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ORIGINAL RESEARCH

Prognostic Factors That Affect Mortality Patients with *Acinetobacter baumannii* Bloodstream Infection

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Background: To evaluate the clinical features of patients with *Acinetobacter baumannii* bloodstream infection (BSI).

Methods: Totally 200 inpatients with *Acinetobacter baumannii* BSI were included, clinical features of *Acinetobacter baumannii* BSI inpatients between 90-day survival and 90-day mortality groups, between 30-day survival and 30-day mortality groups, between patients infected with multidrug-resistant (MDR group) and sensitive *Acinetobacter baumannii* (sensitive group) were analyzed. The prognostic factors of 90-day mortality were analyzed by univariate logistic regression and multivariate logistic regression. The survival curve in bloodstream infectious patients with multidrug-resistant (MDR group) and sensitive *Acinetobacter baumannii* (sensitive group) was analyzed by Kaplan–Meier analysis.

Results: The 90-day mortality patients had significantly higher carbapenem-resistant bacterial infection and critical care unit (ICU) admission. The 90-day and 30-day mortality groups showed higher C-reactive protein (CRP) and serum creatinine (Scr) levels and lower red blood cells (RBC) and albumin (ALB) levels than their survival counterparts, respectively. Critical surgery, ICU admission and delayed antibiotic treatment were independently prognostic risk predictors for 90-day mortality in *Acinetobacter baumannii* BSI patients, while critical surgery and diabetes were independently prognostic risk predictors for 90-day mortality in carbapenem-resistant *Acinetobacter baumannii* BSI patients. Compared with sensitive group, MDR group showed significantly longer ICU and whole hospital stay, lower levels of lymphocytes, RBC, hemoglobin, lactate dehydrogenase and ALB, higher frequency of infection originating from the skin and skin structure. Moreover, patients in the MDR group had a significantly worse overall survival than the sensitive group.

Conclusion: We identified the prognostic factors of *Acinetobacter baumannii* BSI and carbapenem-resistant *Acinetobacter baumannii* BSI patients. Critical surgery, ICU admission, delayed antibiotic treatment or diabetes were significantly associated with the mortality of those patients. Moreover, aggressive measures to control MDR *Acinetobacter baumannii* could lead to improved outcomes.

Keywords: *Acinetobacter baumannii*, bloodstream infection, mortality, prognostic predictors, multidrug-resistance

Introduction

Acinetobacter baumannii is a ubiquitous opportunistic pathogen known for its ability to colonize various surfaces and survive in diverse environmental conditions, making it a prevalent cause of biofilm infections in healthcare settings.[1–3] *Acinetobacter baumannii* harbors several mobile DNA elements often encompassing resistance genes and leads to the emergence of multi-drug resistance (MDR) and extensive drug resistance (XDR) phenotypes.[4,5] *Acinetobacter baumannii* infections commonly manifested as bloodstream infection (BSI), respiratory tract infections, infections in the skin and surgical sites, urinary tract infections.[6–8]

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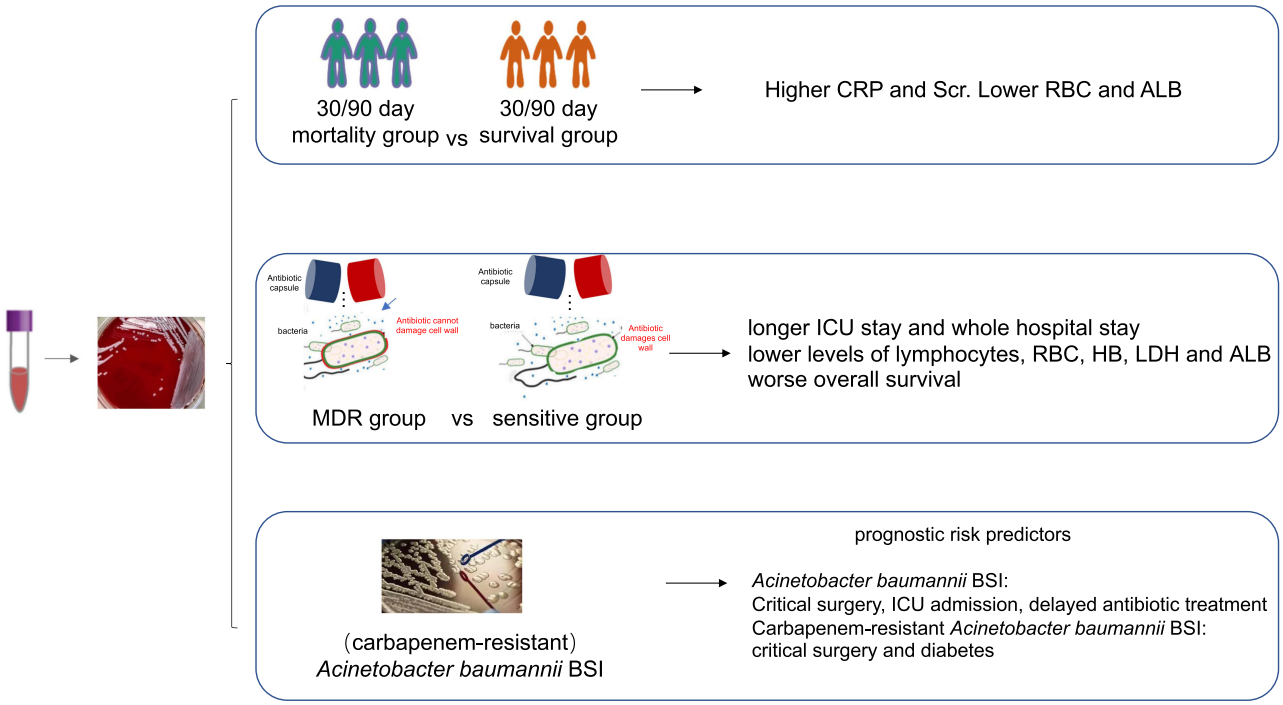
Graphical Abstract



