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Hematologic predictors of in-hospital mortality in chronic hemodialysis patients with catheter-related bloodstream infections

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ABSTRACT

Background: Catheter-related bloodstream infections (CRBSIs) are a significant cause of morbidity and mortality in patients undergoing chronic hemodialysis. Identifying reliable prognostic markers is essential for early risk stratification and clinical decision-making.

Methods: This retrospective study included 147 patients with end-stage renal disease receiving chronic hemodialysis via central venous catheter who were hospitalized with confirmed CRBSIs between 2020 and 2024. Demographic, clinical, and laboratory data were collected on admission and on the third day of hospitalization. Inflammatory markers such as white blood cell count (WBC), neutrophil count, mean platelet volume (MPV), and derived indices including neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and lymphocyte-to-monocyte ratio (LMR) were evaluated in relation to in-hospital mortality.

Results: Thirteen patients (8.8%) died during hospitalization. Age, WBC, neutrophil count, and MPV were significantly higher in the mortality group ($p<0.01$). While NLR and PLR on admission were not significantly different, third-day PLR values were significantly lower in non-survivors ($p=0.033$), showing moderate predictive performance (AUC = 0.679). Point biserial correlation and ROC analysis supported the prognostic utility of WBC, neutrophils, and PLR.

Conclusions: Age, WBC, neutrophils, MPV, and third-day PLR are potential prognostic markers for in-hospital mortality in hemodialysis patients with CRBSIs. Dynamic monitoring of these hematologic indices may support early clinical decision-making.

Keywords: biomarkers, catheter-related infections, mortality, neutrophils, renal dialysis

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INTRODUCTION

Chronic kidney disease (CKD), with a global prevalence of approximately 9%, is one of the most common chronic illnesses and represents an increasing health burden worldwide [1]. The prevalence of end-stage renal disease (ESRD) is also on the rise, with more than 80% of these patients undergoing hemodialysis. Among them, approximately 80% use a central venous catheter (CVC) for vascular access during hemodialysis [2]. One of the most significant risks associated with hemodialysis catheters is bloodstream infections, which are linked to increased morbidity, prolonged hospitalization, and higher mortality rates [3]. Compared to arteriovenous fistulas, the risk of bloodstream infections is approximately eight times higher with catheter use [4]. Moreover, catheter-related bloodstream infections (CRBSIs) continue to represent a substantial healthcare burden across both adult and pediatric populations, despite advancements in prevention and infection control [5,6].

Due to inconsistencies in defining CRBSIs, a multidisciplinary expert panel proposed diagnostic criteria in 2018 for identifying hemodialysis CRBSIs. These criteria include: clinical suspicion of infection (fever> 37.5°C, chills, altered mental status, or new-onset pre-dialysis hypotension [systolic blood pressure <90 mm Hg]), confirmation of bacteremia (positive blood cultures yielding the same organism from both the hemodialysis catheter and a peripheral vein or dialysis blood line), and exclusion of any alternative source of infection [7].

Catheter-related infections are associated with increased mortality, and factors such as inadequate antimicrobial therapy and Staphylococcus aureus bacteremia have been shown to contribute to higher mortality rates [8,9]. Data on the prognostic value of hematologic markers in predicting mortality – particularly among hemodialysis patients with CRBSIs – remain limited. This study aims to address this gap by evaluating the clinical utility of these routinely available indices.

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METHODS

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Antalya Training and Research Hospital (Decision Date: 27/03/2025, Decision No: 6/7). As this was a retrospective study, the requirement for informed consent was waived by the ethics committee.

This retrospective observational study included patients hospitalized between January 1, 2020, and December 31, 2024, based on a review of hospital records and the electronic medical database. The primary objective was to identify clinical and laboratory markers associated with in-hospital mortality among individuals with ESRD receiving maintenance hemodialysis via central venous catheter who were admitted due to catheter-related bloodstream infections (CRBSIs).

Eligible participants were adults (≥18 years), non-pregnant, on chronic hemodialysis through a central venous catheter, and presenting with clinical or laboratory evidence suggestive of catheter-related infection, confirmed by isolation of the same pathogen in both catheter and peripheral blood cultures. Patients younger than 18 years, pregnant women, and those undergoing dialysis with an arteriovenous fistula were excluded.

