Infection and Drug Resistance

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Association Between Red Cell Distribution Width and Mortality in Patients with *Klebsiella pneumoniae* Bloodstream Infection: A Cohort Study

Yingxiu Huang, Ting Ao, Ming Hu, Peng Zhen

Department of Infectious Disease, Beijing Luhe Hospital, Capital Medical University, Beijing, 101149, People's Republic of China

Correspondence: Peng Zhen, Department of Infectious Disease, Beijing Luhe Hospital, Capital Medical University, No. 82 Xinhua South Road, Tongzhou District, Beijing, 101149, People's Republic of China, Email zhenpeng_1130@163.com

Purpose: Despite red blood cell distribution width (RDW) is a routinely available hematological data and has been found to be associated with mortality in different diseases, the specific association of RDW on *Klebsiella pneumoniae* bloodstream infection (KP-BSI) outcome remains underexplored.

Methods: This retrospective cohort study investigates the association between RDW levels and in-hospital mortality in 267 adult patients with KP-BSI admitted to a tertiary hospital between 2019 and 2024. RDW was analyzed both as a continuous variable and categorized into tertiles. The primary outcome was in-hospital mortality. Multivariable logistic regression, subgroup analyses, and sensitivity analyses were systematically employed to investigate the association between RDW levels and mortality risk. Receiver operator characteristic (ROC) curve analysis was performed to evaluate the prognostic value of RDW for in-hospital mortality in KP-BSI.

Results: During hospitalization, 122 mortality events were recorded, constituting 45.7% of the study population (n=267). When RDW was examined as a continuous factor, a significant positive relationship was observed between RDW and mortality in the full adjusted model, the odds ratio (OR) was 1.05 (95% confidence interval [CI] (1.02~1.08), P=0.003). As RDW tertiles elevated, the incidence of mortality increased, with the OR for T3 (>50.8fL) group being higher than that for T1 (<43.2fL) group (OR: 7.63, 95% CI: 2.96–19.69; $p<0.001$) in Model 3. Subgroup and sensitivity analyses remain consistent. ROC analysis showed that RDW predicted in-hospital mortality with an AUC of 0.705.

Conclusion: High RDW values were independently associated with an increased risk of in-hospital mortality in patients with KP-BSI, indicating their potential utility as for prognostic assessment.

Keywords: red cell distribution width, RDW, bloodstream infection, *Klebsiella pneumoniae*, mortality

Introduction

Klebsiella pneumoniae (KP) is a gram-negative, encapsulated bacillus whose global burden of severe infection remains substantial, with estimates of hundreds of thousands of attributable deaths annually.[1] KP pathogenicity is mediated by multiple virulence determinants including a polysaccharide capsule that impairs phagocytosis, lipopolysaccharide (LPS) that triggers strong inflammatory responses, siderophores that enhance iron acquisition, and various adhesins and secreted effectors that facilitate tissue invasion and immune evasion.[2] Hypervirulent and multidrug-resistant strains are associated with more severe clinical courses and higher mortality.[3,4] Bloodstream infection (BSI) due to KP (KP-BSI) commonly progresses to sepsis, septic shock and multiorgan dysfunction, with reported 30-day mortality rates frequently in the range of 20~50% depending on host factors and strain virulence.[3,5–7] *Klebsiella pneumoniae* bloodstream infections (KP-BSI) are a leading cause of sepsis in hospitalized patients, with mortality rates ranging from 20% to 50% depending on host factors and pathogen virulence Immunocompromised states, older adults, and chronic comorbidities (eg, diabetes, renal failure), delays in appropriate antimicrobial treatment, delayed appropriate antimicrobial therapy and infection with resistant strains further worsen outcomes.[8–12] These observations underscore the urgent need for improved prognostic stratification tools that can guide clinical management and optimize resource allocation.

Received: 10 July 2025
Accepted: 4 November 2025
Published: 14 November 2025

Several biomarkers and clinical parameters, such as C-reactive protein (CRP), procalcitonin (PCT), and comorbidity burden, have been investigated for their prognostic value in KP-BSI.[13,14] However, these markers may not be consistently available, and their predictive accuracy remains limited. Red blood cell distribution width (RDW), a routine hematology parameter reflecting erythrocyte size heterogeneity, has emerged as an inexpensive, widely available marker associated with inflammation, oxidative stress and impaired erythropoiesis. In patients with bloodstream infection, the severe inflammatory responses elicited by bacterial infections can result in alterations to blood components, including red blood cells.[15] Emerging evidence has established RDW as a novel prognostic marker across diverse clinical conditions. Particularly, recent investigations have demonstrated significant associations between elevated RDW levels and adverse outcomes in sepsis,[16] sepsis-associated liver injury,[17] coronavirus disease 2019 (COVID-19),[18] heart failure,[19] and non-alcoholic fatty liver disease.[20] Nevertheless, the prognostic relevance of RDW, in predicting in-hospital-mortality among KP-BSI patients remains insufficiently characterized in current clinical research.

Thus, in the cohort study, we explore whether it associated KP-BSI prognosis. This approach aims to assist physicians in promptly evaluating the patient's condition and guiding further prognostic interventions. Our primary hypothesis posits that RDW levels demonstrate significant prognostic associations with clinical outcomes in patients with KP-BSI.

