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Risk Factors and Outcomes for Patients with Bloodstream Infection Due to *Acinetobacter baumannii-calcoaceticus* Complex

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Identifying patients at risk for bloodstream infection (BSI) due to *Acinetobacter baumannii-Acinetobacter calcoaceticus* complex (ABC) and providing early appropriate therapy are critical for improving patient outcomes. A retrospective matched case-control study was conducted to investigate the risk factors for BSI due to ABC in patients admitted to the Detroit Medical Center (DMC) between January 2006 and April 2009. The cases were patients with BSI due to ABC; the controls were patients not infected with ABC. Potential risk factors were collected 30 days prior to the ABC-positive culture date for the cases and 30 days prior to admission for the controls. A total of 245 case patients were matched with 245 control patients. Independent risk factors associated with BSI due to ABC included a Charlson's comorbidity score of ≥3 (odds ratio [OR], 2.34; $P = 0.001$), a direct admission from another health care facility (OR, 4.63; $P < 0.0001$), a prior hospitalization (OR, 3.11; $P < 0.0001$), the presence of an indwelling central venous line (OR, 2.75; $P = 0.011$), the receipt of total parenteral nutrition (OR, 21.2; $P < 0.0001$), the prior receipt of β-lactams (OR, 3.58; $P < 0.0001$), the prior receipt of carbapenems (OR, 3.18; $P = 0.006$), and the prior receipt of chemotherapy (OR, 15.42; $P < 0.0001$). The median time from the ABC-positive culture date to the initiation of the appropriate antimicrobial therapy was 2 days (interquartile range [IQR], 1 to 3 days). The in-hospital mortality rate was significantly higher among case patients than among control patients (OR, 3.40; $P < 0.0001$). BSIs due to ABC are more common among critically ill and debilitated institutionalized patients, who are heavily exposed to health care settings and invasive devices.

During the 1970s, *Acinetobacter baumannii* emerged as a prominent nosocomial pathogen (1), increasingly implicated in bloodstream infections (BSI), ventilator-associated pneumonia, meningitis, and surgical site infections (2). During the past 2 decades, *A. baumannii* strains have evolved as important multidrug-resistant (MDR) bacteria, thriving in hospital environments worldwide and remaining viable on equipment and surfaces for weeks (3). Of particular importance is the ability of *A. baumannii* to cause BSI in critically ill patients admitted to intensive care units (ICUs) (4–6). *A. baumannii* infection also occurs in neonatal ICUs. One study reported *A. baumannii* as the causative agent in 6.2% of cases of septicemia resulting in an overall attributable mortality rate of 20% (7). Higher morbidity and mortality rates have been reported in patients infected with MDR *A. baumannii* strains as opposed to those infected with non-MDR *A. baumannii* strains (8).

Previously published studies investigating the risk factors for BSI due to *A. baumannii* have been limited by several methodological problems, including small sample sizes and suboptimal methodology for case and control group selection (9–12). The risk factors for *A. baumannii* bacteremia reported in these studies included recent invasive procedures, the use of broad-spectrum antimicrobials, prolonged ICU stays, certain underlying diseases or conditions, hospital size, and urinary catheterization (13, 14). The mortality rates reported among patients with *A. baumannii* bacteremia are in excess of 20%, with risk factors predictive of mortality being immunosuppression, shock, recent surgical intervention, central line placement, urinary catheterization, nasogastric tube placement, and mechanical ventilation (15). Given the predilection of *A. baumannii* for critically ill patients, some outbreaks have required closure of ICUs for decontamination, with costs nearing $350,000 (U.S. dollars [USD]) per outbreak (16). Overall, annual health care expenditures for *A. baumannii* infections have been estimated to range between $7.4 million and $26.1 million in the United States (17).

The objective of this study was to analyze the risk factors and outcomes of patients with BSI specifically due to *Acinetobacter baumannii-Acinetobacter calcoaceticus* complex (ABC) through a matched analysis with uninfected control patients. The current study included a large number of cases and matched controls, thereby allowing accurate and reliable assessment of the relationships between the potential risk factors and BSI due to ABC. More importantly, selection of cases was highly refined by including patients with pure ABC infections and excluding patients with ABC colonization or polymicrobial infections.