On admission and on the third day of hospitalization, we recorded demographic variables (age, sex), comorbidities (including diabetes mellitus and cardiovascular disease), and laboratory parameters (white blood cell [WBC], neutrophil, lymphocyte, monocyte, platelet counts, C-reactive protein [CRP], mean platelet volume [MPV], as well as derived indices such as neutrophil-to-lymphocyte ratio [NLR], platelet-to-lymphocyte ratio [PLR], and lymphocyte-to-monocyte ratio [LMR]). In addition, the systemic immune-inflammation index (SII) was calculated using the formula: SII = (neutrophil count (10^3/µl) x platelet count (10^3/µl)) / lymphocyte count (10^3/µl), using absolute cell counts obtained from the same complete blood count sample. Moreover, data on catheter characteristics, interval to infection onset, empirical antimicrobial therapy, and clinical outcomes were analyzed in relation to mortality during hospitalization.

The distribution of the data was evaluated using the Shapiro-Wilk test. For parametric variables, data are given as mean (standard deviation-SD), and the Student's T test was applied with appropriate data. Non-parametric variables are presented as median (interquartile range-IQR), and the Mann-Whitney U test was applied with proper data. The categorical variables were expressed as the total percentage and compared using the chi-square test. The ability of the parameters in the study to predict the 28-day mortality rate, cut-off values, and their sensitivity and specificity were evaluated with Receiver Operator Characteristic (ROC) and Area under Curve (AUC). Point biserial correlation was calculated to assess the potential correlation of study parameters with mortality. Statistical Package for Social Sciences (SPSS) Ver.26.0 commercial software was used for the described statistical analyses. Statistical significance was accepted at the level of $p<0.05$.

RESULTS

A total of 147 chronic hemodialysis patients hospitalized with catheter-related bloodstream infections were included in the study, of whom 13 (8.8%) died during hospitalization. Patients in the mortality group were significantly older and had a higher prevalence of cardiovascular disease compared with survivors, while sex, diabetes mellitus, and hypertension were similarly distributed between groups (Table 1).

On admission, patients who died exhibited a markedly stronger inflammatory response. WBC and neutrophil counts were significantly higher in the mortality group, accompanied by elevated mean platelet volume. In contrast, hemoglobin levels, platelet counts, lymphocyte and monocyte counts, as well as derived inflammatory indices – including NLR, PLR, LMR, and SII – were comparable between groups at baseline, with no statistically significant difference observed for SII (Table 1).

By the third day of hospitalization, WBC and neutrophil counts remained significantly elevated in non-survivors. Notably, derived inflammatory indices became more discriminatory over time. The NLR was significantly higher, whereas the PLR was significantly lower in patients with fatal outcomes. SII remained comparable between groups on day 3, with no statistically significant difference observed (Table 1). Among these indices, third-day PLR demonstrated moderate predictive performance for in-hospital mortality (AUC ≈ 0.68; Table 2).

Point-biserial correlation and ROC analyses further supported the prognostic relevance of hematologic parameters. Admission WBC count and mean platelet volume showed significant associations with mortality, while on day 3, WBC and neutrophil counts exhibited the strongest discriminatory ability (Figure 1).

DISCUSSION

In this study, patients with fatal outcomes were older than survivors, a finding that is consistent with previous reports. Age is not merely a demographic characteristic but a biological factor associated with immunosenescence, increased frailty, and a higher burden of comorbid conditions, all of which predispose patients to more severe disease courses and adverse outcomes. Accord-

Table 1. Demographic, clinical, and laboratory characteristics according to in-hospital mortality groups