Materials and Methods

Data Source

This retrospective analysis was performed at Beijing Luhe Hospital, Capital Medical University (Beijing, China), targeting patients with *Klebsiella pneumoniae* bloodstream infections (KP-BSI). Beijing Luhe Hospital is a tertiary hospital with 1300 inpatient beds, located in eastern Beijing, China. The study encompassed a six-year period from January 2019 through December 2024, with all individuals meeting KP-BSI diagnostic criteria at this tertiary center being systematically enrolled. The study was conducted in accordance with the Declaration of Helsinki, and received approval from the Ethics Committee of Beijing Luhe Hospital, Capital Medical University (NO. 2025-LHKY-017-01). The ethics committee approved the retrospective study as anonymous, thus waiving informed consent. The studies were conducted in accordance with the local legislation and institutional requirements. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines in reporting this study.[21]

Study Population

Clinical data of each patient were obtained from the electronic medical record system. This database was built using patients' clinical records after removing any personally identifiable information. The criteria for inclusion were: 1) A diagnosis of KP-BSI was established when *Klebsiella pneumoniae* was isolated from at least one positive blood culture, with the samples preserved in our laboratory. Only patients with compatible clinical manifestations of bloodstream infection were included, while cases deemed to represent contamination were excluded. 2) age >18 years, 3) complete data of the complete blood cell analysis. For patients with multiple positive culture results, data from only their first culture was incorporated. Patients younger than 18 years, incomplete data, or unspecified infections, were excluded from the study. Figure 1 showed the flow chart of the study.

Microbiological Tests

All clinical isolates underwent standardized species identification and antibiotic susceptibility profiling via the VITEK 2 Compact platform (bioMérieux, France). Antimicrobial susceptibility testing panels were calibrated in accordance with Clinical and Laboratory Standards Institute (CLSI-M100) interpretive criteria for standardized antibiotic resistance profiling.[22]

Variable Extraction

RDW

RDW was evaluated and entered into the clinical records within 24 hours of blood culture. RDW was analyzed as both continuous and categorical variables. Patients were classified into 3 groups based on tertile of RDW: T1 < 43.3fL, T2 43.3–50.8 fL, T3> 50.8fL.

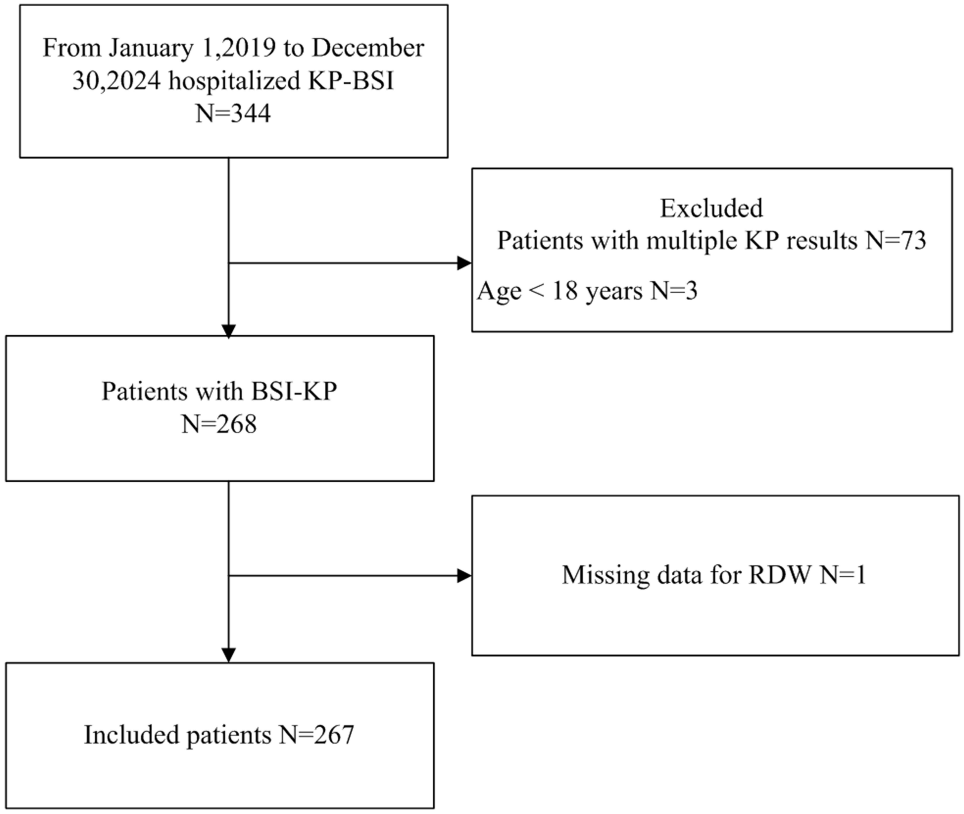

Figure 1 Flow chart of study. KP-BSI *Klebsiella pneumoniae* bloodstream infections.

Covariates

Demographic data, such as gender and age, comorbidities included diabetes, septic shock, malignant tumor, hematological indices collected at the time of blood culture, including the C-reactive protein (CRP), creatinine, albumin, white blood cell (WBC) count, platelet, were assessed and recorded in the clinical records within 24 hours of blood culture. Treatments included continuous renal replacement therapy (CRRT), use of ventilator. Microorganism factors included carbapenem-resistant *Klebsiella pneumoniae* (CRKP). The severity of the disease includes the sequential organ failure assessment (SOFA) score. Other covariates included: intensive care unit (ICU) admission, nosocomial infection, infection site. Septic shock was defined according to the Sepsis-3 consensus as persistent hypotension requiring vasopressors to maintain a mean arterial pressure of ≥65 mmHg, together with a serum lactate level >2 mmol/L despite adequate fluid resuscitation.

Outcomes

The primary outcome was in-hospital mortality.

Statistical Analysis

Descriptive statistics were performed for all patients. Categorical variables were presented as counts and percentages, while continuous variables were reported as means with standard deviations (SD) for normally distributed data or as medians with interquartile ranges for skewed distributions. The chi-square test, one-way ANOVA, and Kruskal–Wallis test was employed to compare categorical, normally distributed, and non-normally distributed continuous variables, respectively. Missing covariates were less than 1%, so we did not perform any imputation. We conducted multivariable logistic regression analyses and to explore the independent relationship between RDW and in-hospital death. Covariates were selected for multivariable adjustment based on a combination of prior literature, statistical significance in univariate analyses, and clinical relevance. Model 1 was crude. Model 2 was adjusted for sex and age. Model 3 was adjusted further for Adjusted for sex, age, diabetes, malignant tumor, chronic kidney disease, central venous catheter placement (CVC), septic shock, white blood cell (WBC), HCT, PCT, albumin. based on Model 2. Tests for trend were performed by incorporating the median value of each tertile as a continuous variable in the models. Additionally, we performed subgroup analysis and sensitivity analysis to explore the effects within specific populations. The same set of covariates was consitently applied in multivariable logistic regression Model 3, as well as in Figure 2, subgroup and sensitivity analyses to ensure comparability and interpretability. To evaluate the discriminative ability of RDW for predicting in-hospital mortality, receiver operating characteristic (ROC) curve analysis was performed. The area under the ROC curve (AUC) and its 95% confidence interval were calculated to quantify the model's predictive performance.

