Comparison of Risk Factors for Recovery of *Acinetobacter baumannii* During Outbreaks at Two Kentucky Hospitals, 2006

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SYNOPSIS

Objectives. *Acinetobacter baumannii* (*A. baumannii*) is a well-described cause of nosocomial outbreaks and can be highly resistant to antimicrobials. We investigated *A. baumannii* outbreaks at two Kentucky hospitals to find risk factors for *Acinetobacter* acquisition in hospitalized patients.

Methods. We performed case-control studies at both hospitals. We defined a case as a clinical culture growing *A. baumannii* from a patient from August 1 to October 31, 2006 (Hospital A), or April 1 to October 31, 2006 (Hospital B).

Results. Twenty-nine cases were identified at Hospital A and 72 cases were identified at Hospital B. The median case patient age was 42 years in Hospital A and 46 years in Hospital B. The majority of positive cultures were from sputum (Hospital A, 51.7%; Hospital B, 62.5%). The majority of case patients had multidrug-resistant *A. baumannii* (Hospital A, 75.9%; Hospital B, 70.8%). Using logistic regression, controlling for age and admitting location, mechanical ventilation (Hospital A odds ratio [OR] = 21.6; 95% confidence interval [CI] 3.5, 265.9; Hospital B OR=4.5, 95% CI 1.9, 11.1) was associated with *A. baumannii* recovery. Presence of a nonsurgical wound (OR=6.6, 95% CI 1.2, 50.8) was associated with recovery of *A. baumannii* at Hospital A.

Conclusions. We identified similar patient characteristics and risk factors for *A. baumannii* acquisition at both hospitals. Our findings necessitate the importance of review of infection control procedures related to respiratory therapy and wound care.

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Acinetobacter baumannii (*A. baumannii*) is a gram-negative bacteria that is ubiquitous in the environment.[1] It is capable of surviving on surfaces for extended periods of time (as long as several months on dry surfaces[2]) and can readily acquire resistance to antimicrobials.[3] *Acinetobacter* species are an increasingly common cause of health-care-associated outbreaks as well as health-care-associated pneumonia, urinary tract infections, and postsurgical soft-tissue infections.[4] Risk factors implicated in previous *Acinetobacter* outbreaks include mechanical ventilation, intensive care unit (ICU) admission, and trauma.[5]

In fall 2006, two tertiary-care hospitals in separate Kentucky cities reported outbreaks of *A. baumannii*. In each facility, the recovery of *A. baumannii* increased from one to two cases/month to more than 10 cases/month. We investigated these outbreaks of *A. baumannii* and conducted a case-control study to identify potentially modifiable risk factors.

METHODS

Setting

Hospital A is an approximately 500-bed tertiary-care medical center that treats medical, surgical, and trauma patients in central Kentucky. Hospital B is an approximately 400-bed tertiary-care facility in central Kentucky that also treats medical, surgical, and trauma patients. According to infection control staff at both hospitals, these facilities are sufficiently separated geographically that they do not share patient populations or nursing or physician staff.

Selection of cases

Cases were defined as having one or more clinical cultures growing *A. baumannii*, based on a culture date between August 1 and October 31, 2006 (Hospital A), or April 1 and October 31, 2006 (Hospital B). We based these inclusion criteria on the outbreak periods at the respective hospitals; the criteria represented an increase from the number of cases seen at each facility in the previous year. Bacteria were identified at Hospital A using the Phoenix™ (Becton Dickinson, Cockeysville, Maryland) and at Hospital B using MicroScan® (Baxter Diagnostics, West Sacramento, California) for speciation. Positive culture results were confirmed with a review of the written and computerized record.

To differentiate risk factors for infection from those related only to colonization, we excluded cases identified initially by surveillance cultures of the axilla or groin performed during the outbreak periods at Hospital A (totaling two) and the throat at Hospital B (none were initially identified by surveillance culture). None of the patients were diagnosed with *A. baumannii* infection prior to hospital admission. We defined multidrug-resistant (MDR) *A. baumannii* as *A. baumannii* resistant to at least two classes of the following antimicrobials: beta-lactams, fluoroquinolones, aminoglycosides, and carbepenems.