Approximately 30 million BSI cases and 6 million deaths annually worldwide were reported estimated from a comprehensive analysis using available data on the national or local population figures to the worldwide population.[9] According to the China Antimicrobial Surveillance Network's 2022 investigation, BSI accounted for approximately 14.8% of 339,513 bacterial samples in China.[10] BSI encompasses a wide range of pathogens and clinical syndromes, often resulting in high morbidity and mortality rates.[10] Among these, *Acinetobacter baumannii* stands out as a major contributor to bloodstream infections, with increasing incidence rates and the detection of drug-resistant strains in recent years.[11] Studies have shown that *Acinetobacter baumannii* BSI accounts for 9–35% of the total BSI cases,[12,13] the prevalence of MDR *Acinetobacter baumannii* has increased from 21.4% (2003–2005) to 35.2% (2009–2012).[14] In a multicenter study in China, 40 from 1358 cases (2.9%) of bacteremia were diagnosed with *Acinetobacter baumannii* bacteremia.[15]

Acinetobacter baumannii BSI was considered to be a common disease in critically ill people, causing an elevation in the mortality rate and medical expense of the patients.[2,16,17] Tigecycline-, ampicillin/sulbactam-, polymyxin B-, carbapenem-, colistin-containing regimens were therapeutic options for *Acinetobacter baumannii* BSI.[18–20] Inappropriate therapy and limited therapeutic options are responsible for negative impact on its outcome, and this infection is associated with high mortality rates, especially in ICU patients.[21,22] Wang et al showed that higher SOFA scores at the time of infection, septic shock, and mechanical ventilation were the prognostic factors of *Acinetobacter baumannii* BSI and patients with those features were more likely to be fatally hit within 28 days and had a poor prognosis.[23] Gu et al reported that neutropenia, ICU admission prior to positive culture, primary infection in the central nervous system, and carbapenem use prior to positive culture, were independently associated with BSI caused by *Acinetobacter baumannii*; however, only a high Pitt bacteremia score was found to be an independent prognostic predictor of mortality in the BSI patients.[24] Well-conducted prognostic research is essential for making clinical decision. The prognostic factors could be specific target for modification, therefore improving the poor outcomes of patients.

Therefore, more research exploring the clinical characteristics and prognostic factors for death in *Acinetobacter baumannii* BSI patients will be of great significance to clinical practice.

In the present study, we analyzed the clinical characteristic of 200 *Acinetobacter baumannii* BSI inpatients in hospital between 90-day survival group and 90-day mortality group, between 30-day survival group and 30-day mortality group. We emphasized on identifying the prognostic predictors of 90-day mortality in *Acinetobacter baumannii* BSI and carbapenem-resistant *Acinetobacter baumannii* BSI patients. In addition, we investigated the clinical features and the outcome of MDR group and the sensitive group in *Acinetobacter baumannii* BSI patients.

Materials and Methods

Subjects and Data Collection

This retrospective, single-center study was conducted between January 2018 and December 2022 at Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China. Patients diagnosed with monomicrobial *Acinetobacter baumannii* BSI infection (age ≥ 18 years) according to the US Centers for Disease Control and Prevention (CDC) criteria[25] were included. Exclusion criteria for the study involved cases of polymicrobial *Acinetobacter baumannii* BSI infections.

This study included 221 patients and excluded 21, who were discharged within 24 hours of admission. A total of 200 eligible *Acinetobacter baumannii* BSI patients were finally considered in this study. The clinical data during hospitalization were collected, including sex, age, admission date, ICU admission date, underlying diseases, comorbid conditions, primary site of infection, results of drug sensitivity test, laboratory data (white blood cell counts, neutrophils, lymphocytes, procalcitonin, C-reactive protein, serum creatinine, erythrocyte sedimentation rate, lactic acid dehydrogenase, red blood cell, hemoglobin, glutamic pyruvic transaminase, aspartate transaminase, albumin). We also recorded medical information related to antibiotic treatments, with a particular focus on evaluating antibiotic therapy regimens and the timing of antibiotic administration, including early antibiotic treatment (within 48 hours of blood sample collection) and delayed antibiotic treatment (after 48 hours of blood sample collection).