All analyses were performed using the R statistical software, version 4.3.2 (http://www.R-project.org, The R Foundation) and Free Statistics software version 2.2.0.[23] A two-tailed test was utilized, and a p-value of less than 0.05 was deemed statistically significant.

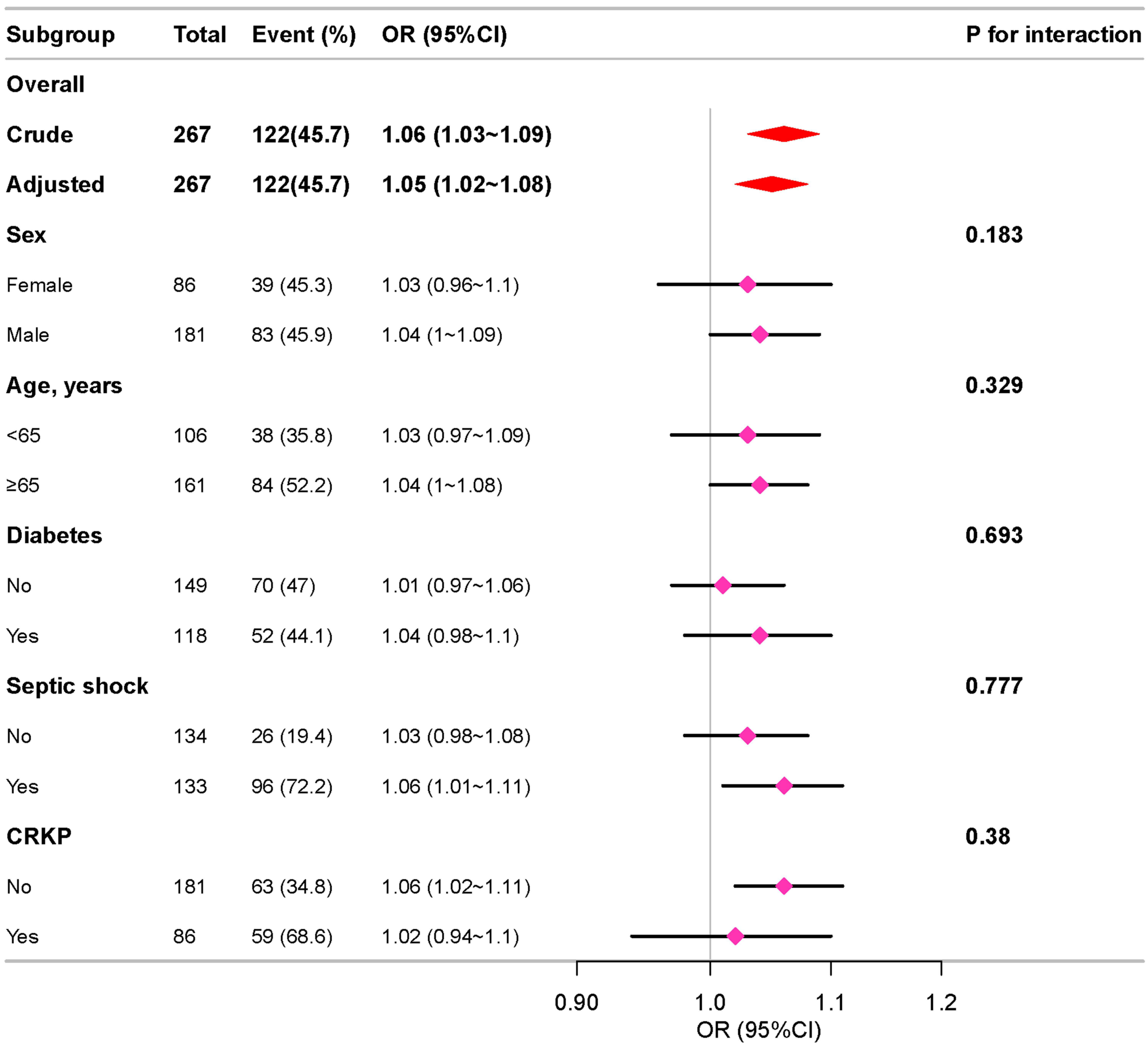

Figure 2 Subgroup analyses of RDW associated with mortality in patients with KP-BSI. Odds ratios (ORs) were adjusted for sex, age, diabetes, malignant tumor, chronic kidney disease, CVC, septic shock, WBC, hematocrit, procalcitonin, albumin.

Abbreviations: RDW, red cell distribution width; KP-BSI, *Klebsiella pneumoniae* bloodstream infections; CVC, central venous catheter placement; WBC, white blood cell; CRKP, carbapenem-resistant *Klebsiella pneumoniae*; CRRT, continuous renal replacement therapy.

Results

Baseline Characteristics of Participants

The characteristics of participants with KP-BSI were analyzed according to the tertiles of RDW (Table 1). Within the original cohort 267 patients were included in our study. Among all these patients, the average age of the participants was 65.9 years and 67.5% were men (Table 1). A total of 122 patients died in, resulting in a mortality rate of 45.7%. Non-survivors were older and had higher rates of CRKP infection, septic shock, ICU admission, CRRT, and mechanical ventilation. They also had higher RDW, CRP, PCT, serum creatinine, and SOFA scores, and lower albumin levels (Supplementary table S1).

