JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Original Article

Clinical characteristics, risk factors, and mortality associated with *Pseudomonas aeruginosa* bacteremia

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Abstract

Introduction: *Pseudomonas aeruginosa* bacteremia (PAB) is a major cause of morbidity and mortality, increasingly complicated by multidrug-resistant (MDR) strains which becomes a challenge to the treating physician. This study aimed to evaluate risk factors associated with PAB and its outcomes.

Methodology: A retrospective cohort study was conducted at the American University of Beirut Medical Center (AUBMC), including 85 patients who were > 18 years of age with confirmed PAB during their hospital stay between 2017 and 2022.

Results: Regarding resistance patterns, 8 (9.4%) patients had MDR strains and 19 (22.4%) were difficult to treat (DTR). Prior antibiotic use within 1 month was associated with the DTR infections (OR 4.97; $p = 0.026$). The in-hospital mortality rate was 51.8%. Male gender was associated with decreased mortality (OR 0.13; $p = 0.036$). Recent central line placement and Pitt bacteremia score were linked to increased mortality (OR 2.63; $p = 0.028$ and OR 51.71; $p < 0.001$, respectively). High-risk primary sources of infection such as central line, gastrointestinal, and respiratory systems had increased mortality compared with low-risk sources such as skin, abscess, and urinary tract (OR 25.96; $p = 0.001$).

Conclusions: Prompt empirical therapy and identifying the infection source are critical in assessing severity of the infection in PAB. Pitt bacteremia score is a valuable predictor of outcomes. Rising DTR rates was linked to prior antibiotic use which highlights the importance of antimicrobial stewardship.

Key words: *Pseudomonas aeruginosa*; bacteremia; mortality; resistance; predictors.

J Infect Dev Ctries 2026; 20(10):1511-1517. doi:10.3855/jidc.22599

(Received 07 November 2025 – Accepted 22 April 2026)

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Introduction

Bloodstream infections (BSI) carry significant implications on patient morbidity and mortality. *Pseudomonas aeruginosa* (PA) is a challenging organism due to its virulence and high rate of emerging resistance [1]. It is a common nosocomial pathogen that is known to prolong the duration of hospitalization and exerts a substantial influence on both morbidity and mortality [2,3]. Its associated mortality is higher than other Gram-negative organisms or *Staphylococcus aureus* even after accounting for patients' characteristics and treatment [4]. The rate of in-hospital mortality from *Pseudomonas aeruginosa* bacteremia (PAB) ranges between 25.5% to 39% [5]. While PA is known to cause bacteremia in immunocompromised individuals, there have been several reports of community acquired BSI in immunocompetent individuals [2,3,6,7], The importance of this pathogen and its increasing rate of resistance has led the World Health Organization (WHO) to classify carbapenem resistant PA as a pathogen of critical priority [8].

Therefore, it is imperative to study the risk factors associated with severe PAB. Immunocompromised patients and patients undergoing invasive procedures are particularly at risk [3]. Antibiotic resistance is another variable of interest that can alter the clinical course of PAB with recent antibiotic use or intensive care unit (ICU) admission as predictors for multi-drug resistant (MDR) PA [9].

Therapeutic options can be limited due to the increasing ability of certain strains of PA to resist almost all currently available antipseudomonal antibiotics; notably aminoglycosides, quinolones and b-lactams [10]. The excessive use of antibiotics is an important factor in the development of MDR PA strains [10,11]. Antibiotic resistance is driven primarily by genetic determinants which allow PSA to resist killing by antimicrobials [12]. These determinants may be intrinsic (chromosomally encoded and naturally present in the species) or acquired through mutation or

horizontal gene transfer [13]. The mechanisms of resistance can vary from enzymatic degradation of the drug, antibiotic target site modification, downregulation of porins, or multidrug efflux pumps [10,12,14]. In addition to genetic resistance mechanisms, PA exhibits adaptive resistance through biofilm formation; this happens most commonly in chronic lung infections. Biofilm formation protects PA from environmental stressors, limits antibiotic penetration, and impairs phagocytosis; thereby facilitating colonization and long-term persistence within the host [10,15]. In the past few years, there has been a notable emphasis on the development of new antibiotic combinations with novel modes of action and routes of administration to treat MDR PA infections [10,14,16]. Carbapenem-resistance is primarily associated with carbapenemase production as well as outer membrane permeability defect with the production of b-lactamases in the presence of the CTX-M variant [17]. Furthermore, some studies looked at non-antibiotic therapeutic approaches such as inhibition of quorum sensing (regulation of gene expression in response to fluctuations in cell-population density) and bacterial lectins, use of iron chelation, vaccines, and other methods [10,14].

