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Identifying Risk Factors for Myocardial Injury in Elderly Patients with Sepsis

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Background: Myocardial injury is a common complication in elderly patients with sepsis and is associated with poor prognosis. This study aimed to identify clinical characteristics and independent risk factors for myocardial injury in elderly sepsis patients admitted to the Emergency Intensive Care Unit (EICU).

Material/Methods: A retrospective analysis was conducted on 160 elderly patients with sepsis admitted to the EICU, categorized into myocardial injury and non-myocardial injury groups. Demographic data, inflammatory markers, echocardiographic parameters, and blood urea nitrogen-to-albumin ratio (BAR) values were compared. Logistic regression identified independent risk factors, and ROC curve analysis assessed the predictive value of BAR.

Results: Of 160 patients, 106 (63.1%) had myocardial injury, with an average age of 77.56±7.49 years. Myocardial injury was associated with lower ejection fraction (EF), and elevated procalcitonin, lactate, and BAR levels ($P<0.05$). Logistic regression identified septic shock (RR=2.612, P=0.003), elevated BAR (RR=2.272, $P=0.035$) and lactate levels (RR=1.145, $P=0.010$) as independent risk factors for myocardial injury. In contrast, increased EF (RR=0.932, $P=0.007$) was identified as protective against myocardial injury, with lower EF associated with a higher risk. ROC analysis showed that BAR had moderate predictive value (AUC=0.653, $P<0.01$), with sensitivity of 76.4% and specificity of 53.2% at an optimal cutoff of 0.33.

Conclusions: Septic shock, reduced EF, and elevated BAR and lactate levels are independent risk factors for myocardial injury in elderly patients with sepsis. BAR serves as an early marker for myocardial injury, aiding in risk assessment and management in the EICU.

Keywords: Critical Care Outcomes • Intensive Care Units • Sepsis • Serum Albumin, Human

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Introduction

Sepsis remains a leading cause of morbidity and mortality, particularly among elderly patients, who are more susceptible to its devastating effects due to the inherent physiological decline associated with aging. Myocardial injury, a common complication of sepsis, significantly worsens outcomes [1,2], contributing to increased mortality, prolonged hospital stays, and greater demand on healthcare resources [3-5]. Understanding and effectively mitigating myocardial injury in elderly patients with sepsis is critical for improving patient outcomes and optimizing the use of healthcare resources. Timely identification and appropriate management of myocardial injury could lead to better-targeted interventions, reducing the overall burden on healthcare systems and enhancing the prognosis for these vulnerable patients [6].

The pathophysiology of sepsis-induced myocardial injury is complex, involving a combination of inflammatory cytokine release, microcirculatory dysfunction, and myocardial cell apoptosis. These mechanisms contribute to impaired cardiac contractility and the development of heart failure in sepsis patients [7]. Recent studies have highlighted the role of systemic inflammation, oxidative stress, and impaired mitochondrial function in driving myocardial dysfunction during sepsis. The challenge lies in accurately identifying myocardial injury early in the course of sepsis, especially in elderly patients, who often present with atypical symptoms [8]. Despite advancements in understanding sepsis and myocardial injury, there remains a significant knowledge gap regarding the role of novel biomarkers, such as the blood urea nitrogen (BUN)-to-albumin ratio (BAR), in the early identification and management of myocardial injury in elderly patients with sepsis. While troponin and brain natriuretic peptide are commonly used markers, BAR has recently emerged as a potential predictor of adverse outcomes in critically ill patients. However, its specific role in predicting myocardial injury within this patient population is not well established. This study aims to address this gap by investigating the clinical characteristics and risk factors associated with myocardial injury in elderly sepsis patients, with a particular focus on the predictive value of BAR in early detection and clinical decision-making [9,10].

We hypothesize that the BAR, in conjunction with traditional biomarkers like troponin, can serve as an early, reliable predictor of myocardial injury, thereby improving clinical decision-making and outcomes in elderly sepsis patients. The primary aim of this study is to evaluate the role of biomarkers, particularly BAR, in the early prediction of myocardial injury in elderly sepsis patients admitted to the Emergency Intensive Care Unit (EICU). We aim to determine whether BAR, in combination with other established markers, can serve as a reliable tool for early identification of myocardial injury, ultimately influencing clinical decision-making and improving patient outcomes in this high-risk group.