The Association Between RDW and In-Hospital Mortality

Table 2 presents the findings from the multivariable logistic regression analysis regarding the association between RDW and mortality in KP-BSI patients. When RDW was examined as a continuous factor, a significant independent positive relationship was observed between RDW and mortality in the unadjusted model (OR: 1.06, 95% CI:1.03–1.09; $p < 0.001$). Furthermore,

Table 1 Baseline Characteristics of KP-BSI Patients

Variables	Total (n = 267)	RDW Tertile (fL)			P value
		T1 (<43.3) (n = 84)	T2 (43.3–50.8) (n = 92)	T3 (>50.8) (n = 91)	
Age, years	65.9 ± 13.8	62.6 ± 13.4	66.3 ± 13.8	68.5 ± 13.7	0.018
Sex, male, n (%)	181 (67.8)	52 (61.9)	63 (68.5)	66 (72.5)	0.319
CRKP, n (%)	86 (32.2)	13 (15.5)	28 (30.4)	45 (49.5)	< 0.001
Diabetes, n (%)	118 (44.2)	48 (57.1)	41 (44.6)	29 (31.9)	0.003
Chronic heart failure, n (%)	39 (14.6)	4 (4.8)	15 (16.3)	20 (22)	0.005
Chronic liver disease, n (%)	26 (9.7)	4 (4.8)	6 (6.5)	16 (17.6)	0.007
Chronic kidney disease, n (%)	39 (14.6)	9 (10.7)	8 (8.7)	22 (24.2)	0.006
Hematological disease, n (%)	30 (11.2)	19 (22.6)	2 (2.2)	9 (9.9)	< 0.001
Malignant tumor, n (%)	48 (17.9)	13 (15.5)	16 (17.2)	19 (20.9)	0.633
CVC, n (%)	119 (44.6)	21 (25)	46 (50)	52 (57.1)	< 0.001
Admitted to ICU, n (%)	160 (59.9)	27 (32.1)	68 (73.9)	65 (71.4)	< 0.001
Ventilator use, n (%)	138 (51.7)	20 (23.8)	59 (64.1)	59 (64.8)	< 0.001
CRRT, n (%)	47 (17.6)	7 (8.3)	19 (20.7)	21 (23.1)	0.025
Nosocomial infection, n (%)	112 (41.9)	17 (20.2)	43 (46.7)	52 (57.1)	< 0.001
Septic shock, n (%)	133 (49.8)	34 (40.5)	50 (54.3)	49 (53.8)	0.129
Pneumonia, n (%)	140 (52.4)	35 (41.7)	53 (57.6)	52 (57.1)	
Urinary tract infection, n(%)	58 (21.7)	16 (19)	23 (25)	19 (20.9)	0.641
Intra-abodominal infection, n (%)	27 (10.1)	2 (2.4)	7 (7.6)	18 (19.8)	< 0.001
Soft tissue infection, n (%)	23 (8.6)	7 (8.3)	7 (7.6)	9 (9.9)	0.845
WBC, 10^9/L	10.1 (6.1, 15.3)	8.5 (4.4, 14.1)	11.6 (6.5, 16.2)	9.2 (6.1, 15.8)	0.023
Hematocrit	0.300 ± 0.084	0.314 ± 0.087	0.310 ± 0.085	0.278 ± 0.076	0.007
Platelet, 10^9/L	132.0 (51.0, 210.5)	111.5 (38.5, 207.0)	137.0 (55.5, 200.0)	137.0 (66.0, 214.5)	0.533
CRP, mg/L	162.4 ± 81.8	176.0 ± 82.5	169.1 ± 78.7	143.2 ± 81.6	0.018
Procalcitonin, ng/mL	9.8 (3.2, 25.8)	11.7 (4.6, 24.2)	10.1 (2.9, 28.5)	7.3 (2.3, 20.0)	0.169
Albumin, g/L	29.9 ± 12.2	33.4 ± 19.8	29.0 ± 5.6	27.4 ± 4.8	0.004
Creatinine, umol/L	95.0 (61.2, 193.2)	81.5 (56.8, 136.0)	104.5 (73.0, 194.0)	115.5 (63.0, 252.5)	0.006
SOFA score	7.3 ± 4.4	5.6 ± 3.8	7.6 ± 4.4	8.4 ± 4.4	< 0.001
Length of stay, days	19.0 (10.0, 34.0)	16.5 (9.0, 30.0)	19.0 (9.8, 34.0)	23.0 (11.0, 43.5)	0.209
Outcome					
Mortality, n (%)	122 (45.7)	17 (20.2)	46 (50)	59 (64.8)	< 0.001

Notes: Categorical variables are presented as counts and percentages (n, %), normally distributed continuous variables as mean ± standard deviation (SD), and non-normally distributed continuous variables as median with interquartile range (IQR).

Abbreviations: RDW, red blood cell distribution width; CRKP, carbapenem-resistant *Klebsiella pneumoniae*; ICU, intensive care unit; CRRT, continuous renal replacement therapy; WBC, white blood cell; CRP C,-reactive protein; SOFA, sequential organ failure assessment.

Table 2 Association Between RDW and Morality in Patients with KP-BSI

Variable	n.event %	Model 1		Model 2		Model 3	
		OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
RDW continuous (fL)	122 (45.7)	1.06 (1.03~1.09)	<0.001	1.05 (1.03~1.08)	<0.001	1.05(1.02~1.08)	0.003
RDW tertile (fL)							
T1 (<43.3)	17 (20.2)	1(Ref)		1(Ref)		1(Ref)	
T2 (43.3–50.8)	46 (50)	3.94 (2.01~7.71)	<0.001	3.79 (1.9~7.6)	<0.001	3.6 (1.51~8.61)	0.04
T3 (>50.8)	59 (64.8)	7.27 (3.66~14.41)	<0.001	6.53 (3.2~13.31)	<0.001	7.63 (2.96~19.69)	<0.001
P for trend			<0.001		<0.001		<0.001

