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ORIGINAL RESEARCH

# Nosocomial, Healthcare-Associated, and Community-Acquired *Acinetobacter baumannii* in China: Clinical Characteristics, Antimicrobial Resistance Patterns and Risk Factors Associated with Carbapenem Resistance

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**Background:** *Acinetobacter baumannii (A. baumannii*) is an widespread pathogen and carbapenem-resistant strains are great threat to hospitalized patients. This study is aimed to investigate the clinical characteristics, antimicrobial resistance patterns, and risk factors associated with carbapenem resistance in nosocomial, healthcare-associated (HCA), and community-acquired (CA) *A. baumannii* infections.

**Methods:** This study retrospectively reviewed cases in a tertiary hospital in southern China between January 1, 2019, and December 31, 2021. Univariate and multivariate logistic regression analyses were performed to identified the risk factors of carbapenem resistance in nosocomial, HCA and CA *A. baumannii* infections.

**Results:** A total of 391 patients with *A. baumannii* infection were included. Of these patients, 96 (24.6%) had nosocomial infections, 215 (55.0%) had HCA infections, and 80 (20.5%) had CA infections. The overall 30-day mortality rates of nosocomial and HCA infection patients was significantly higher than that of CA infection ($P<0.05$). The incidence of antimicrobial resistance was also higher in nosocomial and HCA bacteremia than that in CA bacteremia ($P<0.05$). Logistic regression analysis identified age ≥60 years, urethral catheterization, and exposure to two or more antibiotics as the independent risk factors for carbapenem-resistant *A. baumannii* (CRAB) infection in the nosocomial infection group and exposure to two or more antibiotics and endotracheal intubation in the HCA infection group. However, malignant tumors and hematological diseases were identified as protective factors against CRAB infection in the HCA group.

**Conclusion:** These data suggest that HCA *A. baumannii* infection is quite different from CA infection, with antimicrobial resistance and 30-day mortality rates similar to those of nosocomial infections. Additionally, the risk factors for CRAB development in the CA, HCA, and nosocomial groups were not the same, which may provides the help for controlling practices and instruction empirical clinical medication.

**Keywords:** *Acinetobacter baumannii*, community-acquired, healthcare-associated, nosocomial, antimicrobial resistance, risk factor

## Introduction

*Acinetobacter baumannii*, a nonfermenting gram-negative bacterium, is widespread in hospital and community environments. It can colonize a large variety of surfaces and is able to cause various infections opportunistically.[1,2] These infections are characterized by costly treatment and high mortality rates because an extensive range of infections are caused by multidrug-resistant *A. baumannii*.[3] Carbapenems are broad-spectrum antibacterial drugs usually recommended

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for treating serious infections caused by multidrug-resistant *A. baumannii*. However, with the misuse of antibacterial agents and poor infection control practices, the detection rate of carbapenem-resistant *A. baumannii* (CRAB) isolates is increasing which has become a global health concern.[1,4]

Infections are generally classified into community-acquired (CA) and nosocomial infections based on their origin. In most studies, nosocomial infections are severer than CA infections, and nosocomial infection-associated pathogens have a greater degree of drug resistance.[5] For the past few years, community-onset infections that occur in inpatients who have recently received health care services and undergone medical procedures have received increasing attention.[6–8] This type of infection is separate from CA infection and is referred to as community-onset healthcare-associated (HCA) infection. Several studies have explored this new type of infection. A study from southern China found that HCA infections presented similar clinical features and antimicrobial resistance to nosocomial infections but were distinct from CA infections.[8] Another study in Taiwan showed that HCA infections are quiet different from CA and nosocomial infections in antimicrobial resistance patterns.[7] However, these studies focused on *Klebsiella pneumoniae* or *Stenotrophomonas maltophilia* bacteremia. Data on *A. baumannii* infection have rarely been reported. Moreover, the risk factors for CRAB infection in nosocomial, HCA, and CA infection groups have never been explored.

Therefore, this study aimed to compare the clinical characteristics, antimicrobial resistance patterns, and risk factors of carbapenem-resistant isolates among CA, HCA, and nosocomial *A. baumannii* infections. Our study may provide a scientific basis for the reasonable clinical management of *A. baumannii* infections in both hospitals and communities.

