, 685 West Baltimore Street, MSTF 334D, Baltimore, MD 21201 (dmorgan@epi.umaryland.edu).
D.J.M. and S.Y.L. contributed equally to this article.

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CONCLUSIONS—Gowns, gloves, and unwashed hands of HCWs were frequently contaminated with MDR *A. baumannii*. MDR *A. baumannii* appears to be more easily transmitted than MDR *P. aeruginosa* and perhaps more easily transmitted than previously studied methicillin-resistant *Staphylococcus aureus* or vancomycin-resistant *Enterococcus*. This ease of transmission may help explain the emergence of MDR *A. baumannii*.

Multidrug-resistant (MDR) *Acinetobacter baumannii* and MDR *Pseudomonas aeruginosa* have become progressively more common in hospitalized patients, resulting in significant morbidity and mortality.[1,2] There are few antimicrobial agents effective against these organisms.[3] The Centers for Disease Control and Prevention recommend contact precautions, including the use of gloves and protective gowns, in the care of hospitalized patients infected or colonized with MDR organisms.[4] Although large clinical studies have evaluated the benefits of contact precautions in reducing the rates of infections due to MDR gram-positive organisms in hospitalized patients,[5,6] there is a paucity of data with regard to the benefit of contact precautions in reducing the rates of infections due to MDR gram-negative organisms, especially in the endemic setting.[4,7,8] In addition, there are few data on the added utility of hand hygiene after wearing gloves when caring for patients infected with MDR gram-negative bacteria.[9]

In this study, we evaluated the incidence of MDR *A. baumannii* and MDR *P. aeruginosa* infections and the risk factors for MDR *A. baumannii* and MDR *P. aeruginosa* contamination of HCW gloves, gowns, and hands during routine patient care activities. We then derived an estimate of incidence of MDR *A. baumannii* contamination of HCWs in relation to variable adherence to contact precautions and hand hygiene.

METHODS

This study was conducted in the 29-bed medical and 19-bed surgical intensive care units at the University of Maryland Medical Center (Baltimore) in August and September 2008. In both units, MDR *A. baumannii* and MDR *P. aeruginosa* are endemic. The study was approved by the Institutional Review Board of the University of Maryland, Baltimore.

Patients were identified as colonized with MDR *A. baumannii* or as colonized with both MDR *A. baumannii* and MDR *P. aeruginosa* as a part of routine care on the basis of active surveillance or by the results of clinical cultures performed during their index hospitalization (upon identification, they were placed under contact precautions). Active surveillance, when used, consisted of culturing specimens obtained from the sputum, groin, perirectal area, and wound, if present. In our hospital, contact precautions are used for all patients infected with MDR *A. baumannii* that is susceptible to no more than 2 antimicrobial classes and for all patients infected with MDR *P. aeruginosa* that is susceptible to no more than 1 antimicrobial class, excluding tigecycline or polymyxin (all isolates of either species were imipenem resistant). HCWs (registered nurses, patient care technicians, respiratory therapists, occupational or physical therapists, and physicians) were approached for participation in the study before they engaged in routine, nonemergent clinical care activities for these patients.

Cultures were performed as described previously.[10] In brief, sterile cotton-tipped applicators (220093 CultureSwab; Becton Dickinson) were moistened with liquid Amies transport media (Becton Dickinson). Hand and glove samples were obtained with a standardized process, by swabbing the dorsum of each finger 3 times and the palm of each hand 2 times with a twirling motion of the swab; a single swab was used for both hands or both gloves. Gowns were sampled by swabbing each forearm twice and then swabbing a “W” along the belt line, all with a single swab and performed with a twirling motion. Hands were first

sampled before the HCW donned gown and gloves. Data from observations in which HCW hands were colonized before room entry were excluded from the analysis. HCW activities were observed and documented, including the duration and nature of HCW-patient contact. Upon completion of activities and before the HCW exited the patient room, the HCW gloves and gown were swabbed by investigators. The bare hands of the HCWs were immediately sampled a second time, before hand hygiene.