Notes: Model 1: Unadjusted. Model 2: Adjusted for sex, age. Model 3: Adjusted for sex, age, diabetes, malignant tumor, chronic kidney disease, CVC, septic shock, WBC, hematocrit, procalcitonin, albumin. n.event % represents the number and percentage of in-hospital deaths within each RDW tertile.
Abbreviations: RDW, red cell distribution width; KP-BSI, *Klebsiella pneumoniae* bloodstream infections; CVC, central venous catheter placement; WBC, white blood cell.

additional adjustments did not substantially alter these findings. Following adjustments for sex, age, diabetes, malignant tumor, chronic kidney disease, CVC, septic shock, WBC, hematocrit, procalcitonin, albumin and SOFA score in model 3, the adjusted OR was 1.05 (95% CI 1.02–1.08, *p*=0.003). As RDW tertiles elevated, the incidence of mortality increased, with the OR for T3 being higher than that for T1 (OR: 7.27, 95% CI: 3.66–14.41; *p*<0.001, model 1) in the crude model, and the association between RDW and mortality is statistically significant (OR: 7.63, 95% CI: 2.69–19.69; *p*<0.001) in Model 3. The p-values for the trend tests were all less than 0.001 across all three models.

Subgroup Analysis

In this study, we conducted stratified and interaction analyses to assess whether the relationship between RDW levels and mortality incidence was consistent across different subgroups. Stratified analysis indicated that the results remained consistent across the groups when categorized by sex, age, diabetes, septic shock, CRKP. Interaction analysis indicated that there was no interaction between RDW and the subgroups (p for interaction were both >0.05) (Figure 2).

Sensitivity Analysis

To confirm the robustness of our results, we performed sensitivity analyses excluding patients with hematological diseases, chronic heart failure, or chronic liver disease, with additional adjustment for SOFA score. As shown in Table 3, RDW remained significantly associated with in-hospital mortality.

Receiver Operating Characteristic (ROC) Curve Analysis

The discriminative ability of RDW, CRP, and PCT for predicting in-hospital mortality in patients with KP-BSI was assessed using receiver operating characteristic (ROC) curve analysis. As shown in Figure 3, RDW demonstrated the highest predictive value with an AUC of 0.705 (95% CI: 0.641–0.766), followed by PCT with an AUC of 0.698 (95% CI: 0.635–0.761), whereas CRP showed a relatively lower predictive ability with an AUC of 0.632 (95% CI: 0.565–0.699). These results suggest that RDW may serve as a moderate prognostic marker compared to CRP and PCT in this patient population.

Discussion

In this retrospective cohort study, we aimed to investigate the association between RDW and in-hospital mortality in patients with KP-BSI. A positive relationship was identified between RDW and mortality within the cohort. Our research confirms the clinical utility of RDW in enhancing mortality risk assessment for patients with KP-BSI.

The RDW quantifies variability in erythrocyte volumes within the bloodstream. Elevated RDW levels frequently originate from hematological disturbances that modify erythrocytic morphology or accelerate premature erythrocyte release into systemic circulation. Emerging clinical research has validated RDW as a prognostic parameter across different diseases, including COVID-19,[18,24] sepsis,[16,25,26] sepsis associated liver injury,[17] severe osteomyelitis,[27] heart failure,[19] and non-

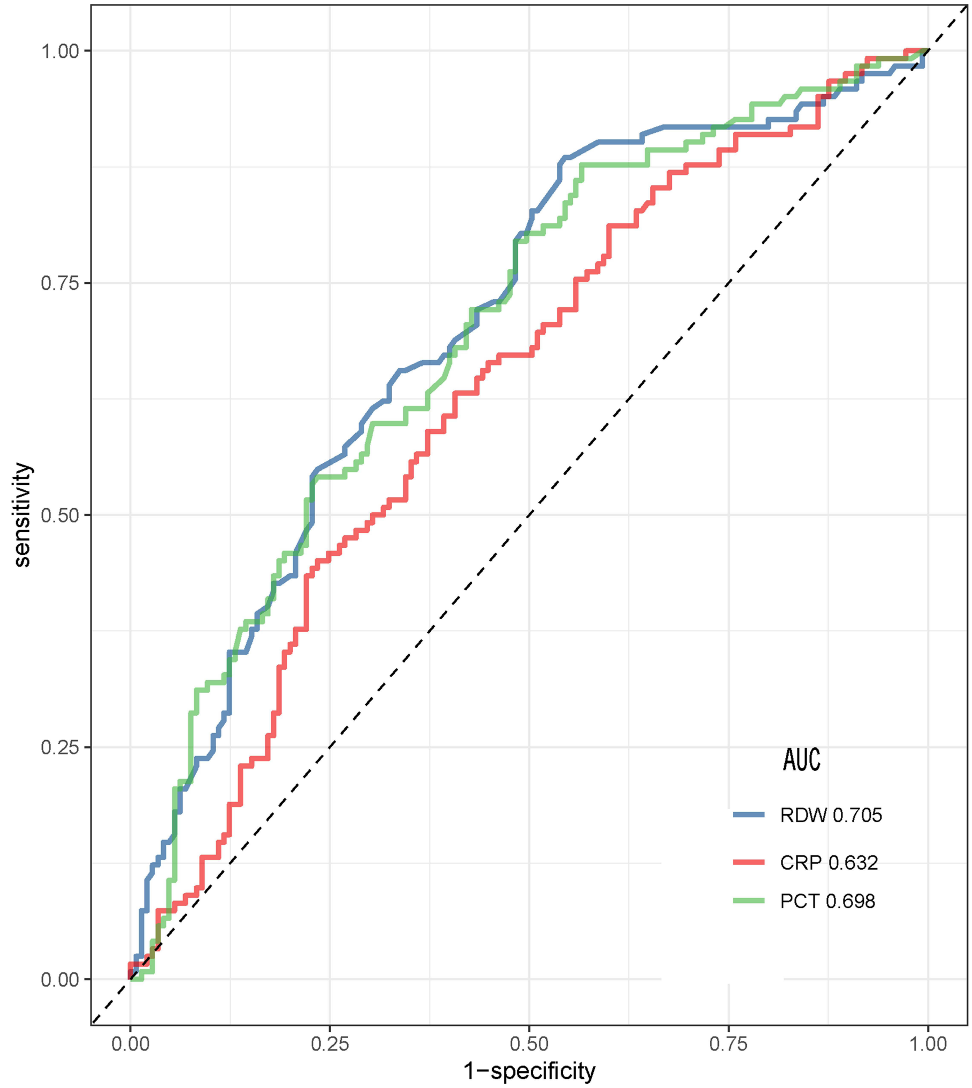

Figure 3 Receiver Operating Characteristic (ROC) Curves Assessing RDW's Predictive Performance for In-Hospital Mortality.
Abbreviations: AUC, area under the curve; RDW, red cell distribution width.