Selection of control subjects

We selected control subjects by generating a list of all patients hospitalized during the outbreak period for at least the mean length of stay of case patients before the first positive culture. For Hospital A, the mean length of stay for patients prior to positive culture was 14 days. Therefore, for Hospital A we selected control subjects who were hospitalized for at least 14 days. For Hospital B, the mean length of stay prior to positive culture among cases was 17 days; therefore, we selected control subjects who had been hospitalized for at least 17 days. Control subjects were randomly selected from these lists without replacement at a 1:1 ratio to cases. To improve our assessment of risk factors associated with *A. baumannii* infection, controls were not matched based on risk factors other than length of stay.

Chart review

We reviewed each patient's paper and computerized record to determine underlying diseases, invasive procedures, surgeries, admission location, antibiotic and respiratory medications, and admitting and consulting services. For cases, we documented mechanical ventilation, tracheostomy, arterial and central venous catheters, and hospital location within 48 hours prior to culture. To compare the presence of these potential risk factors between cases and controls, we documented for control subjects the presence or absence of these risk factors within 48 hours of the mean time to initial positive culture for cases. For Hospital A, we documented for controls the presence of these risk factors within 48 hours of the 14th day of hospitalization. For Hospital B, we documented risk factors within 48 hours of the 17th day of hospitalization.

Presence of a previous MDR organism was defined as a prior positive culture from any past or current hospitalization for methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, or other gram-negative bacteria resistant to at least two classes of antimicrobials. When not found by chart review, we obtained this information by consulting with infection control staff.

Statistical methods

We evaluated differences between categorical variables by using the Chi-square test, or Fisher's exact test when data cell sizes were ≤5. We evaluated differences between continuous variables by using the student's

t-test. We performed exact multivariable logistic regression analysis, evaluated multiple models, and controlled for age and admitting location during the analysis. The number of variables in the final model was limited by sample size and to exclude those causing a problem with collinearity. The final model included factors that met a significance level of $p<0.05$ on univariate analysis for at least one of the hospitals as well as established risk factors for recovery of *Acinetobacter*. We conducted all data analyses using SAS® software.[6]

RESULTS

We enrolled 29 cases and 33 controls at Hospital A, and 72 cases and 71 controls at Hospital B. Table 1 demonstrates that for both facilities, the most common initial source of positive *A. baumannii* culture was from a respiratory specimen; the second most common source was from a wound. Seventy-five percent of cases at Hospital A and 71% of cases at Hospital B were culture-positive for MDR *A. baumannii*.

The median case age was 42 years (range: 0–74 years) in Hospital A and 46 years (range: 16–87 years) in Hospital B. The median length of stay was 19.5 days for cases at Hospital A (range: 2–72 days) and 31.0 days for cases at Hospital B (range: 2–207 days). At Hospital A, eight died; five died of sepsis, one died of multisystem organ failure, one died of renal failure, and one died of pulmonary hemorrhage. At Hospital B, 11 cases died; two died of sepsis and one died of multisystem organ failure. Of the remaining eight cases, one died of a gunshot wound to the neck, one died of an aneurysm, one died of anoxic brain injury and bacteremia, one died of closed head injury, one died of respiratory failure, one died of endocarditis, one died from a cerebrovascular accident, and one cause of death was listed as unknown. Four patients from Hospital A and four patients from Hospital B were discharged to a long-term-care facility; one patient from each hospital was discharged to a rehabilitation facility.

We identified no statistically significant difference between case and control age, mean length of stay, or comorbidity in either facility (Tables 2 and 3). At

Table 1. Initial source from which *A. baumannii* was recovered at two hospitals in Kentucky during an outbreak of *A. baumannii*, 2006

Source	*Hospital A (n=29)* N *(percent)*	*Hospital B (n=72)* N *(percent)*
Sputum	15 (51.7)	45 (62.5)
Wound	9 (30.8)	9 (12.5)
Blood	4 (13.8)	5 (6.9)
Body fluid	0 (0.0)	2 (2.8)
Catheter	1 (3.5)	2 (2.8)
Bone	0 (0.0)	4 (5.6)
Urine	0 (0.0)	5 (6.9)

A. baumannii = Acinetobacter baumannii

Table 2. Patient characteristics of cases and controls during an outbreak of *Acinetobacter baumannii* at two hospitals in Kentucky, 2006