	Total (n=147)	Survivors (n=134)	Non-survivors (n=13)	*p*-value
Age, years, mean ± SD	62.58 ± 16.45	61.47 ± 16.29	74.0 ± 14.05	0.008
Female, % (n)	53.7 (79)	48.3 (71)	5.4 (8)	0.555
Comorbid conditions				
Diabetes mellitus, % (n)	46.9 (69)	42.2 (62)	4.8 (7)	0.601
Hypertension, % (n)	83.0 (122)	74.8 (110)	8.2 (12)	0.698
Cardiovascular disease, % (n)	62.6 (92)	54.4 (80)	8.2 (12)	0.032
Laboratory findings on admission				
WBC (10^3/μL), median (IQR)	11.50 (8.10)	10.80 (7.45)	18.50 (7.20)	0.001
Hemoglobin (g/dL), mean (SD)	9.88 (1.68)	9.88 (1.68)	9.84 (1.74)	0.932
Platelets (10^3/μL), median (IQR)	170 (120)	166 (122)	192 (70)	0.392
Neutrophils (10^3/μL), median (IQR)	8.7 (7.3)	8.5 (7.0)	14.6 (10.4)	0.006
Lymphocytes (10^3/μL), median (IQR)	1.1 (1.0)	1.05 (1.0)	1.1 (1.1)	0.418
Monocytes (10^3/μL), median (IQR)	0.80 (0.70)	0.80 (0.63)	1.10 (1.30)	0.283
NLR, median (IQR)	9.00 (10.79)	8.68 (10.53)	13.17 (20.16)	0.248
LMR, median (IQR)	1.33 (1.29)	1.33 (1.30)	1.17 (1.30)	0.604
PLR, median (IQR)	185.45 (189.67)	189.38 (190.10)	170.00 (226.05)	0.539
MPV (fL), median (IQR)	9.29 (1.42)	9.18 (1.3)	10.38 (1.60)	0.004
CRP (mg/L), median (IQR)	144 (137)	141 (133)	198 (158)	0.147
SII, median (IQR)	1819.75 (2673.00)	1647.40 (2340.51)	2538.24 (3284.37)	0.172
Laboratory findings on day 3 of admission				
WBC (10^3/μL), median (IQR)	9.70 (5.50)	9.40 (4.98)	17.70 (17.95)	0.002
Hemoglobin (g/dL), mean (SD)	9.80 (1.49)	9.79 (1.44)	9.88 (1.97)	0.827
Platelets (10^3/μL), median (IQR)	186 (133)	194 (147)	141 (104)	0.057
Neutrophils (10^3/μL), median (IQR)	7.4 (5.0)	7.1 (4.7)	13.2 (13.2)	0.007
Lymphocytes (10^3/μL), median (IQR)	1.3 (0.9)	1.3 (0.9)	1.3 (1.05)	0.733
Monocytes (10^3/μL), median (IQR)	0.80 (0.60)	0.80 (0.63)	1.10 (1.50)	0.106
NLR, median (IQR)	5.06 (4.95)	5.00 (4.25)	8.42 (11.36)	0.031
LMR, median (IQR)	1.67 (1.22)	1.72 (1.36)	1.22 (0.74)	0.066
PLR, median (IQR)	150.0 (124.62)	152.76 (119.54)	114.55 (90.81)	0.033
MPV (fL), median (IQR)	9.10 (1.70)	9.10 (1.90)	9.90 (2.30)	0.005
SII, median (IQR)	990.00 (1130.57)	989.93 (977.22)	1182.23 (2344.41)	0.976

Abbreviations: CRP- C-reactive protein, IQR- interquartile range, LMR- lymphocyte-to-monocyte ratio, MPV- mean platelet volume, NLR- neutrophil-to-lymphocyte ratio, PLR- platelet-to-lymphocyte ratio, SD- standard deviation, SII- systemic immune-inflammation index, WBC- white blood cell.

Table 2. Diagnostic performance and correlation of laboratory parameters with in-hospital mortality

	Point biserial correlation		ROC analysis				
	r	*p*-value	Cut-off	Sensitivity (%)	Specificity (%)	AUC, CI	*p*-value
Admission							
WBC	0.286	0.001	13.75	76.9	70.1	0.770, 0.652 – 0.887	0.001
Neutrophils	0.232	0.005	12.50	69.2	73.1	0.732, 0.600 – 0.865	0.006
NLR	0.053	0.527	9.95	61.5	57.5	0.597, 0.427 – 0.768	0.248
LMR	0.146	0.062	1.17	53.8	59.7	0.544, 0.379 – 0.708	0.604
PLR	-0.058	0.483	171.66	61.5	57.5	0.552, 0.386 – 0.717	0.539
MPV	0.239	0.004	9.45	76.9	63.4	0.710, 0.571 – 0.850	0.013
SII	0.024	0.777	1154.21	53.8	57.5	0.615, 0.456 – 0.773	0.172
Day 3 of admission							
WBC	0.402	<0.001	12.7	76.9	77.6	0.761, 0.580 – 0.942	0.002
Neutrophils	0.345	<0.001	10.05	69.2	82.1	0.728, 0.546 – 0.910	0.007
NLR	0.151	0.069	7.36	69.2	74.6	0.682, 0.507 – 0.856	0.031
LMR	-0.094	0.257	1.46	61.5	62.7	0.654, 0.496 – 0.813	0.066
PLR	-0.095	0.253	126.04	69.2	64.2	0.679, 0.517 – 0.842	0.033
MPV	-0.025	0.761	9.75	76.9	70.9	0.738, 0.621 – 0.855	0.005
SII	0.020	0.807	2014.89	69.2	61.9	0.503, 0.304 – 0.701	0.976

Abbreviations: AUC- area under the curve, CI- confidence interval, LMR- lymphocyte-to-monocyte ratio, MPV- mean platelet volume, NLR- neutrophil-to-lymphocyte ratio, PLR- platelet-to-lymphocyte ratio, ROC- receiver operating characteristic, SII- systemic immune-inflammation index, WBC- white blood cell.

ingly, age has frequently been identified as an independent prognostic factor in multivariate analyses, underscoring its role not only as a surrogate of comorbidity but also as a determinant of mortality risk [10,11].