alcoholic fatty liver disease.[20] For example, Wu[26] et al analyzed data from 256,387 critically ill septic patients and revealed that those with an RDW >16% exhibited a significantly higher mortality risk, with a hazard ratio (HR) of 1.887 (95% CI, 1.847–1.928) in comparison to patients with an RDW < 16%. Liu et al[27] included 1109 patients with osteomyelitis, and founded that elevated RDW levels increased risk of mortality (HR = 2.128, 95% CI 1.324–3.420). Furthermore, Chun-Fu Yeh et al[28] have reported that RDW is an independent predictor of 28-day mortality in patients visiting the emergency department with BSI. These studies focused on various disease populations and indicated significant associations of higher RDW with adverse outcomes. These studies, covering diverse patient populations, consistently demonstrated that elevated RDW is associated with adverse outcomes. To our knowledge, this is the first study to specifically evaluate the association between RDW and mortality in patients with KP-BSI. Our findings are consistent with prior reports and provide strong evidence that elevated RDW independently predicts in-hospital mortality in this population.

The biological mechanisms between elevated RDW and adverse outcomes in KP-BSI patients remains unclear. The possible mechanisms between RDW and mortality risk in KP-BSI emerges from a tripartite interplay of erythrocyte dysregulation, systemic inflammation, and microbial virulence factors. First, LPS from KP can induce pyroptosis in erythroid

Table 3 Sensitivity Analysis

Variable	n.total	n.event_%	Crude Model		Adjusted Model	
			OR (95% CI)	P value	OR (95% CI)	P value
Excluding patients with hematological disease						
RDW continuous (fL)	238	109 (45.8)	1.07 (1.04~1.11)	<0.001	1.05 (1~1.1)	0.035
RDW tertile (fL)						
T1(<43.3)	65	13 (20)	1(Ref)		1(Ref)	
T2 (43.3–50.8)	91	44 (48.4)	3.74 (1.8~7.8)	<0.001	3.03 (1.16~7.89)	0.023
T3 (>50.8)	82	52 (63.4)	6.93 (3.26~14.76)	<0.001	8.08 (2.73~23.87)	<0.001
Excluding patients with liver disease						
RDW continuous (fL)	228	98 (43)	1.05 (1.02~1.08)	<0.001	1.04 (1.01~1.08)	0.012
RDW tertile (fL)						
T1(<43.3)	80	17 (21.2)	1(Ref)		1(Ref)	
T2 (43.3–50.8)	77	39 (50.6)	3.8 (1.89~7.64)	<0.001	3.03 (1.23~7.46)	0.016
T3 (>50.8)	71	42 (59.2)	5.37 (2.63~10.97)	<0.001	5.92 (2.18~16.1)	<0.001
Excluding patients with chronic heart failure						
RDW continuous (fL)	241	109 (45.2)	1.06 (1.03~1.09)	<0.001	1.04 (1.01~1.08)	0.012
RDW tertile (fL)						
T1(<43.3)	80	17 (21.2)	1(Ref)		1(Ref)	
T2 (43.3–50.8)	86	44 (51.2)	3.88 (1.96~7.68)	<0.001	3.7 (1.52~9.02)	0.004
T3 (>50.8)	75	48 (64)	6.59 (3.23~13.45)	<0.001	5.77 (2.15~15.47)	<0.001
Additional adjustment for SOFA score based on Model 3 in Table 2						
RDW continuous (fL)	267	122(45.7)	1.06 (1.03~1.09)	<0.001	1.06 (1.01~1.12)	0.011
RDW tertile (fL)						
T1(<43.3)	84	17 (20.2)	1(Ref)		1(Ref)	
T2 (43.3–50.8)	92	46 (50)	3.94 (2.01~7.71)	<0.001	1.79 (0.45~7.07)	0.408
T3 (>50.8)	91	59 (64.8)	7.27 (3.66~14.41)	<0.001	5.74 (1.23~26.82)	0.026

Note: Adjusted for sex, age, diabetes, malignant tumor, chronic kidney disease, CVC, septic shock, WBC, hematocrit, procalcitonin, albumin.

Abbreviations: RDW, red cell distribution width; KP-BSI, *Klebsiella pneumoniae* bloodstream infections; CVC, central venous catheter placement; WBC, white blood cell.

precursors, leading to increased phosphatidylserine exposure and subsequent clearance of damaged red blood cells by macrophages.[29,30]. This elevates RDW as spleen macrophages target damaged red cells.[31] Second, Infection triggers the release of pro-inflammatory cytokines such as interleukin-1 (IL-1), IL-6, and tumor necrosis factor-alpha (TNF-α), which can disrupt erythropoiesis by inhibiting red blood cell maturation and promoting the release of reticulocytes into the peripheral blood. This disruption contributes to an increase in RDW.[32] Third, The presence of LPS on the surface of KP can activate Toll-like receptor 9 (TLR9) in erythroblasts, impairing enucleation and leading to erythropoietic dysfunction.[33] Additionally, oxidative stress during infection generates reactive oxygen species (ROS) and reactive nitrogen species (RNS), which can damage red blood cell membranes, alter their deformability, and shorten their lifespan. These changes contribute to an increase in RDW and may exacerbate organ dysfunction and mortality.[34,35] Moreover, oxidative stress can also damage other tissue cells, impair organ function, worsen the condition, and increase the risk of death.[36] While RDW serves as a valuable prognostic marker, it should not be used in isolation. Our study's findings are consistent with existing literature; however, further research is needed to elucidate the molecular mechanisms linking RDW to mortality in KP-BSI patients and to assess its utility in conjunction with other clinical parameters for comprehensive risk stratification.