# Materials and Methods

## Study Design and Population

This retrospective study was conducted at a comprehensive tertiary hospital in Guangzhou, China, with approximately 2300 beds, including 110 beds in the intensive care unit (ICU). The data were collected consecutively from January 2019 to December 2021. All inpatients who developed *A. baumannii* infections at any location were enrolled in the study. The exclusion criteria were as follows: 1) patients with incomplete clinical data and those who could not complete follow-up, 2) colonized or contaminating bacteria, and 3) duplicate isolates from the same patient. The study protocol was approved by the ethics committee of Zhujiang Hospital, Southern Medical University, Guangzhou, China. Due to the retrospective and observational nature of the study, the ethics committee waived written informed consent for all participants. The privacy and personal identity information of included patients was well protected and all procedures of the study were carried out based on the Helsinki declaration.[9] In addition, for organ transplant in this study, written informed consent was obtained from each donor, and those were conducted in accordance with the Declaration of Istanbul.[10]

## Definitions

Patients with *A. baumannii* infection were assessed according to the definition proposed in the literature.[8] Nosocomial *A. baumannii* infection was defined as an infection that occurred 48 hours after the patient's admission (nosocomial infection in newborns was not limited by time). HCA *A. baumannii* infection was defined as an infection developing within 48 hours of admission in patients meeting any of the following criteria: 1) having received intravenous therapy or renal dialysis within the last 30 days, 2) having been hospitalized for two or more days within the last 90 days, and 3) having received chemotherapy or radiotherapy in an outpatient clinic within the last 30 days. CA *A. baumannii* infection was defined as an infection that developed within 48 hours of admission but did not fulfill the definition of HCA infection. Furthermore, microorganisms were defined as CRAB if *A. baumannii* was resistant to one or more carbapenem agents, such as meropenem (MICs $\geq$ 16 mg/L) or imipenem (MICs $\geq$ 16 mg/L).[4] The diagnosis of infection referred to Centers for Disease Control and Prevention and National Health care Safety Network surveillance definition.[11] If the presentation of *A. baumannii* did not cause adverse clinical symptoms or signs, it was considered a colonized or contaminating bacterium.

## Data Collection

The clinical data collected included patient demographic data (age and sex), infection location (respiratory tract, bloodstream, urinary tract, skin and soft tissue, abdominal or pelvic cavity, cerebrospinal fluid, biliary tract, and articular cavity),

relevant comorbidities (diabetes mellitus, hypertension, chronic pulmonary disease, malignant tumor, organ failure, hematological disease, stroke, and severe injury), invasive procedures during the 30 days preceding infection onset (chemotherapy or radiotherapy, application of immunosuppressants, organ transplantation, renal dialysis, surgery, central venous catheterization, urethral catheterization, and endotracheal intubation), The class of antibiotics used during the 30 days preceding infection onset (penicillin, cephalosporin, quinolone, aminoglycoside, macrolides, sulfonamides, carbapenem, polymyxin B, tetracycline, and other antibacterial drugs), and outcomes (mortality at 30 days). A history of ICU admission was defined as admission to the ICU for at least 24 h within 30 days preceding the onset of infection. In addition, the hospitalization time before infection in the nosocomial infection group was considered.

## Microbiological Methods

Bacterial isolation and antimicrobial susceptibility testing were performed in accordance with the methodology of the Clinical and Laboratory Standards Institute(CLSI).[12] Antimicrobial susceptibility testing was performed using the Vitek-2 automated system (BioMerieux, France) or the E-test minimum inhibitory concentration method. The results were interpreted CLSI guideline breakpoints. The antimicrobials tested included imipenem, meropenem, piperacillin/tazobactam, sulfamethoxazole, gentamicin, ciprofloxacin, levofloxacin, ceftazidime, cefoperazone/sulbactam, cefepime, tobramycin, tigecycline, doxycycline, and minocycline. In cases of intermediately susceptible isolates, the microbes were classified as resistant according to the same guidelines.

## Statistical Analyses

Data were analyzed using SPSS software (version 22.0). Categorical variables were compared using chi-square or Fisher's exact tests. Univariate and multivariate logistic regression analyses were used to identify risk factors for CRAB in nosocomial, HCA, and CA infections. Variables with a p value $< 0.05$ in the univariate analysis were included in the stepwise forward-backward multivariate logistic regression analysis. Statistical significance was set at $P < 0.05$.

# Results

## Demographic and Clinical Characteristics of Patients with CA, HCA, and Nosocomial Infections

In this study, 391 patients with *A. baumannii* infections were enrolled; the percentages of patients with CA, HCA, and nosocomial infections were 20.5% (80), 55.0% (215), and 24.5% (96), respectively. The majority of the patients were ≥60 years old (48.3%), and the number of male patients was 259 (66.2%).

The nosocomial infection group (19.8%) had more patients aged ≤17 years than the CA (6.3%) and HCA (7.0%) groups, whereas patients aged ≥60 years were more predominant in the CA group (60.0%). No significant differences were observed in sex among the three groups.