Swab samples were vortexed in 5 mL of brain-heart infusion broth with imipenem, 6 μg/mL (imipenem was added to enhance detection of MDR *A. baumannii* and MDR *P. aeruginosa*, because all isolates were carbapenem resistant). Broths were kept at 35°C overnight. Then, 50 μL of the broth was plated to MacConkey agar with and without imipenem, 6 μg/mL. Plates were incubated overnight at 35°C. Non–lactose-fermenting colonies were subcultured to trypticase soy agar with 5% sheep blood. Oxidase-negative isolates were identified as *A. baumannii* by analytical profile index 20E test strip or Vitek II (bioMérieux). Oxidase-positive isolates were subcultured onto triple sugar iron (TSI) and *Pseudomonas* agar (P-agar) slants. TSI slants were incubated overnight at 35°C, and P-agar slants were kept at 42°C overnight. *P. aeruginosa* isolates were identified as K/K on TSI slants and were pyocyanin-producing on P-agar.

Pulsed-field gel electrophoresis (PFGE) was performed on *A. baumannii* isolates in accordance with a protocol described elsewhere,[11] with modifications.[12] In brief, DNA was digested with *Apa*I in accordance with manufacturer recommendations (New England Biolabs). DNA was separated in 1% agarose on a contour-clamped homogeneous-field machine (CHEF-DR II; Bio-Rad). Electrophoresis was performed at 6 V/cm for 18.5 hours, with pulse times ranging 7–20 seconds. After electrophoresis, gels were stained with ethidium bromide and were photographed under ultraviolet illumination. Photographic images of gels were saved digitally with the Geldoc EQ (BioRad) and saved as TIFF files for gel analysis with Gel Compare (Applied Math). The resulting band patterns were compared with the Dice coefficient 100 by means of the unweighted pair group method to define pulsed-field type clusters, in accordance with the criteria established by Tenover et al.[13]

Risk factor analysis was conducted using the Fisher exact test to measure the significance of associations between binary variables and the dependent variable of MDR *A. baumannii* contamination of gowns or gloves. Time in room was non-normally distributed (mean, 8.5 minutes; median, 5.0 minutes; interquartile range, 3.0–9.0 minutes); therefore, time was dichotomized about the median for further analysis to have a more meaningful metric than would be obtained with log transformation. A logistic regression model was constructed, adding potential confounders one by one, in the order of most significant association on bivariate analysis (ie, lowest *P* value). The change in the β coefficient for wound care for each model was observed, and the covariate was included if the change was greater than 5%. The Breslow-Day test was used to assess for interactions. We report adjusted odds ratios (aORs) and 95% confidence intervals (CIs) from the multivariate logistic regression model. All statistical tests were 2-sided; $P < .05$ was considered to be statistically significant. All analyses were performed using SAS, version 9.1 (SAS).

The frequency of MDR *A. baumannii* isolation from HCWs' protective equipment was used to estimate the risk of HCW contamination. This information was combined with differential adherence to contact precautions and hand hygiene. For this estimate, we assumed that eradication of MDR *A. baumannii* with hand hygiene was 100% and that adherence to contact precautions and adherence to hand hygiene after glove removal were independent.

RESULTS

We observed 202 unique HCW-patient interactions that occurred between 17 unique patients and 59 unique HCWs. More than 95% of HCWs approached agreed to participate in the study. Initial HCW hand samples before patient contact were positive for MDR *A. baumannii* in 3 interactions (1.5%), which were subsequently excluded from the final analysis. Of the remaining 199 observed HCW-patient interactions, all were with patients colonized or infected with MDR *A. baumannii*, whereas 134 interactions occurred with patients who were positive for both MDR *A. baumannii* and MDR *P. aeruginosa*. All HCWs adhered to contact precautions and to hand hygiene after removal of gloves while under direct observation. No HCWs were observed changing gowns or gloves while in a patient room during this study.