Markers of systemic inflammation were more pronounced among patients who did not survive hospitalization, supporting the close link between inflammatory burden and mortality in catheter-related bloodstream infections. Elevated white blood cell counts reflect activation of the acute-phase response and have long been considered indicators of infection severity. Although WBC is often incorporated into composite inflammatory indices such as the NLR or PLR, some studies suggest that it may also retain prognostic value when evaluated independently [12]. In contrast, large cohort studies have reported that isolated white blood cell measurements may be less reliable than derived indices such as NLR for mortality prediction [13,14]. This discrepancy likely reflects the nonspecific nature of total leukocyte counts, whereas ratio-based indices better capture the balance between inflammatory activation and immune regulation. Nevertheless, the observed association between leukocytosis and mortality in our cohort supports its continued clinical relevance in the setting of severe

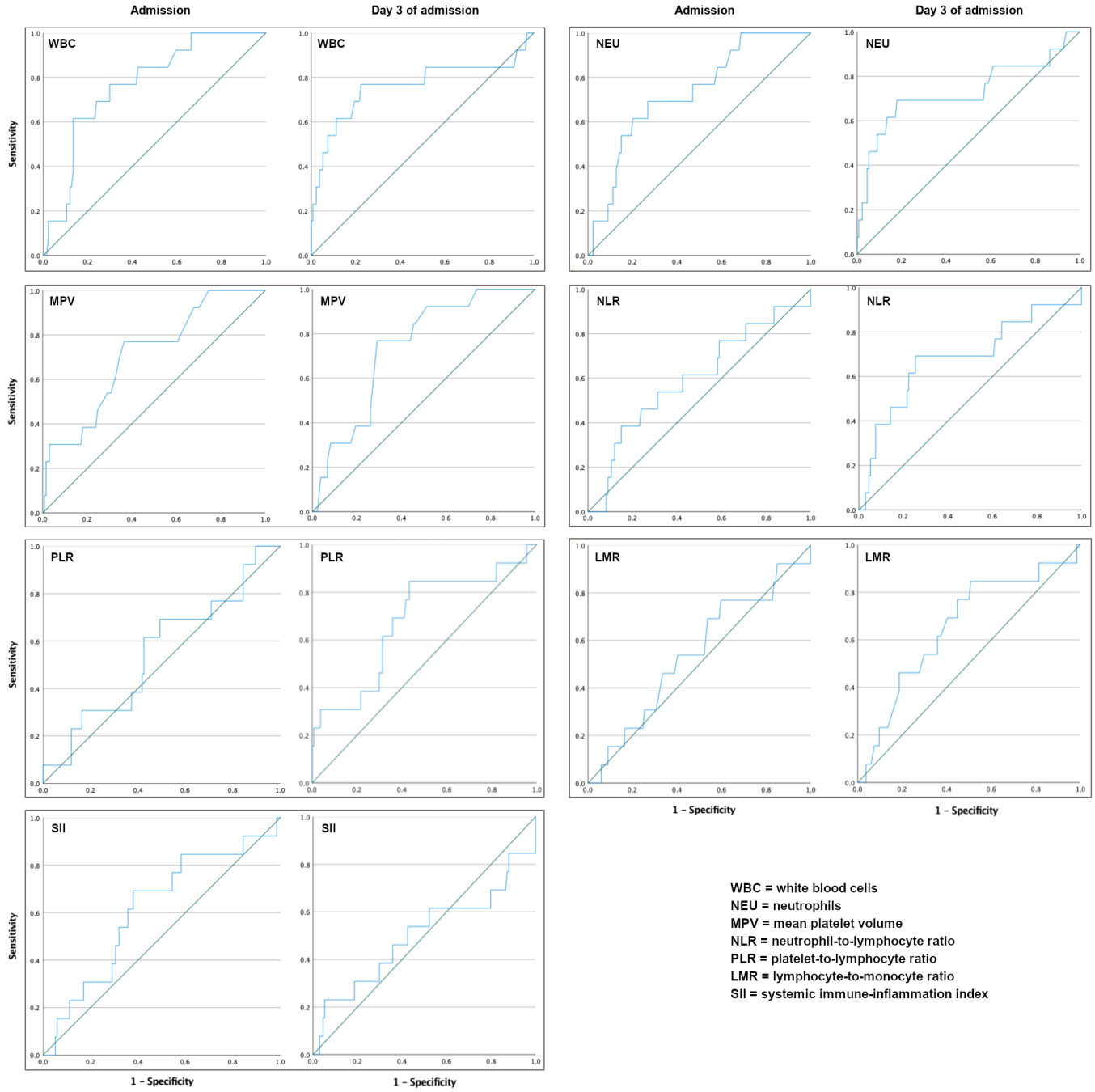

Figure 1. ROC curves for hematological biomarkers on admission and after three days for predicting in-hospital mortality in chronic hemodialysis patients with catheter-associated bloodstream infections

inflammatory stress. Similarly, increased neutrophil counts were observed among patients with fatal outcomes, consistent with prior studies demonstrating a positive association between neutrophilia and mortality. Importantly, the prognostic utility of neutrophil counts appears to be enhanced when interpreted alongside lymphocyte levels, as reflected in the NLR [15,16].

In recent years, hematological indices such as NLR and PLR have gained increasing attention as prognostic markers in chronic kidney disease, particularly among patients receiving maintenance hemodialysis. In our study, derived inflammatory indices demonstrated greater discriminatory value during follow-up rather than at admission, suggesting that dynamic changes over the course of hospitalization may better reflect evolving inflammatory status. This observation aligns with the concept that static baseline measurements may underestimate the prognostic impact of sustained or progressive inflammation in patients with bloodstream infections.

The prognostic value of NLR has been extensively validated in large-scale studies, particularly in relation to all-cause mortality. In a cohort of 108,548 hemodialysis patients, elevated NLR was strongly associated with short-term mortality, whereas the contribution of PLR appeared more limited [17]. Similarly, in a multicenter cohort of 1,720 patients, both NLR and PLR were initially higher among non-survivors, but only NLR remained independently associated with all-cause and cardiovascular mortality