The most common location of *A. baumannii* infection was the respiratory tract, and the incidence of respiratory tract infection in the HCA (66.0%) group was significantly higher than that in the CA (47.5%, $P = 0.004$) and nosocomial (37.5%, $P< 0.001$) groups. Bloodstream infections were dominant in the nosocomial group (29.2%), whereas skin and soft tissue infections were more frequent in the CA group (26.3%).

A significant difference in the underlying diseases was observed. Compared to patients in the HCA group, the proportion of patients with stroke was significantly lower in the CA and nosocomial groups, but the proportion of patients with malignant tumors was higher, and the difference was statistically significant ($P < 0.05$). Furthermore, patients in the nosocomial infection group were more likely to have a hematological disease, whereas organ failure was more rare in the CA group.

Intravenous therapy before infection was compared between the HCA and nosocomial groups. Similar patterns in the use of immunosuppressants, renal dialysis, organ transplantation, urethral catheterization, and endotracheal intubation were observed in the two groups; however, the prevalence of surgery (65.6%), chemotherapy or radiotherapy (16.7%), and central venous catheterization (85.4%) was much higher in patients with nosocomial infections ($P < 0.05$).

Prior antibiotic exposure was also assessed in all three groups. Antibiotics in double and triple combinations were more common in the HCA and nosocomial groups.

Patients with both HCA (14.0%) and nosocomial (14.6%) infections had a higher 30-day mortality rate than those with CA infections (3.8%). However, no statistically significant differences were found between those two groups (P > 0.05) (Table 1).

## Antimicrobial Resistance of Nosocomial, HCA, and CA A. Baumannii Isolates

Overall, the antimicrobial resistance rates for the nosocomial and HCA isolates were significantly higher than those for the CA group (P < 0.001). More than 60% of the isolates from the nosocomial and HCA groups were resistant to almost

**Table 1** Clinical Characteristics of Patients with Community-Acquired, Healthcare-Associated, and Nosocomial A. Baumannii Infections

| Demographic and Clinical Variables | CA (n=80) | HCA (n=215) | Nosocomial (n=96) | P-value | | |
|---|---|---|---|---|---|---|
| | | | | CA Versus HCA | CA Versus Nosocomial | HCA Versus Nosocomial |
| **Age** | | | | | | |
| 0–17 | 5 (6.3%) | 15 (7.0%) | 19 (19.8%) | 0.825 | **0.009** | **0.001** |
| 18–59 | 27 (33.8%) | 100 (46.5%) | 36 (37.5%) | **0.049** | 0.605 | 0.139 |
| ≥60 | 48 (60%) | 100 (46.5%) | 41 (42.7%) | **0.039** | **0.022** | 0.534 |
| **Sex** | | | | | | |
| Male | 51 (63.8%) | 151 (70.2%) | 57 (59.4%) | 0.287 | 0.553 | 0.060 |
| Female | 29 (36.2%) | 64 (29.8%) | 39 (40.6%) | | | |
| **The location of infections** | | | | | | |
| Respiratory tract | 38 (47.5%) | 142 (66.0%) | 36 (37.5%) | **0.004** | 0.181 | **<0.001** |
| Bloodstream | 6 (7.5%) | 26 (12.1%) | 28 (29.2%) | 0.259 | **<0.001** | **<0.001** |
| Urinary tract | 11 (13.8%) | 17 (7.9%) | 2 (2.1%) | 0.128 | **0.008** | 0.085 |
| Skin and soft tissue | 21 (26.3%) | 25 (11.6%) | 17 (17.7%) | **0.002** | 0.170 | 0.147 |
| Others[a] | 4 (5.0%) | 5 (2.3%) | 13 (13.5%) | 0.260 | 0.073 | **<0.001** |
| **Relevant comorbidities** | | | | | | |
| Diabetes mellitus | 19 (23.8%) | 43 (20.0%) | 13 (13.5%) | 0.482 | 0.080 | 0.171 |
| Hypertension | 30 (37.5%) | 72 (33.5%) | 18 (18.8%) | 0.520 | **0.005** | **0.008** |
| Chronic pulmonary disease | 8 (10.0%) | 24 (11.2%) | 5 (5.2%) | 0.775 | 0.226 | 0.095 |
| Malignant tumor | 13 (16.3%) | 16 (7.4%) | 18 (18.8%) | **0.024** | 0.665 | **0.003** |
| Organ failure | 9 (11.3%) | 64 (29.8%) | 24 (25.0%) | **0.001** | **0.020** | 0.389 |
| Hematological disease | 4 (5.0%) | 6 (2.8%) | 16 (16.7%) | 0.468 | 0.059 | **<0.001** |
| Stroke | 14 (17.5%) | 76 (35.3%) | 17 (17.7%) | **0.003** | 0.971 | **0.002** |
| Severe injury | 3 (3.8%) | 28 (13.0%) | 6 (6.3%) | **0.019** | 0.513 | 0.077 |
| **Invasive procedures**[b] | | | | | | |
| Chemotherapy or radiotherapy | - | 10 (4.7%) | 16 (16.7%) | - | - | **<0.001** |
| Application of immunosuppressant | - | 11 (5.1%) | 5 (5.2%) | - | - | 1.000 |
| Organ transplantation | - | 5 (2.3%) | 4 (4.2%) | - | - | 0.465 |
| Renal dialysis | - | 14 (6.5%) | 10 (10.4%) | - | - | 0.233 |
| Surgery | - | 84 (39.1%) | 63 (65.6%) | - | - | **<0.001** |
| Central venous catheterization | - | 122 (56.7%) | 82 (85.4%) | - | - | **<0.001** |
| Urethral catheterization | - | 131 (60.9%) | 69 (71.9%) | - | - | 0.063 |
| Endotracheal intubation | - | 117 (54.4%) | 58 (60.4%) | - | - | 0.325 |
| **Admission to ICU**[b] | - | 112 (52.1%) | 64 (66.7%) | - | - | **0.017** |
| **Number of antibiotics used**[b] | | | | | | |
| Any | 51 (63.7%) | 30 (14.0%) | 10 (10.4%) | **<0.001** | **<0.001** | 0.389 |
| One | 18 (22.5%) | 55 (25.6%) | 24 (25.0%) | 0.586 | 0.698 | 0.913 |
| Two | 0 (0.0%) | 52 (24.2%) | 17 (17.7%) | - | - | 0.204 |
| More than two | 2 (2.5%) | 78 (36.3%) | 45 (46.9%) | **<0.001** | **<0.001** | 0.077 |
| **30-day crude mortality** | 3 (3.8%) | 30 (14.0%) | 14 (14.6%) | **0.024** | **0.030** | 0.883 |