Determination of the antibiotic sensitivity of MDR Acinetobacter baumannii

MDR *Acinetobacter baumannii* strains are defined as isolates not susceptible to at least one agent in three or more antimicrobial categories.[26] Broth microdilution and agar disk diffusion assays were used to measure the antimicrobial susceptibility of the MDR *Acinetobacter baumannii* according to the Clinical and Laboratory Standards Institute guidelines. The minimum inhibitory concentration (MIC): the lowest concentration of antibiotic necessary for inhibiting 99.9% of the observable growth was determined. Moreover, CLSI breakpoints for antibiotics were evaluated using both MIC and disk diffusion zone diameter measurements and interpreted as values reflecting the clinical efficacy of antibiotics.

Statistical Analysis

Statistical analysis of the clinical data was performed using SPSS version 26.0. Continuous variables were expressed as mean (± standard deviation) and analyzed using the Student's *t*-test. Discontinuous variables were presented as Median value (P25-P75) and assessed by the Mann–Whitney test. Categorical variables were represented as sample numbers and percentages (%) and analyzed using the chi-square ($\chi 2$) test or Fisher's exact test, as appropriate. Univariate logistic regression and multivariate logistic regression were employed to explore the prognostic predictors of 90-day mortality. The survival curve in bloodstream infectious patients with multidrug-resistant (MDR group) and sensitive *Acinetobacter baumannii* (sensitive group) was analyzed by Kaplan–Meier analysis with the Log rank test. A significance level of $P < 0.05$ was considered statistically significant.

Statement of Ethics Compliance

This retrospective study obtained ethical clearance from the Medicine Ethics Committee of Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China. All complete data were afterwards retrospectively extracted,

and the Ethics Committee waived the need for informed consent. And the patient data confidentiality was ensured. The study adhered to the principles of the Declaration of Helsinki.

Results

Study Population

Over a five-year period (from January 2018 to December 2022), clinical data from 200 *Acinetobacter baumannii* BSI inpatients were recorded. Among these patients, 122 survived for 90 days, while 78 experienced 90-day mortality. In 90-day mortality group, 49 patients were male, and the median inpatient age was 65 years (Interquartile Range: 52.75–76.00). The 90-day mortality *Acinetobacter baumannii* BSI group showed significantly higher rate of ICU admission (70.5% vs 54.9%, $P = 0.027$) and Carbapenem-resistant bacterial infection (76.9% vs 48.4%, $P < 0.0001$) than the 90-day survival group (Table 1). The most common underlying diseases were hypertension (32.8% vs 35.9%), coronary heart disease (24.6% vs

Table 1 Clinical Features of Bloodstream Infection with Acinetobacter Baumannii in 90-Day Survival Group and 90-Day Mortality Group

N (Total=200)	90-Day Survival (N=122)	90-Day Mortality (N=78)	P value
Age(years)	62.00(49.50–71.00)	65(52.75–76.00)	0.155
BMI(Kg/m2)	22.86(20.66–25.37)	24.00(21.79–26.59)	0.063
Sex			0.605
Male	81(66.4%)	49(62.8%)	
Female	41(33.6%)	29(37.2%)	
ICU admission	67(54.9%)	55(70.5%)	0.027
Mechanical ventilation	1(0.8%)	2(2.6%)	0.694
Carbapenem-resistant bacterial infection	59(48.4%)	60(76.9%)	<0.0001
Length of ICU stay (days)	27.93±63.73	18.82±18.08	0.139
Length of hospital stay (days)	49.36(24.89–94.04)	31.87(18.69–47.59)	<0.0001
Underlying diseases			
Hypertension	40(32.8%)	28(35.9%)	0.651
Diabetes	29(23.8%)	22(28.2%)	0.483
Chronic respiratory diseases	3(2.5%)	7(9.0%)	0.084
Chronic renal diseases	9(7.4%)	2(2.6%)	0.255
Coronary heart disease	30(24.6%)	23(29.5%)	0.444
Heart Valve Disease	26(21.3%)	13(16.7%)	0.419
Rheumatic heart disease	7(5.7%)	4(5.1%)	1.000
Cardiomyopathy	10(8.2%)	4(5.1%)	0.585
Previous cerebral infarction	9(7.4%)	10(12.8%)	0.200
Rheumatic system diseases	5(4.1%)	0(0)	0.159
Solid tumor	29(23.8%)	4(5.1%)	0.001
Hematological malignancy	4(3.3%)	3(3.8%)	1.000
Liver cirrhosis	1(0.8%)	1(1.3%)	1.000
Burn	17(13.9%)	9(11.5%)	0.623
Aortic Aneurysm	2(1.6%)	4(5.1%)	0.324
Aortic coarctation	4(3.3%)	2(2.6%)	1.000
Anemia	11(9.0%)	6(7.7%)	0.743
Hypoproteinemia	8(6.6%)	10(12.8%)	0.131
Pulmonary arterial hypertension	6(4.9%)	2(2.6%)	0.646
CRP (mg/L)	61.5(29.68–117.18)	134.8(57.3–198)	<0.0001
PCT (ng/mL)	0.62(0.33–2.04)	2.39(0.82–7.1)	0.0003
Scr (μmol/L)	75(55–117)	109.5(72.25–186.75)	0.0005
ESR (mm/h)	41(16–61)	12(7–37)	0.0035

(*Continued*)

Table 1 (Continued).