in multivariate analyses [18]. Elevated NLR has also been linked to left ventricular hypertrophy and cardiovascular mortality [14], and has demonstrated superior sensitivity compared with CRP in detecting persistent microinflammation in hemodialysis populations [19]. When combined with procalcitonin and high-sensitivity CRP, NLR has shown improved diagnostic accuracy for infectious complications, such as pulmonary infections, in this setting [15].

Despite the strong evidence supporting NLR, accumulating data suggest that PLR may represent a particularly robust prognostic marker, especially for cardiovascular outcomes. Several studies have highlighted the potential superiority of PLR over NLR. For example, PLR elevation has been associated with increased mortality risk in Kaplan–Meier analyses, whereas NLR did not consistently reach statistical significance in some cohorts [12,19]. Mechanistic studies further support the inflammatory relevance of PLR, demonstrating stronger correlations with pro-inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α when compared with NLR [20]. In addition, PLR has shown closer associations with inflammatory and nutritional markers, including ferritin and interleukin-6 [21]. In prospective and retrospective cohorts of hemodialysis patients, PLR has been identified as an independent predictor of both all-cause and cardiovascular mortality, even after multivariate adjustment [22,23]. These findings suggest that PLR may better integrate inflammatory activation and platelet-related pathways implicated in cardiovascular risk.

MPV has also emerged as a potential marker of inflammation and platelet activation. In our study, higher MPV values were observed among patients with fatal outcomes, supporting a possible link between platelet activation and adverse prognosis. Several studies have reported associations between elevated MPV and both all-cause and cardiovascular mortality in dialysis populations [24,25]. However, other investigations have failed to confirm this relationship and have questioned the reliability of MPV as a marker of inflammation [26]. These conflicting results highlight the need for larger, prospective studies to clarify the prognostic significance of MPV, particularly in populations with high inflammatory burden.

Overall, the available evidence indicates that NLR is a robust marker of systemic inflammation, whereas PLR may serve as a stronger predictor of cardiovascular mortality and overall inflammatory burden. In line with these observations, our findings suggest that dynamic assessment of PLR over time may enhance its prognostic utility. Rather than relying solely on admission values, incorporating temporal changes in inflammatory indices may provide a more accurate assessment of risk in patients with catheter-related bloodstream infections.