**Note**: P-values marked with bold indicate statistically significant p-values; [a]Others included cerebrospinal fluid, biliary tract, ascites, articular cavity; [b]During the 30 days preceding infection onset; – not applicable.

**Abbreviations**: CA, community-acquired; HCA, healthcare-associated; ICU, intensive care unit.

**Table 2** Antimicrobial Resistance Rates of Clinical Isolates of Community-Acquired, Healthcare-Associated, and Nosocomial A. Baumannii Bacteremia

| variable | CA (n=80) | HCA (n=215) | Nosocomia (n=96) | CA vs HCA | CA vs Nosocomial | HCA vs Nosocomial |
|---|---|---|---|---|---|---|
| Imipenem | 20 (25.0%) | 156 (72.6%) | 63 (65.6%) | **<0.001** | **<0.001** | 0.216 |
| Piperacillin/ Tazobactam | 22 (27.5%) | 167 (77.7%) | 71 (74.0%) | **<0.001** | **<0.001** | 0.475 |
| Sulfamethoxazole | 13 (16.3%) | 127 (59.1%) | 52 (54.2%) | **<0.001** | **<0.001** | 0.419 |
| Ceftazidime | 22 (27.5%) | 161 (74.9%) | 68 (70.8%) | **<0.001** | **<0.001** | 0.454 |
| Cefepime | 20 (25.0%) | 161 (74.9%) | 68 (70.8%) | **<0.001** | **<0.001** | 0.454 |
| Cefoperazone/sulbactam | 19 (23.8%) | 149 (69.3%) | 63 (65.6%) | **<0.001** | **<0.001** | 0.520 |
| Tobramycin | 18 (22.5%) | 151 (70.2%) | 58 (60.4%) | **<0.001** | **<0.001** | 0.089 |
| Levofloxacin | 19 (23.8%) | 167 (77.7%) | 68 (70.8%) | **<0.001** | **<0.001** | 0.195 |
| Gentamicin | 23 (28.7%) | 160 (74.4%) | 64 (66.7%) | **<0.001** | **<0.001** | 0.159 |
| Ciprofloxacin | 19 (23.8%) | 168 (78.1%) | 68 (70.8%) | **<0.001** | **<0.001** | 0.164 |
| Meropenem | 21 (26.3%) | 156 (72.6%) | 65 (67.7%) | **<0.001** | **<0.001** | 0.384 |
| Tigecycline | 2 (2.5%) | 45 (20.9%) | 20 (20.8%) | **<0.001** | **<0.001** | 0.985 |
| Doxycycline | 18 (22.5%) | 158 (73.5%) | 63 (65.6%) | **<0.001** | **<0.001** | 0.158 |
| Minocycline | 12 (15.0%) | 108 (50.2%) | 39 (40.6%) | **<0.001** | **<0.001** | 0.117 |