Our study has several advantages: First, this is the first study to examine the connection between RDW and mortality among Chinese patients suffering from KP-BSI. Second, we utilized various statistical methods, including logistic regression and analysis of subgroups, to confirm the robustness of the findings. However, several limitations of the present study should be acknowledged. First, the research was conducted at a single center in China and utilized a retrospective design, which may limit its accuracy compared to more rigorous multicenter prospective studies from various countries. Second, there is a risk of selection bias due to the study's reliance on a single measurement of RDW, with no follow-up assessments. This approach precludes analysis of how RDW levels at different time points may have influenced the outcomes. Additional research is needed to explore the mechanisms underlying the relationship between RDW and clinical outcomes in patients with KP-BSI. Conducting more multicenter studies on this readily accessible variable would be crucial for the early identification of outcomes, ultimately benefiting treatment strategies.

Conclusion

To summarize, RDW was associated with the prognosis of KP-BSI patients at the time of blood culture collection. Patients with KP-BSI and high RDW levels demonstrated a higher mortality rate. Therefore, RDW may act as an independent risk factor for predicting outcomes in individuals with KP-BSI.

Data Sharing Statement

The original contributions presented in this study are included in this article/supplementary material, further inquiries can be directed to the corresponding author.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Beijing Luhe Hospital, Capital Medical University (NO. 2025-LHKY-017-01). As this study was retrospective, informed consent was waived by my ethics committee.

Acknowledgments

The authors sincerely thank the Physician Scientist Team for their enthusiastic and meticulous teaching and guidance on data analysis.

Author Contributions

All authors made a significant contribution to the work reported, whether that is 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 has been submitted; and agree to be accountable for all aspects of the work.

Funding

There is no funding to report.

Disclosure

The authors declare that they have no competing interests.

References

1. GBD 2019 Antimicrobial Resistance Collaborators. Global mortality associated with 33 bacterial pathogens in 2019: a systematic analysis for the global burden of disease study 2019. *Lancet Lond Engl*. 2022;400:2221–2248. doi:10.1016/S0140-6736(22)02185-7
2. Abbas R, Chakkour M, Zein El Dine H, et al. General overview of Klebsiella pneumonia: epidemiology and the role of siderophores in its pathogenicity. *Biology*. 2024;13:78. doi:10.3390/biology13020078
3. Li D, Huang X, Rao H, et al. Klebsiella pneumoniae bacteremia mortality: a systematic review and meta-analysis. *Front Cell Infect Microbiol*. 2023;13:1157010. doi:10.3389/fcimb.2023.1157010