An important observation of the present study is that conventional inflammatory markers such as C-reactive protein measured at admission did not differ between survivors and non-survivors, whereas hematological indices – particularly the neutrophil-to-lymphocyte ratio – demonstrated prognostic relevance during the clinical course. This finding suggests that routinely used acute-phase reactants may not fully capture the complex immune dysregulation associated with adverse outcomes in patients with catheter-related bloodstream infections.

Hematological indices derived from complete blood counts reflect the dynamic balance between innate immune activation and adaptive immune suppression. In contrast to CRP, which represents a downstream hepatic acute-phase response, the neutrophil-to-lymphocyte ratio may better reflect early immune alterations, stress-related lymphocyte depletion, and sustained inflammatory activation. Consistent with this concept, meta-analyses in adult sepsis populations have shown that higher neutrophil-to-lymphocyte ratio is associated with increased mortality risk [27,28]. Moreover, in haemodialysis cohorts, neutrophil-to-lymphocyte ratio has been reported to be strongly associated with mortality, supporting the clinical utility of complete blood count-derived indices for risk stratification in this population [18]. We also as-

sessed the SII, calculated as (neutrophil count × platelet count) / lymphocyte count, which was originally described as a prognostic biomarker in oncologic settings [29]. Subsequent studies have suggested that higher SII may be associated with adverse outcomes in maintenance hemodialysis populations, including all-cause and cardiovascular mortality [30] and meta-analytic data indicate that elevated admission SII is associated with short-term mortality in sepsis [31]. In the present cohort, however, SII did not differ significantly between survivors and non-survivors on admission or on day 3. This lack of association may be explained by several factors: platelet-related components can be substantially influenced by dialysis-related and uremia-related factors (e.g., anticoagulation during dialysis sessions and platelet dysfunction), potentially attenuating the prognostic signal of composite indices; in addition, chronic baseline inflammation and immune dysregulation in end-stage kidney disease may limit between-group separation of indices that incorporate lymphocyte and platelet counts in an acute infectious context. Finally, the relatively small number of fatal events may have reduced statistical power to detect modest differences in SII. Collectively, all these data support the use of simple, readily available hematological indices as practical prognostic markers, particularly when serial measurements are incorporated into clinical assessment.

Several limitations of this study should be acknowledged. First, the retrospective and single-center design limits generalizability and precludes causal inference. Second, the relatively small number of mortality events may have reduced statistical power for detecting weaker associations. Third, although CRP was routinely measured at admission, serial measurements during hospitalization were not consistently available, as follow-up testing was performed according to clinical judgment rather than a standardized protocol. To avoid potential selection bias related to incomplete data, follow-up CRP values were not included in the analysis. Similarly, procalcitonin measurements were not systematically performed and were requested selectively, resulting in heterogeneous data that could not be reliably analyzed. In addition, only in-hospital mortality was evaluated, and longer-term outcomes were not assessed. Finally, detailed analyses of antimicrobial therapy timing, adequacy, and microbiological factors were beyond the scope of this study.

Despite these limitations, the use of readily available hematologic indices reflects real-world clinical practice and supports the practical applicability of the findings. Future prospective, multicenter studies incorporating standardized inflammatory biomarker monitoring are warranted to validate and extend these results.

CONCLUSIONS

In this observational study, easily obtainable hematologic parameters such as WBC, neutrophil count, MPV, and PLR were found to be associated with in-hospital mortality among hemodialysis patients presenting with CRBSIs. Dynamic monitoring of these markers may aid in early risk stratification. However, these findings warrant validation through larger, multicenter prospective studies.

ABBREVIATIONS

AUC – area under the curve
CKD – chronic kidney disease
CRBSI – catheter-related bloodstream infection
CRP – C-reactive protein
CVC – central venous catheter
ESRD – end-stage renal disease
IQR – interquartile range
LMR – lymphocyte-to-monocyte ratio
MPV – mean platelet volume
NLR – neutrophil-to-lymphocyte ratio
PLR – platelet-to-lymphocyte ratio
ROC – receiver operator characteristic
SD – standard deviation
SII – systemic immune-inflammation index
WBC – white blood cell

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AUTHORS' CONTRIBUTION

GK: conceptualization, supervision, writing- review & editing.
MAC: investigation, writing- original draft
LZK: investigation, writing- original draft
BBB: data curation, formal analysis
All authors have read and approved the final version of the manuscript.

CONFLICT OF INTEREST

None to declare.

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