N (Total=200)	90-Day Survival (N=122)	90-Day Mortality (N=78)	P value
WBC (x10^9/L)	9.41(6.77–12.80)	11.43(6.53–15.02)	0.252
Neutrophils (x10^9/L)	8.05(5.88–11.89)	9.89(6.23–13.94)	0.055
Lymphocytes (x10^9/L)	0.67(0.45–1.1)	0.6(0.4–0.86)	0.142
RBC (x10^12/L)	3.09(2.65–3.66)	2.63(2.36–3.1)	0.0002
HB (g/L)	92(77–110.75)	81(71–94)	0.0008
LDH (IU/L)	300(201–470)	372.5(278.75–551)	0.016
ALT (IU/L)	28(16–55.5)	23(14–55)	0.679
AST (IU/L)	37.5(24.25–63.75)	44(27–77)	0.149
ALB (g/L)	36(32–38.75)	32(28–34)	<0.0001
Comorbidities			
Acute kidney injury	10(8.2%)	13(16.7%)	0.067
Acute liver injury	7(5.7%)	11(14.1%)	0.044
Acute myocardial infarction	2(1.6%)	5(6.4%)	0.163
Acute respiratory failure	10(8.2%)	2(2.6%)	0.183
Source of infection			
Digestive tract	27(22.1%)	14(17.9%)	0.475
Respiratory tract	35(28.7%)	26(33.3%)	0.487
Skin and skin structure	22(18.0%)	11(14.1%)	0.465
CVC-related infection	7(5.7%)	1(1.3%)	0.231
Urinary tract	2(1.6%)	0(0)	0.522
Primary cause of bloodstream infection			
Burn	17(13.9%)	9(11.5%)	0.623
Critical surgery	63(51.6%)	9(11.5%)	<0.0001
Transplantation (solid organ and stem Cell)	2(1.6%)	1(1.3%)	1.000
Chemotherapy	5(4.1%)	2(2.6%)	0.856
Myelosuppressed status	1(0.8%)	5(6.4%)	0.066
Time to appropriate antibiotic treatment			0.001
No active antibiotics use	57(46.7%)	57(73.1%)	
Early antibiotics treatment [a]	49(40.2%)	16(20.5%)	
Delayed antibiotics treatment [b]	16(13.1%)	5(6.4%)	
Antibiotic therapy			
Imipenem containing-regimen	61(50.0%)	37(47.4%)	0.723
Meropenem containing-regimen	77(63.1%)	58(74.4%)	0.098
Polymyxin containing-regimen	24(19.4%)	30(38.5%)	0.004
Tigecycline containing-regimen	22(18.0%)	18(23.1%)	0.384
Cefoperazone and Sulbactam containing-regimen	45(36.9%)	29(37.2%)	0.966

Notes: [a]Antibiotics were used within 48 hours, [b]Antibiotics were used after 48 hours.
Abbreviations: CRP, C-reactive protein; PCT, Procalcitonin, Scr, serum creatinine; ESR, erythrocyte sedimentation Rate; WBC, white blood cells; LDH, lactic acid dehydrogenase; RBC, red blood cell; HB, Hemoglobin; ALT, glutamic pyruvic transaminase; AST, aspartate transaminase; ALB, albumin.

29.5%) and diabetes (23.8% vs 28.2%). Notably, more patients in the 90-day survival group had solid tumors (23.8% vs 5.1%, P = 0.001) than those in the 90-day mortality group. The baseline features of included people are demonstrated in Table 1.

The Clinical Characteristics in Patients with Acinetobacter baumannii BSI in 90-Day Survival Group and 90-Day Mortality Group

We analyzed the clinical characteristics of patients with *Acinetobacter baumannii* BSI between the 90-day survival group and 90-day mortality group, including clinical indices, complications, source of infection, primary cause of BSI, time to appropriate antibiotic treatment and antibiotic therapy (Table 1). Patients with *Acinetobacter*

baumannii BSI in the 90-day mortality group showed significantly higher C-reactive protein (CRP), Procalcitonin (PCT), serum creatinine (Scr) and lactic acid dehydrogenase (LDH) levels than the 90-day survival group. Conversely, the 90-day mortality group exhibited significantly lower levels of red blood cells (RBC), hemoglobin (HB), and albumin (ALB) than the 90-day survival group (Table 1).