The frequency of detection of MDR *A. baumannii* and MDR *P. aeruginosa* on HCW gloves, gowns, or hands after patient care is reported in Table 1 for the 65 interactions with patients colonized with MDR *A. baumannii* only and for the 134 interactions with patients colonized with both MDR *A. baumannii* and MDR *P. aeruginosa*. Of 199 interactions between HCWs and patients colonized or infected with MDR *A. baumannii*, 77 interactions (38.7% [95% CI, 31.9%–45.5%]) resulted in contamination with the organism to HCW gloves, gown, or both; and 9 interactions (4.5% [95% CI, 1.6%–7.4%]) resulted in contamination of HCW hands after removal of gloves before hand hygiene. Of 17 patients known to be colonized with MDR *A. baumannii*, 15 (88.2%) transmitted MDR *A. baumannii* at least once (the 2 who did not transmit MDR *A. baumannii* had a total of 4 HCW observations). Of 12 patients known to be colonized with MDR *P. aeruginosa*, 4 (25%) transmitted MDR *P. aeruginosa* at least once, all of whom also transmitted MDR *A. baumannii*. The patients in the study had a median of 9 HCW contacts. We were unable to determine how many individual HCWs were contaminated with *A. baumannii* or *P. aeruginosa*. Of 134 interactions between HCWs and patients with MDR *P. aeruginosa*, 11 interactions (8.2% [95% CI, 3.6%–12.9%]) resulted in contamination with the organism to the HCW gloves, gown, or both; and 1 interaction resulted in contamination of HCW hands after removal of gloves before hand hygiene. Contamination with MDR *A. baumannii* to gown or gloves was more frequent than contamination with MDR *P. aeruginosa* to gown or gloves (38.7% vs 8.2% of encounters; $P < .01$, by uncorrected χ^2 test assuming independence of observations).

Using this observed frequency of contamination with MDR *A. baumannii*, we derived an estimate of the risk of HCW contamination in relationship to different levels of adherence to contact precautions and hand hygiene. For this model, all adherence rates are hypothetical, because compliance was 100% under direct observation in our study. An important assumption of the model is that hand hygiene is 100% effective at removing organisms from HCW hands (Table 2).

Of the 9 episodes of hand contamination with MDR *A. baumannii* after glove removal, isolates from the gown or gloves of the same HCW were found to be identical by PFGE (8 of 8 available pairs of MDR *A. baumannii* isolates identified).

Risk factors significant for MDR *A. baumannii* contamination of HCW gown or gloves after patient care were evaluated with bivariate analysis (Table 3) followed by multiple logistic regression analysis. Results of the Breslow-Day test for each covariate showed no significant interactions. The final model included wound dressing (aOR, 25.9 [95% CI, 3.1–208.8]), care or use of endotracheal tube or tracheostomy site (aOR, 2.1 [95% CI, 1.1– 4.0]), time in room of more than 5 minutes (aOR, 4.3 [95% CI, 2.0–9.1]), and clinical role of physician or nurse practitioner (aOR, 7.4 [95% CI, 1.6–35.2]) or nurse (aOR, 2.3 [95% CI,

1.1–4.8]), compared with clinical role of therapists (occupational, physical, and respiratory) (Table 4).

DISCUSSION

We observed that gloves and gowns of HCWs were frequently contaminated with MDR *A. baumannii* and less so with MDR *P. aeruginosa* during routine care of patients infected or colonized with these organisms. Gloves were contaminated more frequently than gowns, and the hands of HCWs after glove removal were contaminated with MDR *A. baumannii* after nearly 5% of contacts.

MDR *A. baumannii* was detectable on HCW gloves and/or gowns after 38.7% of contacts. Previously, in a separate study that used the same methodology, we found that methicillin-resistant *Staphylococcus aureus* was detectable on HCW gloves and/or gowns after 18.5% of encounters and that vancomycin-resistant *Enterococcus* was detectable on HCW gloves and/or gowns after 8.5% of encounters.[10] This relatively high frequency of MDR *A. baumannii* contamination suggests that *A. baumannii* has a higher propensity to be transmitted to HCWs than do other MDR bacteria. This may be a factor in nosocomial spread, explaining in part the recent worldwide emergence of MDR *A. baumannii*.[1,2]

The benefit of contact precautions for the control of gram-negative pathogens has been debated.[14–16] We found that protective gloves reduced the incidence of transfer of MDR *A. baumannii* to the hands of HCWs 8-fold, from 36.2% to 4.5%. This reduction in transfer to hands emphasizes the potential benefit of the use of contact precautions for patients colonized or infected with MDR *A. baumannii*. Hand hygiene after the removal of gown and gloves remains important to address the 4.5% of HCWs with contaminated hands. HCWs removed gowns and gloves in a standard fashion and maintained precautions; however, incidental contact with gowns and/or gloves was observed, which likely explains the 4.5% frequency of contamination before hand hygiene.