	Hospital A			*Hospital B*		
Characteristic	*Cases (n=29)* N *(percent)*	*Controls (n=33)* N *(percent)*	P-*value*	*Cases (n=72)* N *(percent)*	*Controls (n=71)* N *(percent)*	P-*value*
Race/ethnicity						
White	27 (93.1)	28 (87.5)	0.31	53 (79.1)	49 (69.0)	0.54
Black	2 (6.9)	4 (12.5)	0.68	13 (19.4)	14 (19.7)	0.80
Hispanic	0	0		1 (1.5)	2 (2.8)	0.55
Mean age (in years)	42.9	45.2	0.63	47.2	48.5	0.67
Median age (in years)	42.4	52.5	0.21	46.0	48.0	0.56
Comorbidity						
Coronary artery disease	4 (13.8)	7 (21.2)	0.67	10 (13.9)	8 (11.3)	0.83
Pulmonary disease	5 (17.2)	6 (18.2)	0.99	5 (6.9)	8 (11.3)	0.54
Congestive heart failure	5 (17.2)	5 (15.2)	0.99	3 (4.2)	3 (4.2)	0.99
Diabetes	8 (27.6)	9 (27.3)	0.99	15 (20.8)	17 (23.9)	0.81
Liver disease	2 (6.9)	3 (9.1)	0.99	2 (2.8)	4 (5.6)	0.67
Renal disease	3 (10.3)	6 (18.2)	0.61	6 (8.3)	5 (7.0)	0.99
Malignancy	4 (13.8)	6 (18.2)	0.91	9 (12.5)	15 (21.1)	0.25
Mean total antibiotic days prior to culture	11.8	13.2	0.62	11.7	15.3	0.02[a]

[a]Statistically significant at $p<0.05$

Table 3. Univariate analysis of factors associated with recovery of *A. baumannii* among cases and controls during an outbreak of *A. baumannii* at two hospitals in Kentucky, 2006

	Hospital A					*Hospital B*				
Factors	*Cases (n=29)* N *(percent)*	*Controls (n=33)* N *(percent)*	*Odds ratio*	*95% CI*	P-*value*	*Cases (n=72)* N *(percent)*	*Controls (n=71)* N *(percent)*	*Odds ratio*	*95% CI*	P-*value*
Trauma admission	10 (34.5)	5 (15.5)	3.0	0.8, 12.6	0.14	43 (59.7)	25 (35.2)	2.7	1.3, 5.7	<0.01[a]
ICU at admission	19 (65.6)	10 (30.3)	4.3	1.3, 14.6	0.01[a]	56 (77.8)	37 (52.1)	3.2	1.4, 7.1	<0.01[a]
ICU at culture	20 (71.4)	10 (31.2)	5.3	1.6, 19.4	<0.01[a]	50 (69.4)	28 (39.4)	3.4	1.7, 7.4	<0.01[a]
Previous MDRO	10 (34.5)	4 (12.1)	3.7	0.9, 18.7	0.07	24 (33.3)	16 (22.5)	1.7	0.8, 3.9	0.21
Mechanical ventilation	23 (79.3)	4 (12.1)	25.6	6.0, 142.8	<0.01[a]	43 (59.7)	14 (19.7)	6.0	2.7, 13.8	<0.01[a]
Tracheostomy	10 (34.5)	2 (6.1)	7.9	1.5, 81.7	0.01[a]	34 (47.2)	17 (23.7)	2.8	1.3, 6.2	<0.01[a]
Central line	21 (72.4)	14 (48.4)	2.9	0.9, 10.8	0.09	46 (63.9)	35 (49.3)	1.8	0.9, 3.9	0.11
Arterial line	14 (48.2)	6 (20.0)	4.1	1.2, 16.0	0.02[a]	31 (43.1)	9 (12.7)	5.1	2.1, 13.6	<0.01[a]
Nonsurgical wound	18 (62.1)	6 (18.2)	7.4	2.3, 23.5	<0.01[a]	25 (34.7)	15 (21.1)	2.0	0.9, 4.2	0.07
Previous surgery	17 (58.6)	13 (39.4)	2.2	0.7, 6.8	0.21	57 (79.2)	45 (63.4)	2.2	1.0, 5.0	0.06
Mean length of stay (number of days)	26.9	20.6			0.12	36.7	31.2			0.16
Mortality	8 (27.6)	1 (3.0)	11.8	1.4, 557.4	0.02[a]	11 (15.3)	5 (7.0)	2.4	0.7, 9.2	0.19

[a]Statistically significant at $p<0.05$

A. baumannii = *Acinetobacter baumannii*

CI = confidence interval

ICU = intensive care unit

MDRO = multidrug-resistant organism

Hospital A, we detected no difference in the mean number of days of antimicrobial therapy before positive culture. At Hospital B, control subjects had more days of antibiotic exposure than case patients did.