The complications of patients with *Acinetobacter baumannii* BSI in the 90-day survival group and 90-day mortality group were mainly acute kidney injury (8.2% vs 16.7%), acute liver injury (5.7% vs 14.1%) and acute respiratory failure (8.2% vs 2.6%). The source of infection in both groups mainly originated from the respiratory tract (28.7% vs 33.3%), digestive tract (22.1% vs 17.9%) and skin (18.0% vs 14.1%). The primary causes of BSI were mainly critical surgery (51.6% vs 11.5%) and burn (13.9% vs 11.5%). Antibiotic therapies included Imipenem containing-regimen (50.0% vs 47.4%), Meropenem containing-regimen (63.1% vs 74.4%), Cefoperazone and Sulbactam containing-regimen (36.9% vs 37.2%) and Tigecycline containing-regimen (18.0% vs 23.1%). Interestingly, the 90-day mortality group had a higher proportion of patients using polymyxin-containing regimens compared to the 90-day survival group ($P < 0.05$). Additionally, a higher frequency of patients in the 90-day mortality group did not receive active antibiotic treatment, and the proportion of patients receiving active antibiotics within 48 hours was significantly lower in the 90-day mortality group than in the 90-day survival group. These findings suggest a potential causal relationship between the timing of appropriate antibiotic treatment and disease prognosis (Table 1).

The Clinical Characteristics in Patients with Acinetobacter baumannii BSI in 30-Day Survival Group and 30-Day Mortality Group

We also analyzed the characteristics of patients with *Acinetobacter baumannii* BSI between the 30-day survival group and 30-day mortality group. Among these patients, 164 survived for 30 days, while 36 experienced 30-day mortality. Patients with *Acinetobacter baumannii* BSI in the 30-day mortality group showed significantly higher CRP level, Scr levels, white blood cell (WBC) counts and neutrophils than the 30-day survival group. Conversely, the 30-day mortality group exhibited significantly lower levels of RBC and ALB than the 30-day survival group. The 30-day survival group showed higher proportion of patients using Imipenem containing-regimen, Meropenem containing-regimen, Cefoperazone and Sulbactam containing-regimen and Tigecycline containing-regimen (Supplementary Table A1 and Supplementary Figure A2).

The Clinical Characteristics of Internal Medical Patients with Acinetobacter baumannii BSI in 30-Day Survival Group and 30-Day Mortality Group, in 90-Day Survival Group and 90-Day Mortality Group

Among the 200 patients with *Acinetobacter baumannii* BSI, 65 were internal medical patients. Interestingly, the trends of comparisons of clinical indices between the 30-day survival group and 30-day mortality group were similar to that between the 90-day survival group and 90-day mortality group among internal medical patients with *Acinetobacter baumannii* BSI. For instance, the 30-day and 90-day mortality group showed shorter hospital stay, worse liver function, lower RBC and ALB levels than the 30-day and 90-day survival group. Moreover, 30-day mortality group showed higher proportion of patients using mechanical ventilation and higher neutrophils than the 30-day survival group (Supplementary Table A3, A4 and Supplementary Figure A5, A6). The 90-day mortality group showed higher CRP and ESR levels, worse renal function (Supplementary Table A3 and Supplementary Figure A5).

Prognostic Predictors of 90-Day Mortality in Acinetobacter baumannii BSI Patients

The prognostic predictors of 90-day mortality were explored by operating univariate logistic regression and multivariate logistic regression. Critical surgery (odds ratio [OR]: 10.329, 95% confidence interval [CI]: 4.169–25.589, $P < 0.0001$), ICU admission (OR: 2.596, 95% CI: 1.199–5.621, $P = 0.016$), time of appropriate antibiotic >48h (OR: 3.774, 95% CI: 1.081–13.168, $P = 0.037$) were significantly different between the 90-day survival group and 90-day mortality group (Table 2). Therefore, critical surgery, ICU admission and time of appropriate antibiotic >48h were considered as independently prognostic risk predictors for 90-day mortality in *Acinetobacter baumannii* BSI patients.

Table 2 Univariate and Multivariate Analysis of Factors Related to 90-Day Mortality in Bloodstream Infection with Acinetobacter Baumannii

Variable (Total=200)	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Critical surgery	8.186(3.752–17.861)	P<0.0001	10.329(4.169–25.589)	<0.0001
Solid tumor	5.769(1.941–17.142)	0.002	N/A	0.549
ICU admission	1.963(1.074–3.589)	0.028	2.596(1.199–5.621)	0.016
Acute liver injury	N/A	0.050	N/A	N/A
Polymyxin containing-regimen	0.392(0.207–0.742)	0.004	N/A	0.167
Carbapenem-resistant bacterial infection	3.559(1.886–6.718)	P<0.0001	N/A	0.306
Delayed antibiotics treatment	2.232(1.380–3.611)	0.001	3.774(1.081–13.168)	0.037

Prognostic Predictors of 90-Day Mortality in Carbapenem-Resistant Acinetobacter baumannii BSI Patients

In this retrospective study, 119 patients were diagnosed with carbapenem-resistant *Acinetobacter baumannii* BSI and we conducted a comparison between the 90-day survival and 90-day mortality groups. This analysis revealed that critical surgery (OR: 6.063, 95% CI: 2.090–17.587, *P = 0.001*), diabetes (OR: 4.369, 95% CI: 1.340–14.240, *P = 0.014*) were significantly different between 90-day survival group and 90-day mortality group (Table 3). We could suppose that critical surgery and diabetes were independently prognostic risk predictors for 90-day mortality in carbapenem-resistant *Acinetobacter baumannii* BSI patients.