MDR PA have been steadily increasing in Lebanon [18–20] where there is scarcity of research about PAB with its associated risk factors [19–21]. The objective of this study was to describe the characteristics and outcomes of PBA and to identify readily available clinical parameters that can predict in-hospital mortality.

Methodology

Definitions

The sources of infection were allocated to either a high-risk source or a low-risk source, depending on their mortality rates. Central line and pulmonary infections were identified as high-risk; while abscess, skin, and urinary infections were identified as low-risk sources of infection.

Antimicrobial susceptibility testing of PA isolates was performed by the microbiology laboratory at the American University of Beirut Medical Center (AUBMC) using standard clinical laboratory procedures. Susceptibility testing was conducted using automated systems and/or disk diffusion methods, and interpretation of minimum inhibitory concentrations (MICs) and susceptibility categories followed the Clinical and Laboratory Standards Institute (CLSI) guidelines [22].

MDR and difficult-to-treat resistance (DTR) were identified using 5 classes of antibiotics: antipseudomonal cephalosporins, antipseudomonal penicillin, fluoroquinolones, carbapenems, and aminoglycosides. MDR was identified if PA was resistant to at least 3 classes of antibiotics. DTR PA was identified when the isolates were resistant to all 5 classes of antibiotics.

Community acquired bacteremia was defined as a positive blood culture obtained within 48 hours of hospital admission in patients without significant prior healthcare exposure. Hospital-acquired bacteremia was defined as a positive blood culture obtained ≥ 48 hours after hospital admission. Healthcare-associated bacteremia was defined as bacteremia identified within 48 hours of admission in patients with prior healthcare exposure

Device-associated infections were defined according to the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) surveillance definitions [23]. Ventilator-associated pneumonia (VAP) and ventilator-associated events (VAE), central line–associated bloodstream infection (CLABSI), and catheter-associated urinary tract infection (CAUTI) were identified using these standardized criteria. Device exposure and infection classification were determined through review of clinical documentation, microbiological results, and device utilization data recorded in the electronic medical record.

Study design

This was a retrospective cohort study involving adult participants admitted between January 2017 and December 2022 with positive blood cultures for PA. This study was approved and conducted in accordance with the ethical standards of the Institutional Review Board (IRB) at the AUBMC, a tertiary healthcare center in Lebanon. Demographic, clinical, and microbiology data were obtained by reviewing electronic medical records (Table 1). The patients were classified based on the route of acquisition into 3 categories: community acquired, hospital acquired, and healthcare associated as defined above. The classification was based on previously published definitions of these entities. If there were multiple sources of infection or the primary source was never identified, then the source was classified as unknown. The risk of critical illness and death was estimated using the Pitt Bacteremia score (PBS) which is a validated, bacteremia-specific tool based on readily available clinical variables and has been shown to predict short-term mortality in Gram-negative bloodstream infections. It consists of 5

variables that are routinely documented, making it feasible and practical in retrospective studies (mental status, body temperature, hypotension or need for vasopressors, mechanical ventilation support, and cardiac arrest). In contrast, comprehensive ICU-based scores require multiple laboratory and clinical parameters that are not consistently recorded for all patients, particularly outside the intensive care setting [24]. The risk of 10-year mortality was estimated using Charlson Comorbidity index.

Statistical analysis

SPSS version 25 was used for all data analyses (IBM SPSS Statistics for Windows, Version 25.0, IBM Corp, Armonk, NY, USA). The parameters relating to the general description of the patient population were analyzed using univariable analysis. Categorical and continuous variables were compared using Chi-squared test and t-test respectively. Multivariable backward logistic regression was performed for mortality analysis to control for confounders and establish independent associations between mortality and various patient characteristics. A cutoff p value of < 0.2 on bivariable analysis was used to determine which variables should be included in the regression model.

Table 1. Demographic and clinical characteristics of the patients with P. aeruginosa bacteremia.