**Note**: P-values marked with bold indicate statistically significant p-values.
**Abbreviations**: CA, community-acquired; HCA, healthcare-associated;

all the antibiotics tested, except for tigecycline (nosocomial group, 20.8%; HCA group, 20.9%), minocycline (nosocomial group: 40.6%; HCA group: 50.2%), and sulfamethoxazole (nosocomial group, 54.2%; HCA group, 59.1%). Similarly, lower resistance rates were observed for the three antibiotics mentioned above than for the other antibiotics in the CA infection group (Table 2).

## Risk Factors for the Occurrence of CRAB Isolates in the Nosocomial, HCA, and CA A. Baumannii Infection Groups

According to the univariate regression analysis, an age ≥60 years (P < 0.001), surgery (P = 0.004), urethral catheterization (P < 0.001), endotracheal intubation (P < 0.001), ICU admission (P < 0.001), exposure to two or more antibiotics (P = 0.014), and hospitalization for ≥10 days (P = 0.038) were associated with CRAB infection in the nosocomial *A baumannii* infection group. Hematological disease (P = 0.007) and chemotherapy or radiotherapy (P = 0.007) were associated with carbapenem-sensitive *A. baumannii* (CSAB). The multivariate logistic regression analysis revealed three independent risk factors related to CRAB infection: an age ≥60 years (OR = 9.652; P = 0.010), urethral catheterization (OR = 55.650; P = 0.002), and exposure to two or more antibiotics (OR = 11.280; P = 0.001) within 30 days before *A. baumannii* infection (Table 3).

**Table 3** Logistic Regression Analysis of Risk Factors for Carbapenem-Resistant Acinetobacter Baumannii (CRAB) Infection in Nosocomial Infection Patients

| variable | Univariate OR (95% CI) | P-value | Multivariate OR (95% CI) | P-value |
|---|---|---|---|---|
| Age | | | | |
| 0–17 | 0.994 (0.327–3.026) | 0.992 | | |
| 18–59[a] | —— | —— | | |
| ≥60 | 6.442 (2.057–20.174) | **0.001** | 9.652 (1.712–54.419) | **0.010** |
| Gender (male) | 0.727 (0.300–1.760) | 0.479 | | |
| Diabetes mellitus | 1.697 (0.432–6.665) | 0.449 | | |
| Hypertension | 1.853 (0.555–6.184) | 0.316 | | |
| Chronic Pulmonary Disease | 1.967 (0.211–18.377) | 0.553 | | |

(*Continued*)

**Table 3** (Continued).

| variable | Univariate OR (95% CI) | P-value | Multivariate OR (95% CI) | P-value |
|---|---|---|---|---|
| Malignant Tumor | 0.943 (0.317–2.804) | 0.916 | | |
| Hematological Disease | 0.214 (0.069–0.660) | **0.007** | 3.991 (0.149–106.933) | 0.409 |
| Stroke | 2.562 (0.678–9.682) | 0.165 | | |
| Chemotherapy or Radiotherapy[b] | 0.214 (0.069–0.660) | **0.007** | 0.765 (0.039–15.120) | 0.860 |
| Immunosuppressant[b] | 0.296 (0.047–1.873) | 0.196 | | |
| Organ Transplantation[b] | 0.146 (0.015–1.464) | 0.102 | | |
| Renal dialysis[b] | 4.821 (0.583–39.883) | 0.145 | | |
| Surgery[b] | 3.719 (1.505–9.192) | **0.004** | 0.173 (0.016–1.891) | 0.150 |
| Central Venous Catheterization[b] | 2.417 (0.765–7.637) | 0.133 | | |
| Urethral Catheterization[b] | 20.650 (6.684–63.799) | **<0.001** | 55.650 (4.347–712.406) | **0.002** |
| Endotracheal Intubation[b] | 7.486 (2.869–19.534) | **<0.001** | 1.246 (0.082–18.933) | 0.874 |
| Admitted to ICU[b] | 10.309 (3.816–27.847) | **<0.001** | 1.498 (0.060–37.468) | 0.894 |
| Exposure to two or more antibotics[b] | 6.028 (1.439–25.245) | **0.014** | 11.280 (2.829–44.975) | **0.001** |
| Hospitalization days≥10 | 3.420 (1.069–10.943) | **0.038** | 1.642 (0.202–13.383) | 0.643 |

**Note**: P-values marked with bold indicate statistically significant p-values; [a]Reference; [b]During the 30 days preceding infection onset.
**Abbreviations**: OR, odds ratio; CI, confidence interval; ICU, intensive care unit.