Clinical Features of Bloodstream Infections in Patients with Multidrug-Resistant (MDR) and Sensitive Acinetobacter baumannii

Subsequently, we analyzed the clinical data of bloodstream infectious patients infected with multidrug-resistant (MDR group) and sensitive *Acinetobacter baumannii* (sensitive group). There were no significant differences in age, BMI, sex, ICU admission and the use of mechanical ventilation between the two groups. The MDR group showed significantly longer ICU stay and whole hospital stay than the sensitive group ($P < 0.05$) (Table 4). The MDR group showed significantly lower levels of lymphocytes counts, RBC, HB, LDH and ALB than the sensitive group ($P < 0.05$) (Table 4). The MDR group showed higher frequency of infection originating from the skin and skin structure than the sensitive group ($P < 0.05$) (Table 4). Moreover, the Kaplan–Meier curve indicated that patients in the MDR group had a significantly worse overall survival than the sensitive group (Figure 1, $P < 0.0001$).

Discussion

BSI is a severe disease with reported crude mortality rates varying from 34% to 50%, especially in MDR Gram-negative BSI.[27,28] *Acinetobacter baumannii* is a major cause of hospital-acquired infections in patients who are critically ill, mainly manifested as ventilator-associated pneumonia and BSI.[29] The mortality rate of *Acinetobacter baumannii* BSI was reported to reach as high as 29% to 73%.[11,30,31] Previous studies usually evaluated the mortality rate of *Acinetobacter baumannii* BSI within 30 days. Gu et al reported that overall 30-day mortality rate among the patients with BSI caused by *Acinetobacter baumannii* was 34.0%,[24] the figure in the research of Matthaios et al was 39.5%.[32] In our study, we

Table 3 Univariate and Multivariate Analysis of Factors Related to 90-Day Mortality in Bloodstream Infection with Carbapenem-Resistant Acinetobacter Baumannii

Variable (Total=119)	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Critical surgery	5.351(1.979–14.472)	0.001	6.063(2.090–17.587)	0.001
Solid tumor	N/A	0.063	N/A	N/A
Diabetes	3.927(1.333–11.567)	0.013	4.369(1.340–14.240)	0.014

Table 4 Clinical Features of Bloodstream Infection with Multidrug-Resistant (MDR) and Sensitive Acinetobacter Baumannii

N (Total=200)	MDR Group (N=127)	Sensitive Group (N=73)	P value
Age (years)	56.0(45.5–72.0)	67(56.0–72.0)	0.056
BMI (Kg/m2)	23.24(20.98–25.54)	23.24(20.96–26.03)	0.826
Sex			0.282
Male	79(62.2%)	51(69.9%)	
Female	48(37.8%)	22(30.1%)	
ICU admission	48(37.8%)	30(41.1%)	0.65
Mechanical ventilation	25(19.7%)	19(26%)	0.375
Length of ICU stay (days)	28.5(18–52.25)	14(9–39)	0.007
Length of hospital stay (days)	45(26–82.5)	31(19–52)	0.016
CRP (mg/L)	95(34.7–166.45)	64(36.5–133.2)	0.247
PCT (ng/mL)	1.11(0.39–3.32)	1.35(0.42–6.58)	0.506
Scr (μmol/L)	79(56.5–143)	94.5(74.25–179.5)	0.053
ESR (mm/h)	17(9–37.5)	44(15–60)	0.040
WBC (x10^9/L)	9.57(6.43–13.9)	10.22(7.41–13.97)	0.589
Neutrophils (x10^9/L)	8.82(5.58–12.82)	8.2(8.2–12.43%)	0.875
Lymphocytes (x10^9/L)	0.6(0.41–0.87)	0.74(0.74–1.3)	0.018
RBC (x10^12/L)	2.75(2.4–3.17)	3.26(3.26–3.8)	<0.0001
HB (g/L)	81(72.75–96.25)	98(98–111)	<0.0001
LDH (IU/L)	294.5(225.75–448)	401(401–715)	0.004
ALT (IU/L)	23(15–48)	32.5(32.5–75)	0.120
AST (IU/L)	36(26–68)	46.5(46.5–91)	0.291
ALB (g/L)	32.78±5.42	35.87±3.98	0.0003
Source of infection			
Digestive tract	23(18.1%)	18(24.6%)	0.280
Respiratory tract	38(29.9%)	23(31.5%)	0.873
Skin and skin structure	32(25.2%)	1(1.4%)	<0.0001
CVC-related infection	2(1.6%)	6(8.2%)	0.053
Urinary tract	0(0)	2(2.7%)	0.132
Underlying diseases			
Hypertension	40(31.5%)	28(38.3%)	0.354
Diabetes	23(18.1%)	28(38.3%)	0.002
Coronary heart disease	33(26.0%)	20(27.4%)	0.868
Chronic renal dysfunction	5(3.9%)	6(8.2%)	0.213
Comorbidities			
Acute respiratory failure	8(6.3%)	4(5.5%)	>0.999
Acute liver injury	15(11.8%)	3(4.1%)	0.076
Acute Cardiac dysfunction	50(39.4%)	35(47.9%)	0.298
Acute kidney injury	19(14.9%)	4(5.5%)	0.063