4. Hala S, Malaikah M, Huang J, et al. The emergence of highly resistant and hypervirulent Klebsiella pneumoniae CC14 clone in a tertiary hospital over 8 years. *Genome Med*. 2024;16:58. doi:10.1186/s13073-024-01332-5
5. Yu X, Zhao Y, Sun X, et al. Association between clinical-biological characteristics of Klebsiella pneumoniae and 28-day mortality in patients with bloodstream infection. *BMC Microbiol*. 2024;24:552. doi:10.1186/s12866-024-03714-6
6. Ramos-Castañeda JA, Ruano-Ravina A, Barbosa-Lorenzo R, et al. Mortality due to KPC carbapenemase-producing Klebsiella pneumoniae infections: systematic review and meta-analysis: mortality due to KPC Klebsiella pneumoniae infections. *J Infect*. 2018;76:438–448. doi:10.1016/j.jinf.2018.02.007
7. Li Y, Li J, Hu T, et al. Five-year change of prevalence and risk factors for infection and mortality of carbapenem-resistant Klebsiella pneumoniae bloodstream infection in a tertiary hospital in North China. *Antimicrob Resist Infect Control*. 2020;9:79. doi:10.1186/s13756-020-00728-3
8. Van Heuverswyn J, Valik JK, Desirée van der Werff S, et al. Association between time to appropriate antimicrobial treatment and 30-day mortality in patients with bloodstream infections: a retrospective cohort study. *Clin Infect Dis off Publ Infect Dis Soc Am*. 2023;76:469–478. doi:10.1093/cid/ciac727
9. Fostervold A, Raffelsberger N, Hetland MAK, et al. Risk of death in Klebsiella pneumoniae bloodstream infections is associated with specific phylogenetic lineages. *J Infect*. 2024;88:106155. doi:10.1016/j.jinf.2024.106155
10. Varon B, Palacios-Baena ZR, de Kraker ME, et al. Universal Risk Factors for Mortality in Bloodstream Infections (UNIFORM): a systematic review and Delphi survey. *Clin Microbiol Infect Dis*. 2024;30:453–461. doi:10.1016/j.cmi.2023.12.030
11. Şimşek Bozok T, Bozok T, Şahinoğlu MS, et al. Bloodstream infections caused by carbapenem-resistant Klebsiella pneumoniae: analysis of risk factors, treatment responses and mortality. *Infect Dis Lond Engl*. 2025;57:350–360. doi:10.1080/23744235.2024.2436991
12. Meini S, Del Cesta R, Sbrana F, et al. Clinical outcomes of patients hospitalized in internal medicine wards adequately treated for bloodstream infections caused by NDM-producing Klebsiella pneumoniae. Results from a real-life retrospective multi-center study in an endemic area. *Infection*. 2025;53(5):1737–1744. doi:10.1007/s15010-025-02488-x
13. hertz FB, Ahlström MG, Bestle MH, et al. Early biomarker-guided prediction of bloodstream infection in critically ill patients: c-reactive protein, procalcitonin, and leukocytes. *Open Forum Infect Dis*. 2022;9:ofac467. doi:10.1093/ofid/ofac467
14. Gao Y, Lin H, Xu Y, et al. Prognostic risk factors of carbapenem-resistant gram-negative bacteria bloodstream infection in immunosuppressed patients: a 7-year retrospective cohort study. *Infect Drug Resist*. 2022;15:6451–6462. doi:10.2147/IDR.S386342
15. Fagerberg SK, Patel P, Andersen LW, et al. Erythrocyte P2X1 receptor expression is correlated with change in haematocrit in patients admitted to the ICU with blood pathogen-positive sepsis. *Crit Care*. 2018;22:181. doi:10.1186/s13054-018-2100-3
16. Wang J, He L, Jin Z, et al. Immune dysfunction-associated elevated RDW, APACHE-II, and SOFA scores were a possible cause of 28-day mortality in sepsis patients. *Infect Drug Resist*. 2024;17:1199–1213. doi:10.2147/IDR.S442169
17. Ao T, Huang Y, Zhen P, Hu M. Association between red cell distribution width and 30-day mortality in patients with sepsis-associated liver injury: a retrospective cohort study. *Front Med*. 2024;11:1510997. doi:10.3389/fmed.2024.1510997
18. Mompiere AD, Noble JLMLL, Fleuren-Janssen M, et al. Increased red cell distribution width predicts mortality in COVID-19 patients admitted to a Dutch intensive care unit. *Acute Crit Care*. 2024;39:359–368. doi:10.4266/acc.2023.01137
19. Kim M, Lee CJ, Kang H-J, et al. Red cell distribution width as a prognosticator in patients with heart failure. *ESC Heart Fail*. 2023;10:834–845. doi:10.1002/ehf2.14231
20. Huang Y, Ao T, Wang Y, Zhen P, Hu M. The red blood cell distribution width is associated with all-cause and cardiovascular mortality among individuals with non-alcoholic fatty liver disease. *PLoS One*. 2025;20:e0321789. doi:10.1371/journal.pone.0321789
21. von Elm E, Altman DG, Egger M, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet Lond Engl*. 2007;370:1453–1457. doi:10.1016/S0140-6736(07)61602-X
22. Chen J, Allel K, Zhuo C, et al. Extended-spectrum β-lactamase-producing escherichia coli and Klebsiella pneumoniae: risk Factors and economic burden among patients with bloodstream infections. *Risk Manag Healthc Policy*. 2024;17:375–385. doi:10.2147/RMHP.S453686
23. Huang Y, Ao T, Zhen P, Hu M. Association between serum bicarbonate and 28-day mortality in critically ill patients with infective endocarditis: a cohort study from MIMIC-IV. *Sci Rep*. 2025;15:312. doi:10.1038/s41598-024-84385-1
24. Foy BH, Carlson JCT, Reinertsen E, et al. Association of red blood cell distribution width with mortality risk in hospitalized adults with SARS-CoV-2 infection. *JAMA Network Open*. 2020;3:e2022058. doi:10.1001/jamanetworkopen.2020.22058
25. Wu H, Liao B, Cao T, et al. Diagnostic value of RDW for the prediction of mortality in adult sepsis patients: a systematic review and meta-analysis. *Front Immunol*. 2022;13:997853. doi:10.3389/fimmu.2022.997853
26. Wu Y-C, Chen -H-H, Chao W-C. Association between red blood cell distribution width and 30-day mortality in critically ill septic patients: a propensity score-matched study. *J Intensive Care*. 2024;12(34). doi:10.1186/s40560-024-00747-x
27. Liu Y, Zheng Y, Ding S. Association between red blood cell distribution width and mortality in severe osteomyelitis patients. *Sci Rep*. 2025;15:360. doi:10.1038/s41598-024-82891-w
28. Yeh C-F, Chen K-F, Ye -J-J, Huang C-T. Derivation of a clinical prediction rule for bloodstream infection mortality of patients visiting the emergency department based on predisposition, infection, response, and organ dysfunction concept. *J Microbiol Immunol Infect*. 2014;47:469–477. doi:10.1016/j.jmii.2013.06.012
29. Holmes CL, Albin OR, Mobley HLT, Bachman MA. Bloodstream infections: mechanisms of pathogenesis and opportunities for intervention. *Nat Rev Microbiol*. 2025;23:210–224. doi:10.1038/s41579-024-01105-2
30. Zierke L, Mourad R, Kohler TP, Müsken M, Hammerschmidt S. Influence of the polysaccharide capsule on virulence and fitness of Klebsiella pneumoniae. *Front Microbiol*. 2025;16. doi:10.3389/fmicb.2025.1450984
31. Li H, Qiang Y, Li X, et al. Biomechanics of phagocytosis of red blood cells by macrophages in the human spleen. *Proc Natl Acad Sci U S A*. 2024;121:e2414437121. doi:10.1073/pnas.2414437121
32. Morceau F, Dicato M, Diederich M. Pro-inflammatory cytokine-mediated anemia: regarding molecular mechanisms of erythropoiesis. *Mediators Inflamm*. 2009;2009:405016. doi:10.1155/2009/405016
33. Kou M, Wang L. Surface toll-like receptor 9 on immune cells and its immunomodulatory effect. *Front Immunol*. 2023;14:1259989. doi:10.3389/fimmu.2023.1259989
34. Orrico F, Laurance S, Lopez AC, et al. Oxidative Stress in Healthy and Pathological Red Blood Cells. *Biomolecules*. 2023;13(8):1262. doi:10.3390/biom13081262

35. Pizzino G, Irrera N, Cucinotta M, et al. Oxidative stress: harms and benefits for human health. *Oxid Med Cell Longev*. 2017;2017:8416763. doi:10.1155/2017/8416763
36. Xu X, Pang Y, Fan X. Mitochondria in oxidative stress, inflammation and aging: from mechanisms to therapeutic advances. *Signal Transduct Target Ther*. 2025;10:190. doi:10.1038/s41392-025-02253-4