Admission to the ICU, mechanical ventilation, and requirement for a tracheostomy were associated with recovery of *A. baumannii* at both facilities (Table 3). We also found an association between requirement of an arterial line and recovery of *A. baumannii* at both facilities. However, no statistically significant difference occurred in the likelihood of having a central line for patients at either facility. Diagnosis with a previous MDR organism was not associated with case status at either facility. At Hospital A, recovery of *A. baumannii* was associated with increased in-hospital mortality. Case patients at Hospital A were more likely to have at least one nonsurgical wound indicated on their medical record than were controls; these wounds consisted of decubitus ulcers in 13 cases and trauma-related wounds in seven cases. Cases at Hospital B were more likely to have been admitted to the trauma service (Table 3). However, we identified no association between previous surgery and case status at either facility.

On multivariate analysis, including age, admitting location, mechanical ventilation, and nonsurgical wounds in the model, mechanical ventilation remained significant at both facilities (Tables 4 and 5). Presence of a nonsurgical wound remained significant at Hospital A but was not significantly associated with recovery of *A. baumannii* at Hospital B.

Table 4. Multivariate analysis of factors associated with recovery of *A. baumannii* in cases and controls during an outbreak of *A. baumannii*: Hospital A, Kentucky, 2006[a]

Factor	*Odds ratio*	*95% CI*	*P-value*
Mechanical ventilation	21.6	3.5, 265.9	<0.01
Nonsurgical wound	6.6	1.2, 50.8	0.03
Age (in years)			
0–30	1.0	1.0	0.99
31–45	0.5	0.0, 7.7	0.99
45–60	0.6	0.0, 6.3	0.94
>60	0.3	0.0, 2.7	0.38
Admission to ICU	1.1	0.1, 7.6	0.99

[a]There were 29 cases and 33 controls at Hospital A.

A. baumannii = *Acinetobacter baumannii*

CI = confidence interval

ICU = intensive care unit

Table 5. Multivariate analysis of factors associated with recovery of *A. baumannii* in cases and controls during an outbreak of *A. baumannii*: Hospital B, Kentucky, 2006[a]

Factor	*Odds ratio*	*95% CI*	*P-value*
Mechanical ventilation	4.5	1.9, 11.1	<0.01
Nonsurgical wound	2.3	0.8, 7.9	0.16
Age (in years)			
15–30	1.0	1.0	1.00
31–47	0.7	0.2, 2.4	0.76
48–63	0.5	0.1, 1.8	0.36
>63	0.9	0.2, 3.1	0.99
Admission to ICU	1.4	0.6, 3.7	0.50

[a]There were 72 cases and 71 controls at Hospital B.

A. baumannii = *Acinetobacter baumannii*

CI = confidence interval

ICU = intensive care unit

DISCUSSION

We described case-control findings in two *A. baumannii* outbreaks at unrelated tertiary-care hospitals in Kentucky. Although the outbreaks occurred in different cities, risk factors for *A. baumannii* acquisition were similar. For both facilities, the majority of initial positive specimens came from a respiratory site; the second most common initial positive culture site for both facilities was a wound. On univariate analysis, we found an association between mechanical ventilation, presence of a tracheostomy, and ICU admission with recovery of *A. baumannii* at both institutions; multivariate analysis demonstrated an association with mechanical ventilation in both facilities and nonsurgical wounds in Hospital A.

At both facilities, the population of cases in whom *A. baumannii* was recovered had a wide age range. Our findings are consistent with a review performed by Villegas et al., which identified respiratory and nonrespiratory outbreaks that occurred in pediatric and adult populations.[7] Stephens et al. also identified an age range of 22–85 years in patients diagnosed with MDR *A. baumannii* who were treated in an acute and long-term-care facility within the same building complex.[8] This finding may be consistent with the discovery that *A. baumannii* pneumonia is related to contamination during airway management, and does not seem to be associated with severity of comorbid disease at hospitalization.[9]

On multivariate analysis, the requirement for mechanical ventilation was a risk factor for recovery of *A. baumannii* at both facilities; presence of a nonsurgical

wound was also associated with recovery of *A. baumannii* at Hospital A. These findings are consistent with previous research that has demonstrated respiratory tract infections and wounds to be a common source for recovery of *Acinetobacter* species.[10–14] Although we did not find this association at Hospital B to be statistically significant, we suspect it might have been the result of inconsistencies in chart documentation.