In the HCA *A baumannii* infection group, Univariate analysis revealed that central venous catheterization (P < 0.001), urethral catheterization (P < 0.001), endotracheal intubation (P < 0.001), ICU admission (P < 0.001), and exposure to two or more antibiotics within 30 days (P = 0.007) were significant risk factors for CRAB infection. In contrast, patients with malignant tumors (P = 0.010), hematological disease (P = 0.047), or who received chemotherapy or radiotherapy (P = 0.026) and immunosuppressants (P = 0.042) were more likely to be infected with CSAB. The multivariate logistic regression analysis identified endotracheal intubation (odds ratio [OR] = 2.678; P = 0.005) and exposure to two or more antibiotics (OR = 4.233; P < 0.001) as independent risk factors for CRAB infections, whereas protective effects were observed for malignant tumors (OR = 0.291; P = 0.039) and hematological disease (OR = 0.119; P = 0.024) (Table 4).

Exploring the risk factors for CRAB occurrence in patients with CA *A. baumannii* infections showed that none were associated with CRAB infection. However, malignant tumors appeared to be more closely associated with CSAB infection. Thirteen patients with malignant tumors were all infected with CSAB (Table 5).

**Table 4** Logistic Regression Analysis of Risk Factors for Carbapenem-Resistant Acinetobacter Baumannii (CRAB) Infection in HCA Infection Patients

| Variable | Univariate OR (95% CI) | P-value | Multivariate OR (95% CI) | P-value |
|---|---|---|---|---|
| Age | | | | |
| 0–17 | 0.583 (0.190–1.790) | 0.346 | | |
| 18–59[a] | —— | —— | | |
| ≥60 | 1.231 (0.654–2.320) | 0.519 | | |
| Gender (male) | 0.681 (0.342–1.356) | 0.274 | | |
| Diabetes mellitus | 0.818 (0.392–1.704) | 0.591 | | |
| Hypertension | 1.300 (0.676–2.500) | 0.431 | | |
| Chronic Pulmonary Disease | 1.985 (0.649–6.078) | 0.230 | | |
| Malignant Tumor | 0.254 (0.090–0.718) | **0.010** | 0.291 (0.090–0.939) | **0.039** |
| Organ Failure | 1.301 (0.660–2.562) | 0.447 | | |
| Hematological Disease | 0.174 (0.031–0.978) | **0.047** | 0.119 (0.019–0.760) | **0.024** |
| Stroke | 1.452 (0.757–2.784) | 0.262 | | |
| Severe Injury | 1.819 (0.657–5.036) | 0.249 | | |

(*Continued*)

**Table 4** (Continued).

| Variable | Univariate OR (95% CI) | P-value | Multivariate OR (95% CI) | P-value |
|---|---|---|---|---|
| Chemotherapy or Radiotherapy[b] | 0.227 (0.062–0.834) | **0.026** | 1.923 (0.238–15.535) | 0.540 |
| Immunosuppressant[b] | 0.280 (0.082–0.955) | **0.042** | 0.814 (0.180–3.695) | 0.790 |
| Organ Transplantation[b] | 0.545 (0.089–3.350) | 0.513 | | |
| Renal dialysis[b] | 0.465 (0.154–1.404) | 0.175 | | |
| Surgery[b] | 0.967 (0.522–1.791) | 0.915 | | |
| Central Venous Catheterization[b] | 3.524 (1.871–6.636) | **<0.001** | 1.595 (0.358–7.100) | 0.540 |
| Urethral Catheterization[b] | 3.032 (1.629–5.642) | **<0.001** | 0.445 (0.121–1.631) | 0.222 |
| Endotracheal Intubation[b] | 3.793 (1.992–7.221) | **<0.001** | 2.678 (1.342–5.344) | **0.005** |
| Admitted to ICU[b] | 4.131 (2.137–7.987) | **<0.001** | 1.358 (0.354–5.207) | 0.656 |
| Exposure to two or more antibotics[b] | 3.012 (1.349–6.724) | **0.007** | 4.233 (2.108–8.504) | **<0.001** |

**Notes**: P-values marked with bold indicate statistically significant p-values; [a]Reference; [b]During the 30 days preceding infection onset.
**Abbreviations**: OR, odds ratio; CI, confidence interval; ICU, intensive care unit.