MATERIALS AND METHODS

Study design and setting. We conducted a retrospective matched case-control study to investigate the risk factors predisposing for BSI due to ABC in patients admitted to the Detroit Medical Center (DMC) from January 2006 to April 2009. The DMC consists of eight hospitals located in the greater metropolitan Detroit area containing a total of >2,200 beds. The institutional review boards at the DMC and Wayne State University approved the study prior to its initiation.

Patient population. The study population was identified by querying the DMC Clinical Microbiology Laboratory electronic database for posi-

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TABLE 1 Demographics, comorbidities, and hospital-related exposures prior to positive culture

Variable	Results for: Cases (n = 245)	Controls (n = 245)	OR[a]	95% CI[b]	P
Demographics					
Age (mean ± SD) (yr)	55 ± 24	54 ± 24			0.71
African-American ethnicity (no. [%])	179 (73)	199 (81)	0.63	0.41–0.96	0.031
Male gender (no. [%])	116 (47)	128 (52)	0.82	0.58–1.17	0.28
Severity of illness scores (no. [%])					
Charlson's score of ≥3	165 (67)	101 (41)	2.94	2.03–4.25	<0.0001
Charlson's score (median [IQR])	4 (2–8)	2 (0–4)			<0.0001
Comorbid conditions (no. [%])[c]					
Prior hospitalization	98 (40)	38 (15.5)	3.63	2.36–5.58	<0.0001
Directly admitted from another health care facility	99 (40)	23 (9)	6.51	3.95–10.74	<0.0001
Any dependence for ADL[d]	121 (49)	118 (48)	1.05	0.74–1.50	0.78
Dependence for ≥3 ADL	99 (40)	92 (37)	1.13	0.78–1.62	0.52
Prior use of chemotherapy	39 (16)	3 (1.2)	15	4.65–50.14	<0.0001
Low albumin level	27 (11)	82 (34)	0.24	0.15–0.39	<0.0001
Neutropenia	8 (3)	5 (2)	1.62	0.52–5.02	0.40
Prior receipt of TPN	68 (28)	16 (7)	5.50	3.07–9.77	<0.0001
Hospital exposures prior to culture (no. [%])[c]					
Central line placement	51 (21)	31 (13)	1.81	1.11–2.95	0.015
Use of Foley catheter	21 (8.5)	51 (21)	0.33	0.19–0.60	0.0001
ICU admission	98 (40)	88 (36)	1.20	0.82–1.71	0.35
Intubation	83 (34)	75 (31)	1.16	0.79–1.70	0.44
Prior surgeries	51 (21)	75 (31)	0.60	0.40–0.90	0.013

[a] OR, odds ratio.
[b] CI, confidence interval.
[c] Potential risk factors were assessed for all patients within the 30 days prior to the ABC-positive culture date.
[d] ADL, activities of daily living.

tive ABC blood culture results. Cases were defined based on the systemic inflammatory response syndrome (SIRS) criteria of infection (18) and positive ABC blood cultures. Cases with positive ABC cultures but no SIRS criteria and those with polymicrobial BSIs were excluded from the study. Controls were matched to case patients in a 1:1 ratio based on the admitting hospital, the admitting unit, and the at-risk period (the time from admission to the positive culture date for cases and the total duration of hospitalization for controls). The at-risk time had to be at least as long for the control as for its matched case.

Variables and definitions. Patient charts were reviewed for potential risk factors and pertinent clinical data, including patient demographics, comorbidities, prior antibiotic exposure, activities of daily living (ADL), ICU stays, surgeries, mechanical ventilation, central venous catheters (CVC), urinary catheters, and inpatient mortality. Risk factor data were collected for the 30 days prior to the ABC-positive culture date for the cases and 30 days prior to discharge for the controls. Prior antibiotic exposure in cases was defined as the administration of an antibiotic from 30 days prior to the culture date up to 1 day prior to the culture date. In controls, prior antibiotic exposure was defined as the administration of any antibiotic from 30 days prior to discharge up to the day of discharge. Appropriate antimicrobial therapy was defined as therapy with an agent with *in vitro* activity against the infecting pathogen.