Using the observed frequency of contamination of gloves and of contamination of hands of HCWs after removal of gloves in this study as well as the hypothetical varied adherence to hand hygiene and contact precautions (100% adherence was observed in this study), we extrapolated the likelihood of MDR *A. baumannii* contamination of the hands of HCWs per HCW-patient interaction (Table 2). On the basis of estimates from this simple model, even with 70% adherence to hand hygiene and 80% adherence to contact precautions (an ideal yet to be achieved in the majority of hospitals), 1 in every 30 HCW room entries results in MDR *A. baumannii* contamination, which is close to the 1.5% frequency of MDR *A. baumannii* contamination that we detected on HCW hands before room entry in our study. In the intensive care units where the study was conducted, more than 100 HCW room entries occur daily, and this number is reported in the literature as well.[14]

A higher risk of contamination was observed when contact with a patient wound or mechanical ventilatory equipment occurred, portals commonly positive for MDR *A. baumannii*.[17] Longer time in a patient room was a risk likely related to having greater patient and environmental exposure. A higher incidence of contamination of physicians or nurses, compared with the incidence of contamination of specialty therapists, is especially concerning, because physicians typically see more patients and have lower rates of hand hygiene than other HCWs.[18] In our hospital, wound care is performed by nurses. This may explain the higher rate of transmission to nurses, compared with the rate of transmission to specialty therapists, which includes physical and occupational therapists who do not have patient contact as extensive as that of nurses. Increased transmission with wound contact and ventilator equipment emphasizes the importance of secretions from these areas and the need

for good adherence to standard precautions in all patients, given that colonization with MDR *A. baumannii* is often not recognized.

Because participation was both voluntary and anonymous, a bias from observing the same HCW or patient room multiple times may have occurred. Although we had a significant rate of detection of MDR *A. baumannii*, our sampling technique may have been less sensitive than others.[19] We did not collect patient-specific information, so were unable to assess which or how many sites originally tested positive for these patients, factors that have been associated with transmission in the past.[20] Furthermore, we did not have access to original patient isolates to confirm that organisms obtained from HCWs matched organisms originally recovered from the patient. Although HCWs were undoubtedly aware of being observed, the Hawthorne effect is unlikely to have influenced results beyond adherence to hand hygiene and gown and glove use, because we were not analyzing adherence but rather bacterial transmission to personal protective equipment.

Protective gloves and gowns are contaminated with MDR *A. baumannii* much more often than with other MDR bacteria in the course of routine patient care activities. This may in part explain the rapid emergence of MDR *A. baumannii* in the hospital setting. Both contact precautions and hand hygiene are essential for controlling the spread of this organism.

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TABLE 1

Frequency of Contamination of Gowns, Gloves, and Hands of Healthcare Workers (HCWs) after Caring for Patients Colonized or Infected with Specified Bacteria

Source of culture-positive sample	No. (% [95% CI]) of observations	
	Patients with MDR *Acinetobacter baumannii* carriage (*n* = 199)	**Patients with MDR *Pseudomonas aeruginosa* carriage (*n* = 134)**
Gloves	72 (36.2 [29.5–42.9])	9 (6.7 [2.5–11.0])
Gown	22 (11.1 [6.7–15.4])	6 (4.5 [1.0–8.0])
Gloves and/or gown	77 (38.7 [31.9–45.5])	11 (8.2 [3.6–12.9])
Hands[a]	9 (4.5 [1.6–7.4])	1 (0.7 [0–2.2])

NOTE. CI, confidence interval; MDR, multidrug-resistant.