Characteristic	Value (N = 85)
Age, years (mean ± SD)	64.5 ± 16.8
Male gender	60 (70.6)
BMI, kg/m^2 (mean ± SD)	27.6 ± 5.4
Malignancy	41 (48.3)
Solid	23 (27.1)
Hematologic	18 (21.2)
Diabetes	27 (31.8)
Chronic kidney disease	14 (16.5)
Hemodialysis	6 (7.1)
COPD	6 (7.1)
Burn injury	3 (3.5)
HIV infection	2 (2.4)
Hospital stay > 2 days*	69 (81.2)
ICU stay > 2 days*	45 (52.9)
Mechanical ventilation > 2 days*	37 (43.5)
Central line > 2 days*	56 (65.9)
Urinary catheter > 2 days*	43 (50.6)
Nasogastric tube > 2 days*	36 (42.4)
Steroid use*	47 (55.3)
Surgery*	21 (24.7)
Clean	7 (8.2)
Clean-contaminated/contaminated	14 (16.5)
Route of acquisition	
Hospital-acquired	67 (78.8)
Community-acquired	12 (14.1)
Healthcare-associated	6 (7.1)
Pitt Bacteremia Score > 4	44 (51.8)
Charlson Score > 4	50 (58.8)

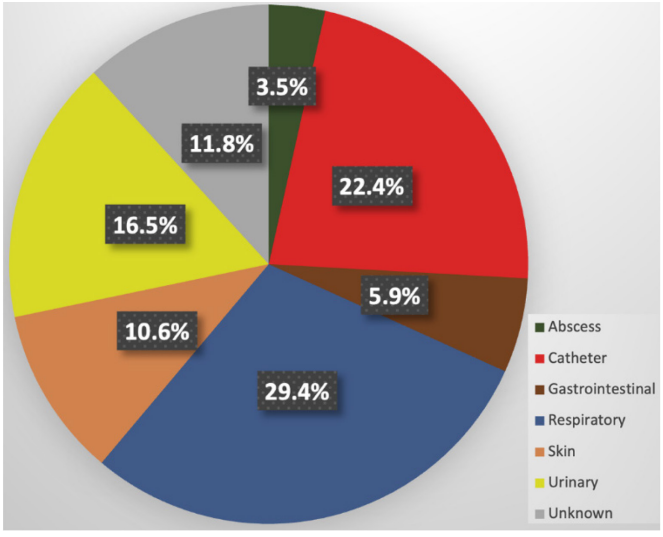
All values represent n (%) except where otherwise indicated. *Within 30 days prior to the infection. SD: standard deviation; BMI: body mass index; COPD: chronic obstructive pulmonary disease; HIV: human immunodeficiency virus; ICU: intensive care unit.

Results

The demographic and clinical characteristics of the patient population are summarized in Table 1. There was a male predominance with 60 (70.6%) males and 25 (29.4%) females, with a mean age of 64.5 years. Most patients had pre-existing medical conditions making them more susceptible to infection, aligning with data from other published studies. Approximately 50% of them had cancer diagnosis. The majority of the patients (69, 81/2%) were admitted to the hospital more than 5 days prior to infection, and 45 (53%) required at least 3-day ICU stay. Moreover, 67 (78.8%) patients had hospital acquired infection; while 6 (7.1%) and 12 (14.1%) had healthcare associated and community acquired PAB, respectively. Antibiotic use within 24 hours before the index infection was noted in 66 patients (77.6%), while 64 (75.3%) patients received an antibiotic course of at least 3 days during the month preceding the infection. The most commonly used antibiotics prior to infection were glycopeptides, aminoglycosides, and carbapenems.

The source of bacteremia was determined by reviewing physician notes in the medical record or contemporaneously cultured PA from a different location (such as sputum or urine). A primary source was identified in 88.2% of patients in the present population. The most common sources of bacteremia were pulmonary (29.4%), central line-associated (22.4%), and urinary (16.5%). The source was deemed unknown in 11.8% of cases (Figure 1).

Figure 1. Infection sources.



Reported as percentages.

The highest rates of resistance were to carbapenems in 34 patients (40%), followed by quinolones in 30 patients (35.3%). Out of the 85 isolates, 8 were considered MDR and 19 DTR. Further susceptibility analysis was performed to ceftolozane-tazobactam in 9 cases (resistance 2/9) and to ceftazidime-avibactam in 16 cases (resistance 6/16). Antibiotic use within 30 days of PAB was significantly associated with DTR, with an odds ratio of 4.97 ($p = 0.026$).