ICU admissions were captured within 30 days of the ABC-positive culture date for the cases and until discharge for the controls. Emergency visits and in-hospital readmissions within 30 days of discharge were captured for all cases and controls. In-hospital mortality rates and mortality rates within 6 months of the primary admission date were captured for both cases and controls.

Microbiology. The DMC has a single centralized clinical microbiology laboratory, which processes ~500,000 samples annually. Bacteria are identified to the species level, and susceptibilities are determined for predefined antimicrobials on the basis of an automated broth microdilution system (MicroScan; Siemens AG, Germany) and in accordance with CLSI criteria (19).

Statistical analysis. All analyses were performed using SAS software, version 9.3 (SAS, Cary, NC). The Student t test and Mann-Whitney U test (Wilcoxon rank-sum test) were used to analyze continuous variables. Both the chi-square and Fisher's exact tests were used for the bivariate analyses of the discrete variables. Variables with a P value of <0.10 in the bivariate analyses were included as candidates for the multivariate model. Multivariate analysis, using logistic regression, was performed to adjust for confounders and to select for variables in the final model. All significance tests were 2-sided and used a 5% level of significance.

RESULTS

Patient characteristics and hospital-related exposures. All cases in this study were selected from a recently published cohort analysis of patients with BSI due to carbapenem- and ampicillin-sulbactam-resistant (CASR) *A. baumannii* (20). In the present study, 245 of these cases with BSI due to ABC were matched to 245 controls not infected with ABC. Forty-five cases (18%) had BSI due to ampicillin-sulbactam-resistant ABC (MIC, ≥16/8 μg/ml), 26 (11%) had BSI due to carbapenem-resistant ABC (MIC, ≥8 μg/ml), and 62 (25%) had BSI due to CASR ABC. The mean age of the case patients was 54 ± 24 years, 47% were males, and 73% were African-Americans. The mean age of the control patients was 54 ± 24 years, 52% were males, and 81% were African-Americans (Table 1).

In the present study, multiple statistically significant ($P < 0.05$) risk factors were identified in the bivariate analysis (Table 1). The

TABLE 2 Exposure to antimicrobials prior to positive culture

Antimicrobial	Exposure (no. [%]) for: Cases ($n = 245$)	Controls ($n = 245$)	OR[a]	95% CI[b]	P
Prior antibiotics by class					
Aminoglycosides	61 (25)	39 (16)	1.75	1.12–2.74	0.014
β-Lactams[c]	143 (58)	88 (36)	2.50	1.74–3.60	<0.0001
Carbapenems	50 (20)	22 (9)	2.60	1.52–4.45	0.0004
Fluoroquinolones	32 (13)	25 (10)	1.32	0.76–2.30	0.32
Prior antimicrobials					
Amikacin	7 (3)	3 (1.2)	2.37	0.61–9.28	0.20
Amphotericin	1 (0.41)	1 (0.41)	1.00	0.06–16	1.00
Ampicillin-sulbactam	34 (14)	22 (9)	1.63	0.92–2.88	0.088
Aztreonam	13 (5)	3 (1.2)	4.52	1.27–16.07	0.011
Cefepime	116 (47)	65 (26.5)	2.50	1.70–3.64	<0.0001
Colistimethate	23 (9)	10 (4)	2.43	1.13–5.23	0.019
Ertapenem	1 (0.41)	1 (0.41)	1.00	0.06–16.08	1.0
Gentamicin	22 (9)	20 (8)	1.11	0.59–2.09	0.75
Imipenem-cilastatin	3 (1.2)	2 (0.8)	1.51	0.25–9.09	0.65
Linezolid	19 (8)	10 (4)	1.97	0.90–4.34	0.085
Meropenem	47 (19)	19 (8)	2.82	1.60–4.97	0.0002
Piperacillin-tazobactam	25 (10)	27 (11)	0.92	0.52–1.63	0.77
Rifampin	10 (4)	8 (3)	1.26	0.49–3.25	0.63
Tigecycline	23 (9)	12 (5)	2.01	0.98–4.14	0.054
Tobramycin	40 (16)	19 (8)	2.32	1.30–4.14	0.0036

[a] OR, odds ratio.
[b] CI, confidence interval.
[c] β-Lactams did not include carbapenems and included only antimicrobials with significant effects on Gram-negative organisms (ampicillin-sulbactam, cefepime, piperacillin, and piperacillin-tazobactam).