**Table 5** Logistic Regression Analysis of Risk Factors for Carbapenem-Resistant Acinetobacter Baumannii (CRAB) Infection in CA Infection Patients

| Variable | Univariate OR (95% CI) | P-value |
|---|---|---|
| Age | | |
| 0–17 | 3.833 (0.479–30.700) | 0.206 |
| 18–59[a] | —— | —— |
| ≥60 | 2.614 (0.768–8.895) | 0.124 |
| Gender (male) | 1.189 (0.416–3.397) | 0.746 |
| Diabetes mellitus | 1.415 (0.458–4.379) | 0.547 |
| Hypertension | 1.035 (0.371–2.889) | 0.948 |
| Chronic Pulmonary Disease | 1.800 (0.391–8.292) | 0.451 |
| Malignant Tumor[b] | —— | —— |
| Organ Failure | 0.782 (0.149–4.100) | 0.771 |
| Hematological Disease | 3.000 (0.395–22.787) | 0.288 |
| Stroke | 1.736 (0.508–5.938) | 0.379 |
| Severe Injury | 1.425 (0.122–16.578) | 0.777 |
| Exposure to two or more antibotics[c] | 1.769 (0.591–5.296) | 0.308 |

**Note**: [a]Reference; [b]Thirteen patients with malignant tumor were all infected with CSAB, therefore, no statistical results were available; [c]During the 30 days preceding infection onset.
**Abbreviations**: OR, odds ratio; CI, confidence interval.

## Discussion

Over the past few decades, *A. baumannii* has become one of the major pathogens worldwide. It is known for its wide colonization and high rate of drug resistance.[13,14] Infections caused by *A. baumannii* have been reported in many countries with a variable prevalence and substantial associated morbidity and mortality.[15–17] In this study, three types of *A. baumannii* infections with different origins were explored from numerous perspectives to provide a useful reference for clinical practice.

The definition of HCA infection was based on the previous literature, and 55.0% of the cases were classified as HCA infections. These data are comparable to those of a previous study conducted in our hospital[8] but relatively higher than those reported in Taiwan.[7] The explanation for this difference is that the current study was conducted in a comprehensive hospital that admitted many critically ill patients from other hospitals. For the group aged ≤17 years, the proportion of

patients with nosocomial infection is much higher than for the other two types of infections. Children are susceptible to nosocomial infections because of their weakened immune system and organ insufficiency. Thus, prevention and control measures, such as strengthened environmental cleaning, adequate patient isolation, and the promotion of hand hygiene, should be strictly implemented in pediatric wards to address the high incidence of nosocomial infection.[18] This study also showed that the distribution of infection sites differed among the three groups. Although the respiratory tract was the most common site in all three groups, bloodstream infections were more prominent in the nosocomial group, and skin and soft tissue infections were more frequently observed in the CA group. This finding has also been reported by other studies.[17,19]

Regarding underlying diseases, the percentage of patients with hematological disease was higher in the nosocomial group. Previous studies have also shown that these patients comprise the largest group of patients with nosocomial *A. baumannii* infections.[19] As patients with hematological diseases undergo prolonged chemotherapy and are in frequent contact with healthcare settings, they are at a high risk of nosocomial infections.[20] Moreover, organ failure was more common in the HCA and nosocomial groups than in the CA group. Organ failure usually indicates a serious medical condition, which suggests a poor prognosis. This result was confirmed by the fact that the 30-day mortality rates were similar for patients with nosocomial and HCA infections, both of which were significantly higher than those in patients with CA infections.

We also analyzed the recent occurrence of invasive procedures, antibiotics used before infection, and antimicrobial resistance patterns in the CA, HCA, and nosocomial infection groups. According to our results, patients with HCA *A. baumannii* infections had a greater rate of exposure to invasive procedures and antibiotics than patients with CA infections and shared similarities with patients with nosocomial infections. HCA *A. baumannii* strains also exhibited antimicrobial resistance patterns similar to those of nosocomial strains, which were more resistant than CA strains. This finding is reasonable, given previous reports that the presence of invasive procedures and exposure to more antibiotics are risk factors for the acquisition of multidrug-resistant *A. baumannii* infection.[21,22] Therefore, for patients with *A. baumannii* infection at the time of admission, deciding on empirical treatment is highly challenging. Clinicians should obtain a detailed medical history, and treatment with broad-spectrum antibiotics or antibacterial agents combination may be considered for patients with HCA infections.