Patient clinical course was monitored for progression of disease, treatment modifications, and complications. Complications included sepsis, septic shock, acute respiratory distress syndrome (ARDS), acute renal failure, cardiovascular or cerebrovascular events, persistent bacteremia, embolism or metastatic infection, prolonged stay or ICU admission, mechanical ventilation, other hospital acquired infections, and mortality (Table 2). The patient's clinical course was complicated in most cases. Out of the 85 patients, 69 (81.2%) had sepsis, 54 (63.5%) required ICU admission, and 49 (57.6%) had septic shock. The overall mortality rate was 51.8% (N = 44) with an attributable mortality of 44.7% (N = 38). The variables significantly associated with increased mortality were female gender, high risk source of infection, and Pitt Bacteremia score ≥ 4 (Table 3). The use of combination therapy and antibiotic resistance of the isolate were not significantly associated with mortality. Secondary antibiotic treatment was initiated in 61 patients (71.8%), with 21 (24.7%) having a secondary antibiotic treatment initiated for inadequate antibiotic coverage of initial therapy due to antibiotic resistance. Tertiary treatment was initiated in 24 patients (28.2%) in case of worsening progression of disease.

Table 2. Complications associated with *P. aeruginosa* bacteremia.

Complications	Frequency (N = 85)
Sepsis	69 (81.2)
ICU admission	54 (63.5)
Septic shock	49 (57.6)
Acute renal failure	48 (56.5)
Hospital-acquired infection	45 (52.9)
Mechanical ventilation	43 (50.6)
Cardiovascular event	30 (35.3)
Persistence/progression of the infection	29 (34.1)
Recurrent infection	19 (22.4)
Acute respiratory distress syndrome	9 (10.6)
Persistent bacteremia	6 (7.1)
Cerebrovascular event	5 (5.9)
Systemic embolism	1 (1.2)

All values represent n (%). ICU: intensive care unit.

Discussion

This retrospective analysis has shed light on the key characteristics of PAB that can increase our understanding of the prognosis and outcome of this disease. Historically, the acute physiology and chronic health evaluation (APACHE) score, age, and MDR were found to be significantly associated with PAB mortality [25]. Early source control and targeted therapy have been reported as protective [26]. However, in recent years, multiple variables were shown to be associated with PAB mortality with mixed results regarding risk factor associations. The beneficial effect of an infectious disease consultation in patients with PAB has been recognized [27]. The American University of Beirut Medical Center has always recognized the value of the infectious disease service which evaluates all patients with BSIs.

Some similarities and key differences can be examined by comparison with other contemporary analyses of PAB performed on different populations. Most notably, the Pitt Bacteremia score with a cutoff of ≥ 4 has been significantly associated with increased mortality in most studies [28,29].

The primary source of infection was proven to be an important prognostic factor, as previously speculated in a study by Joo *et al*. [30]. Similar to the current study, the study by Yoon *et al.* divided the primary sources of infection into high risk and low risk sources of infections with lower respiratory tract, abdomen, soft tissue, and sources of unknown origin as high-risk sources; and pancreaticobiliary tract, intravenous catheters, and the urinary tract as low-risk sources; similar to the current study. These sources showed a

Table 3. Predictors of mortality among patients with *P. aeruginosa* bacteremia.

Variable	Unadjusted OR (95% CI)	*p* value	Adjusted OR (95% CI)	*p* value
Pitt bacteremia score > 4	13.8 (4.9–39.1)	< 0.01	46.8 (4.4–498.8)	< 0.01
High-risk source†	17.5 (4.6–65.7)	< 0.01	23.1 (3.2–165.2)	< 0.01
Hospital stay*	5.6 (1.5–21.8)	< 0.01		
Route of acquisition	5.2 (1.5–17.5)	< 0.01		
Mechanical ventilation*	4.7 (1.9–11.7)	< 0.01		
Central line*	3.9 (1.5–10.4)	0.02		
Steroid use*	3.7 (1.5–9.2)	< 0.01		
ICU stay*	2.2 (0.8–6.1)	0.13		
Male gender	0.4 (0.1–1.0)	0.05		
COPD	Cannot be calculated**	0.03		