TABLE 3 Independent predictors of BSI due to ABC

Variable	OR[a]	95% CI[b]	P
African-American ethnicity	0.36	0.19–0.86	0.001
Charlson's comorbidity score of ≥3	2.34	1.40–3.92	0.001
Direct admission from another health care facility	4.63	2.38–9.20	<0.0001
Prior hospitalization	3.11	1.70–5.67	<0.0001
Central line placement	2.75	1.26–6.00	0.011
Use of Foley catheter	0.24	0.09–0.60	0.002
Prior surgeries	0.51	0.25–1.00	0.051
Low albumin level	0.06	0.03–0.13	<0.0001
Prior receipt of TPN	21.20	7.83–57.37	<0.0001
Prior use of β-lactams	3.58	2.10–6.13	<0.0001
Prior use of carbapenems	3.18	1.39–7.27	0.006
Prior use of chemotherapy	15.42	3.87–61.40	<0.0001

[a] OR, odds ratio.
[b] CI, confidence interval.

case patients with BSI due to ABC were more likely to be directly admitted from another health care facility (including an acute care hospital, a long-term care facility, or a rehabilitation center) than the control patients (odds ratio [OR], 6.51; 95% confidence interval [CI], 3.95 to 10.74; $P < 0.0001$). The cases had higher Charlson's comorbidity scores (score, ≥3) than the controls (OR, 2.94; 95% CI, 2.03 to 4.25; $P < 0.0001$). The top three comorbid conditions more commonly present among the cases than the controls were peripheral vascular disease (OR, 13.00; 95% CI, 5.46 to 30.56; $P < 0.0001$), diabetes with end-organ damage (OR, 11.26; 95% CI, 4.74 to 26.74; $P < 0.0001$), and peptic ulcer disease (OR, 8.54; 95% CI, 3.29 to 22.12; $P < 0.0001$). Forty percent of the patients with BSI due to ABC had a history of prior hospitalization compared to 15.5% of the controls (OR, 3.63; 95% CI, 2.36 to 5.58; $P < 0.0001$). A greater proportion of the cases were found to have had prior recent use of chemotherapy than of the controls (16% versus 1.2%, OR, 15.00; 95% CI, 4.65 to 50.14; $P < 0.0001$). Twenty-eight percent of the case patients with BSI due to ABC received total parenteral nutrition (TPN) compared to 7% of the control patients (OR, 5.50; 95% CI, 3.07 to 9.77; $P < 0.0001$). A central venous catheter was indwelling in 21% of the cases compared to 13% of the controls (OR, 1.81; 95% CI, 1.11 to 2.95; $P = 0.015$).

Prior antimicrobial exposure. There was significantly more prior antimicrobial exposure among cases than among controls (Table 2). Aminoglycosides (OR, 1.75; 95% CI, 1.12 to 2.74; $P = 0.014$), β-lactams (including penicillins and cephalosporins but not carbapenems) (OR, 2.50; 95% CI, 1.74 to 3.60; $P < 0.0001$), and carbapenems (OR, 2.60; 95% CI, 1.52 to 4.45; $P = 0.0004$) were more commonly administered to the case patients than to the control patients. Individual antimicrobials, with significant Gram-negative activity, more commonly used in the cases than in the controls were aztreonam (OR, 4.52; 95% CI, 1.27 to 16.07; $P = 0.011$), cefepime (OR, 2.50; 95% CI, 1.70 to 3.64; $P < 0.0001$), colistin (OR, 2.43; 95% CI, 1.13 to 5.23; $P = 0.019$), meropenem (OR, 2.82; 95% CI, 1.60 to 4.97; $P = 0.0002$), and tobramycin (OR, 2.32; 95% CI, 1.30 to 4.14; $P = 0.0036$).