[a] After removal of gloves and gown and before hand hygiene.

TABLE 2

Derived Hypothetical Rate of Multidrug-Resistant (MDR) *Acinetobacter baumannii* Contamination of the Hands of Healthcare Workers (HCWs) per Patient Visit, Adjusting for Adherence to Hand Hygiene and Use of Gloves as Part of Contact Precautions

	Percentage chance of contamination per patient visit, by rate of adherence to use of gloves						
Rate of adherence to hand hygiene, % of opportunities	**0%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
0%	36.2	20.4	17.2	14.0	10.9	7.6	4.5
50%	18.1	10.2	8.6	7.0	5.4	3.8	2.3
60%	14.5	8.1	6.9	5.6	4.3	3.1	1.8
70%	10.8	6.1	5.2	4.2	3.3	2.3	1.4
80%	7.2	4.1	3.4	2.8	2.2	1.5	0.9
90%	3.6	2.0	1.7	1.4	1.1	0.8	0.5
100%	0	0	0	0	0	0	0

NOTE. For example, an HCW who has a mean adherence to use of gloves as part of contact precautions of 80% and a mean adherence to hand hygiene of 70% has a mean chance of hand contamination of 3.3% per exit of a room occupied by a patient with MDR *A. baumannii* carriage.

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TABLE 3

Bivariate Analysis of Risk Factors for Detection of Multidrug-Resistant *Acinetobacter baumannii* on the Gowns and/or Gloves Worn by Healthcare Workers (HCWs) Caring for Patients with *A. baumannii* Carriage

Nature of HCW-patient contact	No. of observations	No. (%) of positive culture results (*n* = 77)	No. (%) of negative culture results (*n* = 122)	Proportion (%) of contacts that preceded detection of pathogen	*P*[a]
Physical examination	18	11 (14.29)	7 (5.74)	11/18 (61)	.04
Wound dressing	16	15 (19.48)	1 (0.82)	15/16 (94)	<.01
Bathing and/or other form of hygiene	37	20 (25.97)	17 (13.93)	20/37 (54)	.03
Care or use of catheter and/or drain	36	16 (20.78)	20 (16.39)	16/36 (44)	.43
Care or use of endotracheal tube or tracheostomy site	78	37 (48.05)	41 (33.61)	37/78 (47)	.04
Checking vital signs	40	13 (16.88)	27 (22.13)	13/40 (33)	.37
Administering enteral medication	30	10 (12.99)	20 (16.39)	10/30 (33)	.51
Activity with intravenous pumps or lines	98	40 (51.95)	58 (47.54)	40/98 (41)	.54
Time in room of more than 5 minutes	125	64 (83.12)	61 (0.50)	64/125 (51)	<.01
Provider type					<.01
Physical, occupational, respiratory therapist	65	20 (25.97)	45 (36.89)	20/65 (31)	
Registered nurse	123	51 (66.23)	72 (59.02)	51/123 (41)	
Medical doctor or nurse practitioner	10	6 (7.79)	4 (3.28)	6/10 (60)	

NOTE. Each activity in this table is reported as if it occurred independently. However, healthcare workers typically performed multiple activities in each room. The variables of potential interest from this table were examined for independence in the multivariable logistic regression model reported in Table 4.

[a] By χ^2 analysis or Fisher exact test.

TABLE 4

Variables Found to Be Independently Predictive of Healthcare Worker Contamination with Multidrug-Resistant *Acinetobacter baumannii* by Means of Multiple Logistic Regression

Independent variable	aOR (95% CI)	*P*
Wound dressing	25.9 (3.1–208.8)	<.01
Care or use of endotracheal tube or tracheostomy site	2.1 (1.1–4.0)	.03
Time in room of more than 5 minutes	4.3 (2.0–9.1)	<.01
Physician or nurse practitioner, compared with therapist	7.4 (1.6–35.2)	.01
Nurse, compared with therapist	2.3 (1.1–4.8)	.03

NOTE. aOR, adjusted odds ratio; CI, confidence interval.