OR: odds ratio; CI: confidence interval; COPD: chronic obstructive pulmonary disease; ICU: intensive care unit. †Primary bacteremia or pneumonia. *Within 30 days prior to the infection. ** OR could not be calculated since one of the cells in the 2 by 2 tables was 0.

significant association with mortality [29]. In line with the observations reported in other published studies, patients with central line or pulmonary infections as the primary source of bacteremia had a higher rate of mortality [31]. Previous research has demonstrated that inadequate empiric therapy was an independent risk factor for mortality among patients whose infections originate from high-risk sites like the respiratory tract, as opposed to low-risk sites like the urinary tract [32]. This highlights the necessity of identifying patients with high-risk primary sites of infections at the outset to optimize empiric antibiotic treatment.

It has been observed that PAB tends to occur more frequently in males; and in the present study, 70% of the patients were male [31,33]. Bivariable analysis concluded that male gender was associated with decreased mortality, although it did not feature in the final regression model. Increased mortality among women with *Pseudomonas* bacteremia has been reported previously, although the underlying cause for this remains uncertain [34].

Carbapenems are broad spectrum antibiotics recommended for the management of critically ill patients. Prompt empiric antibiotic administration is essential in suspected PAB. Often, carbapenems are either used as monotherapy or in combination with another antipseudomonal agent. However, the threat of carbapenem-resistant PA is on the rise globally. In the present study, approximately 40% of the patients were infected with carbapenem-resistant PA. The prevalence of carbapenem-resistant PA in the neighboring middle east and north Africa regions ranges between 3% in Kuwait to 93% in Jordan [32]. Previous published data from Lebanon places the prevalence of carbapenem-resistant PA at 28% [32]. In the present study, the isolate was least likely to be resistant to colistin (3.5%), amikacin (27.1%), and cefepime (23.5%). Yet carbapenem was the most frequently used antipseudomonal agent empirically (32.9%). Thus, knowledge of epidemiology and resistance patterns within both the medical facility and the entire country is critical to guide empiric therapy.

Antimicrobial resistance and antipseudomonal monotherapy were not associated with increased mortality in the present study. There is conflicting data in literature regarding this issue. While some studies have reported that infection with resistant isolates leads to delay in appropriate antibiotic therapy and thus increase in mortality [33,35], other studies suggested that the impact of antimicrobial resistance could be contingent on the severity of pre-existing medical conditions and the initial site of infection [35,36].

Age, corticosteroid use, hospital acquired infection, inappropriate empiric therapy, previous hospital admission, and renal disease were predictors of increased mortality in some studies [30–40], but none of these factors remained associated with mortality after controlling for confounders. Overall, most studies had an overall PAB mortality rate ranging between 30–40%; in comparison this study had mortality rate of 51.8%, which is similar to the 90-day mortality rate reported in a study by Aviv *et al.* in Israel [41].

This study has several strengths and limitations. The primary strength is that it provides an easy-to-use approach for estimating mortality in PAB patients. In addition, data from the middle east are scarce and the present study provides a description of the epidemiology of an important disease in a new population. The most important limitations are the relatively small sample size and the fact that the data came from a single center.

Conclusions

In addition to prompt anti-pseudomonal empirical treatment in response to PAB, locating the primary source of infection is imperative as it can approximate the severity of the current infection and predict the mortality rate, thereby allowing the clinician to optimize the patients' treatment. Other important predictors include parameters related to recent healthcare contact such as recent insertion of a central line. Increasing antibiotic use has led to increasing rates of DTR *Pseudomonas* infections. However, antibiotic resistance has not been found to be associated with higher mortality. This poses a new challenge as it unravels a new frontier to research the feasibility of aggressive multidrug regimens in treating PAB to improve patient outcomes and decrease mortality. Future multi-centered studies are needed in the region to validate the results of the study.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the American University of Beirut.

Data availability

Study data will be made available by the principal investigator upon request.

Authors' contributions

ZAK: conceptualization, resources, methodology, investigation, validation, formal analysis, visualization, writing—review and editing, supervision; HI: software, data

curation, formal analysis, writing—original draft preparation, writing—review and editing, project administration; LK: data curation, writing—original draft preparation, project administration; MM: data curation, writing—original draft preparation, project administration; JA: data curation, writing—original draft preparation, project administration. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

No conflict of interest is declared.

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