Independent predictors of BSI due to ABC. In multivariate analysis, factors independently associated with the patients with BSI due to ABC included a Charlson's comorbidity score of ≥3 (OR, 2.34; 95% CI, 1.40 to 3.92; $P = 0.001$), a direct admission from another health care facility (including long-term care) (OR, 4.63; 95% CI, 2.38 to 9.20; $P < 0.0001$), a prior recent hospitalization (OR, 3.11; 95% CI, 1.70 to 5.67; $P < 0.0001$), the presence of an indwelling central venous catheter (OR, 2.75; 95% CI, 1.26 to 6.00; $P = 0.011$), receipt of TPN (OR, 21.20; 95% CI, 7.83 to 57.37; $P < 0.0001$), the prior use of β-lactams (OR, 3.58; 95% CI, 2.10 to 6.13; $P < 0.0001$) or carbapenems (OR, 3.18; 95% CI, 1.39 to 7.27; $P = 0.006$), and chemotherapy (OR, 15.42; 95% CI, 3.87 to 61.40; $P < 0.0001$) (Table 3). In contrast, exposures independently associated with a decreased risk for BSI due to ABC included African-American ethnicity (OR, 0.36; 95% CI, 0.19 to 0.68; $P = 0.001$), the presence of an indwelling urinary catheter (OR, 0.24; 95% CI 0.09 to 0.60; $P = 0.045$), and a low albumin level (OR, 0.06; 95% CI, 0.03 to 0.13; $P < 0.0001$). The model was adjusted for the confounding effect of recent prior surgery (OR, 0.51; 95% CI, 0.25 to 1.00; $P = 0.051$).

Clinical outcomes of cases and controls. The median duration of hospitalization was 14 days in the case patients (interquartile range [IQR], 8 to 27 days) and 8 days in control patients (IQR, 3 to 21 days) ($P < 0.0001$). Among the cases, the median duration from the time of the culture to the time of initiation of the appropriate antimicrobial therapy was 2 days (IQR, 1 to 3 days). Compared to the control patients, the case patients with BSI due to ABC were more likely to be admitted to the ICU during the period after culture prior to discharge (OR, 34.00; 95% CI, 4.60 to 252.00; $P < 0.0001$), to have more frequent emergency room visits (OR, 55.00; 95% CI, 7.50 to 401.80; $P < 0.0001$), and to be readmitted to the hospital within 30 days of discharge (OR, 81.00; 95% CI, 11.11 to 589; $P < 0.0001$) (Table 4).

TABLE 4 Clinical outcomes in the cases compared to those in the controls

Variable	Results for: Cases ($n = 245$)	Controls ($n = 245$)	OR[a]	95% CI[b]	*P*
Duration of hospitalization (days)					
Mean ± SD	22 ± 23	17 ± 23			<0.0001
Median (IQR)	14 (8–27)	8 (3–21)			<0.0001
ICU admissions, readmissions, and ER[c] visits (no. [%])					
ICU admission after positive culture	30 (12)	1 (0.41)	34	4.60–252.00	<0.0001
Urgent care visits[d]	45 (18)	1 (0.41)	55	7.50–401.80	<0.0001
30-day readmission[d]	61 (25)	1 (0.41)	81	11.11–589	<0.0001
Mortality					
In-hospital mortality	47 (19)	16 (6.5)	3.40	1.87–6.18	<0.0001
Overall 6-mo mortality	55 (22.4)	18 (7)	3.65	2.07–6.43	<0.0001

[a] OR, odds ratio.
[b] CI, confidence interval.
[c] ER, emergency room.
[d] Urgent care visits and readmissions were assessed within 30 days after discharge.

The in-hospital mortality (OR, 3.40; 95% CI, 1.87 to 6.18; $P < 0.0001$) and overall 6-month mortality (OR, 3.65; 95% CI, 2.07 to 6.43; $P < 0.0001$) were higher among the cases than among the controls.

DISCUSSION

To our knowledge, the present study is the largest case-control analysis pertaining to risk factors for BSI due to ABC. Previously published studies analyzing risk factors for *A. baumannii* infections were limited by several methodological issues, including small sample size, the inclusion of colonized patients, and inappropriate consideration of the at-risk period for matching cases to controls (9–12, 21, 22). In the present study, the large sample size and the matching based primarily on the at-risk period have enabled us to reliably identify risk factors for BSI due to ABC. Moreover, all of the cases in this study were appropriately defined, as the diagnosis of patients was made based on both the clinical picture and a positive culture for ABC organisms isolated from blood samples. In particular, exclusion of subjects deemed to be colonized (and not infected) and patients with polymicrobial infections was a particular strength of this study. This study included cases of ABC with different degrees of antimicrobial resistance. This diversity of susceptibility patterns adds generalizability to the results.