Abbreviations: CRP, C-reactive protein; PCT, Procalcitonin; Scr, serum creatinine; ESR, erythrocyte sedimentation Rate; WBC, white blood cells; RBC, red blood cell; HB, Hemoglobin; LDH, lactate dehydrogenase; ALT, glutamic pyruvic transaminase; AST, aspartate transaminase; ALB, albumin.

reported the 30-day (18%) and 90-day (39%) mortality rate of *Acinetobacter baumannii* BSI. The difference of the 30-day mortality between our and previous studies may lie in the inclusion of only *Acinetobacter baumannii* BSI patients in ICU, multicenter case-control study nature and the smaller sample size in other research. Furthermore, the 30-day survival group had higher proportions of patients using Imipenem containing-regimen, Meropenem containing-regimen, tigecycline containing-regimen, Cefoperazone and Sulbactam containing-regimen, than the 30-day mortality group. However, this phenomenon was not demonstrated in the comparisons between 90-day survival group and 90-day mortality group, indicating that the antibiotic therapy may affect the survival of patients with *Acinetobacter baumannii* BSI within 30 days. Appropriate antimicrobial therapy and the time to antibiotic therapy were of the same importance in

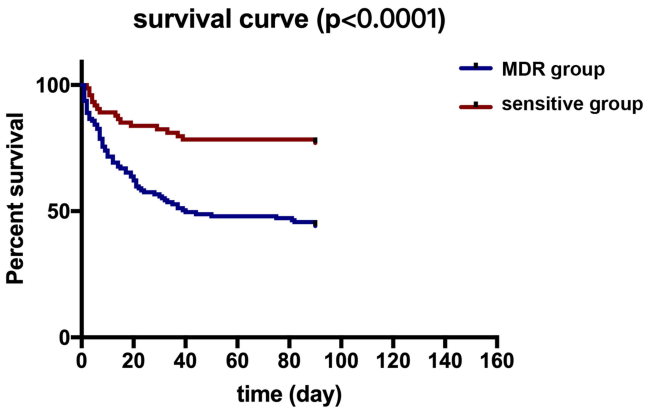


Figure 1 Kaplan–Meier curves for the OS of patients in the MDR group and sensitive group.

Acinetobacter baumannii BSI. Firstly, Lodise et al showed that among patients with carbapenem-resistant Gram-negative -BSIs, the median infection-associated length of stay was 8, 9, 10, and 13 days for patients with days to appropriate antibiotic therapy of 0, 1–2, 3–4, and ≥5 days, respectively.[33] Their results indicated that these patients were more likely to have longer inpatient length of stay and less likely to be discharged home when the appropriate antibiotic therapy was delayed. However, barely study concentrated on the effect of time to appropriate therapy on the mortality of hospitalized patients with *Acinetobacter baumannii* BSI. In the present study, we showed that delayed antibiotic treatment was independently associated with *Acinetobacter baumannii* BSI mortality. The finding highlighted the need of appropriate therapy more expeditiously in patients with *Acinetobacter baumannii* BSI. The above results suggested that in clinical practice, while antibiotics should always be used cautiously, the worsening outcomes with each day delay in appropriate antibiotic treatment sometimes made us forgo waiting for final culture results and to take aggressive and comprehensive antibiotic prescription in patients with serious BSI. Secondly, the overuse and misuse of antibiotics have caused resistant *Acinetobacter baumannii* to emerge at an alarming rate, such as colistin resistance,[34] carbapenem resistance.[35] Until now, it's debatable whether drug resistance is a risk factor for the mortality of patients with *Acinetobacter baumannii* BSI. Liu et al and Pfaller et al demonstrated that drug resistance could increase the mortality of *Acinetobacter baumannii* BSI patients,[36,37] this is inconsistent with previous studies which showed that the resistance of *Acinetobacter baumannii* had nothing to do with a worse clinical prognosis.[11,23,38] Similarly, in the present study, carbapenem resistance was not statistically significant on the mortality of *Acinetobacter baumannii* BSI patients. The inconsistency among the above studies may be that some studies could not adjust for confounding factors such as disease severity and comorbidities.

With the investigations of China Antimicrobial Surveillance Network, the occurrence rate of carbapenem-resistant *Acinetobacter baumannii* BSI kept increasing with an increased morbidity and mortality rate.[39] Carbapenem-resistant *Acinetobacter baumannii* BSI frequently resulted in a poor outcome owing to the delayed effective therapy usage, restricted treatment alternatives and highly appropriate regimen toxics,[40] therefore, Carbapenem-resistant *Acinetobacter baumannii* BSI should be paid more attention in the clinical practice. Previous studies presented that surgery indicated a poor outcome in the infection conditions.[41–43] Identically, our investigation demonstrated that post critical surgery was an independent prognostic risk predictor for 90-day mortality carbapenem-resistant *Acinetobacter baumannii* BSI patients. Some studies reported that diabetes had a significant relationship with poor outcomes in *Acinetobacter baumannii* infection status and even the level of blood glucose was significantly associated with the severity of infectious diseases.[44,45] It was exactly in line with the result of our study, which demonstrated that diabetes was an advent prognostic factor of 90-day mortality carbapenem-resistant *Acinetobacter baumannii* BSI patients.