Although the risk factors for CRAB infection have been well described in numerous hospital-based studies, no studies in the literature have explored the risk factors for CRAB infection in patients with CA, HCA, and nosocomial infections. In the present study, we found that patients with different types of infection had different risk factors. The fact that using two or more antibiotics within 30 days increased the risk of CRAB infection in both the HCA and nosocomial groups is not surprising because previous studies have shown that previous exposure to antibiotics is the most important risk factor for infections caused by carbapenem-resistant pathogens.[23,24] However, this risk factor appeared to have no effect on the CA group because no or only one antibiotic was used by most patients with CA infections. The results revealed that the emergence of carbapenem-resistant pathogens is a significant healthcare burden that could be attributed to the overuse of antibiotics and that the rational use of antibiotics is the key to reducing bacterial resistance. Antimicrobial exposure can be reduced by avoiding unnecessary antibiotics and prescribing antibiotics for the shortest effective duration.[25] Notably, tigecycline had the lowest resistance rate among the *A. baumannii* strains in our study, which is similar to the findings of other countries,[26] indicating that we should be more prudent when choosing tigecycline for empirical therapy to avoid the excessive growth of tigecycline-resistant strains.

Our results showed that recent invasive procedures were closely associated with CRAB infection. According to the univariate analysis, central venous catheterization, urethral catheterization and endotracheal intubation were associated with CRAB acquisition in the HCA group, as were urethral catheterization, endotracheal intubation and surgery in the nosocomial group. The multivariate analysis revealed an independent association between endotracheal intubation and CRAB infections in the HCA group, as well as urethral catheterization and CRAB infections in the nosocomial group. The identification of recent invasive procedures as risk factors for CRAB infection is not unexpected. This result has also been reported in other studies.[23,27–29] These procedures are frequently performed in patients with serious or chronic diseases who require long-term treatment. Many resistant microorganisms colonize the respiratory tract, urinary tract, and skin surfaces of these patients. The use of invasive procedures displaces colonizers and increases the risk of opportunistic infections. Therefore, many experts have suggested that clinicians must assess a patient's condition and remove

unnecessary invasive devices. In addition, an age ≥60 years was an independent risk factor for CRAB infections in the nosocomial group. Elderly patients are more tend to have ICU admission and determine treatment intensity, which makes them more susceptible to resistant infection.[30]

In most previous studies, malignant tumors were considered to be an important factor affecting the incidence of carbapenem-resistant strains.[25,31] Surprisingly, we found that patients with malignant tumors as an underlying disease were more likely to have CSAB infections in the HCA and CA groups, but this outcome was not observed in the nosocomial group. We hypothesized that these observations might reflect discrepancies in the studied populations. In the HCA and CA groups, most patients had malignant tumors at the first diagnosis. These patients tend to have shorter hospitalizations and undergo fewer invasive diagnostic and therapeutic interventions than those with nosocomial infections. Bacteria that colonize their bodies are usually sensitive strains rather than drug-resistant strains. An endogenous infection (due to displacement of the colonizer) caused by immunocompression is the primary cause of *A. baumannii* infection. In fact, a higher rate of malignancy in the CSAB infection group than in the CRAB group has also recently been shown in a large patient cohort in the USA.[32] Certainly, more data are required to prove this point.

This study has several limitations. First, it was a single-center study conducted at a large-scale general hospital in China. For this reason, our conclusions may not be applicable to small or specialized hospitals. These results must be extended in clinic cautiously. Multi-center study with large sample size is also needed to confirmed these results. Second, our study was a retrospective analysis, and most strains were not retained. We were unable to compare the molecular epidemiological characteristics of CA, HCA, and nosocomial *A. baumannii* infections. Finally, we only included the susceptibility results for single antibiotics. More detailed data on combined antimicrobial susceptibility are not available. According to a report by Bian et al, clinically relevant dosing regimens of colistin combined with sulbactam may substantially improve the bacterial killing of CRAB.[33] Another clinical study revealed that the antibacterial regimen consisting of a combination of cefoperazone/sulbactam and tigecycline for multidrug-resistant *A. baumannii* was also effective.[34] Further studies will be performed on the validity of antibiotic combinations against *A. baumannii* in our group.

## Conclusions

In conclusion, our study compared the clinical characteristics, antimicrobial resistance patterns and risk factors associated with carbapenem resistance in nosocomial, HCA, CA *A. baumannii* infections. We found that HCA *A. baumannii* infections are quite different from CA infections, with antimicrobial resistance patterns and 30-day mortality rates similar to those of nosocomial infections. Additionally, the risk factors for CRAB development in the CA, HCA, and nosocomial groups were not the same, which may provides the help for controlling practices and instruction empirical clinical medication.

## Data Sharing Statement

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

## Author Contributions

All authors made a significant contribution to the work reported, whether that was in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article is being submitted; and agree to be accountable for all aspects of the work.

## Disclosure

The authors declare that they have no competing interests.

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