The role of mechanical ventilation as a risk factor for *Acinetobacter* colonization or infection has been reported in several other studies. Robenshtok et al. demonstrated an association between mechanical ventilation and recovery of *Acinetobacter*,[15] and Sofianou et al. identified an association between length of mechanical ventilation and ventilator-associated pneumonia.[16] Previous research has determined that the risk for a positive *Acinetobacter* culture is associated with factors that increase the degree of airway manipulation, and that comorbidity and severity of illness do not play an important role in *Acinetobacter* infection and colonization.[9]

We hypothesize that patients requiring mechanical ventilation not only have an increased risk for becoming colonized or infected with *Acinetobacter*, but also that they have an increased risk for transmitting *Acinetobacter* to other patients in the same area of the hospital after they become colonized or infected. This theory is based on findings from previous *Acinetobacter* outbreak investigations, during which respiratory secretions have been demonstrated to increase environmental contamination.[13,17] Patients with extended lengths of stay have more care provided from physicians, nurses, and respiratory therapists, and, therefore, have increased opportunity to become infected or colonized with *Acinetobacter*. The interaction between the patient and the health-care worker might increase the opportunity for hand contamination and subsequent spread of the *Acinetobacter* organism between patients. Further, contamination of the patient room occurs most commonly in rooms containing patients with colonized or infected wounds.[18] Such patients, after becoming infected or colonized, might therefore serve as a source of infection for other hospitalized patients.

During the process of caring for patient wounds, health-care workers might contaminate either their hands or the patient environment. In fact, one study demonstrated that cross-transmission was responsible for two-thirds of nosocomial *Acinetobacter* transmission in the ICU.[14] In addition, a previous outbreak revealed that the point-prevalence of patients testing culture-positive for MDR *Acinetobacter* in a given hospital was the only risk factor independently associated with *Acinetobacter* infection.[19] As such, increased interaction between patients and health-care workers might increase the likelihood for transient hand contamination of health-care workers and the spread of *Acinetobacter* to other patients.

Spread of *Acinetobacter* through hand carriage has been implicated during previous *Acinetobacter* outbreaks.[20] However, hand carriage appears to be limited and might occur only immediately after completion of patient care and before use of an alcohol-based sanitizer.[21] In addition, patients colonized or infected with *Acinetobacter* typically only spread it to their immediate surroundings.[22] Following infection control precautions such as wearing gowns and gloves prior to care of patients infected or colonized with *Acinetobacter*, and performing correct hand washing when caring for ventilated patients and patients with nonsurgical wounds is, therefore, particularly important. As such, during the outbreaks described at both facilities, infection control staff emphasized the importance of wearing gowns and gloves to patient care staff when caring for patients in whom *A. baumannii* was recovered.

Limitations

This study had two limitations. First, the requirement that controls have a length of stay at least as long as the mean case length of stay prior to recovery of *Acinetobacter* rendered us unable to evaluate the potential association between length of stay and a positive *Acinetobacter* culture. This requirement may also confound our analysis of antibiotic exposure as a risk factor. Because antibiotic doses were recorded for the two weeks prior to day 14 of hospitalization for Hospital A and day 17 of hospitalization for Hospital B, 14 days of antibiotic exposure could always be documented for control subjects. Conversely, for cases, antibiotic exposure was documented two weeks prior to positive culture—a period that often included fewer than 14 days of hospitalization. Second, we had a limited sample size in Hospital A to detect differences among risk factors that might have been associated with recovery of *A. baumannii*.

CONCLUSIONS

The findings of this investigation emphasize the importance of infection control procedures related to respiratory therapy and wound care, and are consistent with previous research in this area. *A. baumannii* is a growing cause of hospital-acquired infections and remains a source of health-care-associated outbreaks.[4] The challenges posed by *Acinetobacter* are compounded by the few antimicrobial options available and the increasing trend toward multidrug resistance in this

organism.[23] Further study of MDR organisms may be warranted to combat this public health problem. Our characterization of risk factors associated with acquisition of *Acinetobacter* during simultaneous outbreaks in two unrelated Kentucky hospitals can be used to help focus future prevention and control efforts.

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