Studies reported that surgical operation (adjusted OR 1.82) was an advent prognostic factor for healthcare-related infection and previous surgery was an independent risk predictor for *P. aeruginosa* infection.[42,43] In our study, post critical surgery was an independent prognostic risk predictor for 90-day mortality *Acinetobacter baumannii* BSI patients. In addition, our analysis acquired the result that ICU admission was an independently prognostic risk predictor for 90-day mortality *Acinetobacter baumannii* BSI patients. This is in line with previous studies reporting

that ICU admission was considered as an advent prognostic factor in many situations, such as *P. aeruginosa* infection, *Acinetobacter baumannii* infection, *Staphylococcus aureus* infection, non-central line-related BSI.[42,43,46–48] Wang et al demonstrated that based on the paired univariate logistics analysis, ICU stay and surgery were not the potential risk factors between survival group and the death group in patients with *Acinetobacter baumannii* BSI, further multivariate logistic regression analysis showed that mechanical ventilation in hospital, the high SOFA score at the time of infection, or septic shock are independent prognostic risk factors for 28-day mortality of *Acinetobacter baumannii* BSI.[23] Therefore, the prognostic risk factors of death in patients with *Acinetobacter baumannii* BSI remained inconsistent, the reasons may be as follows: the difference of study population differences, the existence of failure to differentiate between *Acinetobacter baumannii* colonization or infection in some studies, the existence of confounding factors, and so on.

Acinetobacter baumannii has an extraordinary capacity to develop resistance to multiple antimicrobial agents, and the resistance was mediated by modification of target sites, enzymatic inactivation, active efflux and decreased influx of drugs. A combination of antibiotic appears to be a reasonable alternative to combat multidrug-resistant (MDR) *Acinetobacter baumannii* infection.[29] In present study, MDR *Acinetobacter baumannii* was determined to be a pathogen in 63.5% (127/200) of cases, MDR group in *Acinetobacter baumannii* BSI patients showed significantly longer ICU stay and whole hospital stay than the sensitive group. Moreover, the MDR group showed a significantly worse overall survival than the sensitive group. In line with that, Abbo et al demonstrated that MDR *Acinetobacter baumannii* acquisition is associated with severe adverse outcomes, including increased mortality, need for mechanical ventilation, and reduced functional status.[49] They identified various risk factors for MDR *Acinetobacter baumannii*, of which ICU admission and prior aminoglycoside therapy were independently associated with MDR *Acinetobacter baumannii* acquisition based on multivariate analysis. The emergence of MDR *Acinetobacter baumannii* poses a serious therapeutic challenge against Gram-negative organisms, where only a few antibiotics are active against infections induced by the pathogen. Moreover, potent resistant genes that could aid the spread of highly resistant phenotypes were observed.[50] The interhospital transmission and intrahospital dissemination of MDR *Acinetobacter baumannii* have been reported by several studies.[43,51,52] Therefore, these studies enforced the need for vigilant infection control measures and continuous surveillance for MDR *Acinetobacter baumannii*.

There are some limitations in this study. First, the sample size was relatively small. Second, the retrospective nature of the study made it difficult to collect some variables (antibiotics treatment before admission, and some clinical and laboratory examination results), resulting some hidden biases in the analysis. Third, the investigation was performed in a single center with restricted clinical record collections, Future research could benefit from larger, multicenter studies to further validate these findings and enhance our understanding of *Acinetobacter baumannii* BSI and MDR *Acinetobacter baumannii* infections.

Conclusions

In conclusion, we identified the prognostic factors of *Acinetobacter baumannii* BSI and carbapenem-resistant *Acinetobacter baumannii* BSI patients. Critical surgery, ICU admission, delayed antibiotic treatment or diabetes were significantly associated with the mortality of those patients. Moreover, aggressive measures to control MDR *Acinetobacter baumannii* could lead to improved outcomes. These findings underscore the importance of early intervention and tailored treatment strategies for *Acinetobacter baumannii* BSI, particularly in cases of drug-resistant strains. However, our study had weakness in the relatively small sample size, single-center study and the retrospective nature, thus, further research is warranted to validate these results and explore additional factors influencing the outcomes of *Acinetobacter baumannii* BSI patients.

Data Sharing Statement

The data records were acquired and/or analyzed during the present research are obtained from the corresponding author on justified requirements.

Compliance with Ethics Guideline

This retrospective study had acquired ethical clearance from the Medicine Ethics committee of hospital, the approval of patient informed consent exemption was admitted.

Author Contributions

All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work, and have given their approval for this version to be published.

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Disclosure

There are no competing interests among these authors.

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