The present study demonstrated that TPN is the strongest independent predictor of BSI due to ABC. Yin et al. previously reported that the administration of TPN for ≥2 weeks was associated with a higher incidence of nosocomial *A. baumannii* bacteremia (23). TPN has also been implicated in the nosocomial acquisition of bacteremia due to carbapenem-resistant *A. baumannii* (24, 25). Surprisingly, the multivariate analysis demonstrated that a low albumin level was associated with a decreased risk for BSI due to ABC. This contradicts results of previous studies showing that low albumin levels were significant predictors for acquisition of bacterial infections originating in the bloodstream (26, 27). It has been proposed that a low albumin level may result in significant intestinal edema and capillary leakage, therefore, facilitating the translocation of microorganisms from the intestinal lumen to the bloodstream (27). Perhaps, the ABC species at our facilities might have had less tendency to colonize the intestinal tract than the species reported in other studies.

The multivariate analysis identified receipt of chemotherapy as a strong predictor of BSI due to ABC. This finding was not unexpected, owing to the fact that chemotherapy compromises the host immune system, thus making patients highly vulnerable for opportunistic nosocomial infections such as ABC. Fukuta et al. reported that acquisition of MDR *A. baumannii* infections in cancer patients was not directly related to immunosuppressive therapy and might be attributed to the severity of the underlying illness and the extensive health care exposures associated with their primary condition (28).

In our study, admission from another health care facility, a Charlson's comorbidity score of ≥3, prior hospitalizations, and the prior receipt of carbapenems and β-lactams were all identified as independent predictors of BSI due to ABC. Most of these factors have been reported by other studies as risk factors for *A. baumannii* infections (22, 29–31). This emphasizes the opportunistic nature of ABC infections and reflects the tendency of ABC to infect critically ill patients who have impaired natural host defenses. In addition, the current study demonstrated that the patients who had indwelling central venous catheters had an almost 3-fold increase in the risk of acquiring BSI due to ABC compared to that of the controls. This is concordant with results of other studies which investigated the effect of central venous catheter insertion on the incidence of *A. baumannii* acquisition (29, 30, 32). However, in prior studies, invasive procedures (surgical procedures, endotracheal intubation, and venous and arterial catheter insertion) were combined together as a single variable, and the analyses were performed in ICU settings, which limited the ability to determine the specific risk associated with central venous catheters (29, 30, 32). Because central venous catheters were independently associated with BSI due to ABC and Foley catheters were not, the urinary tract was probably not a common source of ABC infection and contaminated central venous catheters were probably a relatively common infection source.

Being retrospective, this study might have had a selection bias. However, the matched case-control study design helped limit this

type of bias. In addition, although the readmission and mortality rates were significantly higher among the cases than among the controls, these rates could have been attributed to the comorbidities and severity of illness among the cases as opposed to the controls. Moreover, since practices for procedures such as CVC placement and receipt of TPN might differ from one health care facility to another, the potential effect of these practices on acquisition of BSI due to ABC in our study might have been over- or underestimated. Previously, our group described the risk factors for and outcomes associated with BSI due to CASR AB compared to those for more susceptible strains of AB (20). In an attempt to make the findings in this report more generalizable, we chose to focus on BSI due to ABC in general, rather than analyzing different susceptibility phenotypes individually.

In conclusion, this large study demonstrated that acquisition of BSI due to *A. baumannii-calcoaceticus* complex is more common in critically ill patients previously exposed to health care settings. In particular, chemotherapy, TPN administration, and central line placement were strong independent risk factors for BSI due to ABC. These findings stress the importance of central venous catheter care and infection control bundles in preventing BSI due to ABC. Because ABC infection affects some of the sickest, highest risk hospitalized populations and is associated with significant morbidity and mortality (20), attention to optimal infection prevention practices is particularly important in these populations.

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