Material and Methods

Study Design

A retrospective cohort study was conducted, including 160 patients admitted to our institution's EICU between August 2018 and June 2022. All patients were 65 years of age or older and met the diagnostic criteria for sepsis in accordance with the 2016 Sepsis-3 definitions established jointly by the Society of Critical Care Medicine and the European Society of Intensive Care Medicine [11]. Specifically, sepsis was defined as an acute change in organ function due to infection, indicated by a Sequential Organ Failure Assessment (SOFA) score of ≥2. Septic shock was defined as a subset of sepsis in which, despite adequate fluid resuscitation, vasopressor support was required to maintain a mean arterial pressure (MAP) of at least 65 mm Hg (1 mm Hg=0.133 kPa) in the presence of a serum lactate concentration >2 mmol/L.

To minimize bias, we ensured that all data collection, analysis, and interpretation were conducted without any investigator influence on patient management. Furthermore, the inclusion and exclusion criteria were strictly followed, with careful attention to patient characteristics, to control for confounding factors that could affect the results. Additionally, there was no blinding in data collection, as the study design was observational in nature. All research activities, including study design, data collection, and analysis, adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [12]. Informed consent was obtained from all patients and/or their legal guardians. Our study's protocols, design, and methods underwent rigorous review by our hospital's ethics committee and were conducted in compliance with relevant guidelines. We adhered to the ethical standards of the Declaration of Helsinki for medical research involving humans. All data were processed confidentially, with personal identifiers removed to ensure participant privacy.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) patients meeting the diagnostic criteria for sepsis as defined by the 2016 Sepsis-3 guidelines jointly issued by the Society of Critical Care Medicine and European Society of Intensive Care Medicine; (2) availability of complete clinical and laboratory data; and (3) age ≥65 years, with no restrictions on sex.

The exclusion criteria were as follows: (1) patients with pre-existing structural or functional heart diseases, including

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congenital heart disease, valvular disorders, cardiomyopathies, acute or chronic ischemic heart disease, arrhythmias, or refractory heart failure; (2) patients in a terminal condition at the time of admission to the EICU, or those with severe hepatic or renal dysfunction; and (3) patients with known hematologic disorders, ongoing pregnancy, or end-stage malignant tumors.

Patient Grouping

Patients were stratified into 2 cohorts based on the presence or absence of myocardial injury at admission. Myocardial injury was defined as a serum cardiac troponin I (cTnI) level exceeding the institutional upper reference limit (≥0.04 ng/mL). cTnI levels were measured using a microfluidic immunofluorescence assay (MICPOINT M101-091011), a highly sensitive and specific method for detecting cTnI concentrations in serum [13]. The microfluidic assay is calibrated regularly using internal controls to guarantee accuracy and precision in test results. Patients with cTnI concentrations meeting or exceeding this threshold were assigned to the myocardial injury group, while those with values below the cutoff were categorized as the non-myocardial injury group. The cTnI levels from all patients were consistently validated by re-assessing any borderline values to ensure correct categorization and minimize classification errors.

Treatment Protocol

All patients received treatment in accordance with the current sepsis guidelines. Interventions included antimicrobial therapy, nutritional support, and fluid resuscitation, which were administered based on the severity of the patient's condition and the underlying cause of sepsis. For fluid resuscitation, an initial volume of 30 mL/kg of crystalloid fluids was administered within the first 3 h of admission, as per sepsis protocol. Additional fluid boluses were given based on ongoing assessment of hemodynamic status, including monitoring central venous pressure and MAP, with further adjustments based on patient response. For vasopressor therapy, norepinephrine was the first-line agent, initiated when MAP fell below 65 mm Hg despite adequate fluid resuscitation. The dose of norepinephrine was titrated to maintain MAP ≥65 mm Hg, with a target range of 0.05 to 0.5 μg/kg/min. If the desired MAP was not achieved with norepinephrine, additional vasopressors, such as vasopressin or dopamine, were considered, based on individual patient needs and underlying comorbidities. Mechanical ventilation was used in cases of severe respiratory distress or failure, using low tidal volume (6 mL/kg of predicted body weight) to minimize ventilator-associated lung injury, with oxygenation goals based on arterial blood gas analysis and pulse oximetry.

Data Collection and Outcome Measures

Clinical Severity Scores

Within 24 h of admission, clinical severity scores, including the Acute Physiology and Chronic Health Evaluation II (APACHE II) score and the SOFA score, were recorded. These scores were calculated based on patient clinical data obtained directly from the hospital's electronic health records.

Laboratory Tests

Within the same 24-h period, venous blood samples were collected from each patient under sterile conditions by trained nursing staff. Blood samples were processed and analyzed immediately following collection, to ensure timely results. BUN, albumin, and lactate levels were measured using a Hitachi 7600 automated biochemical analyzer, following standard operating procedures to ensure consistency and accuracy. The BAR (BUN-to-albumin ratio) was calculated based on these values. Levels of procalcitonin and C-reactive protein (CRP) were determined by a microfluidic immunofluorescence method (MICPOINT M101-091011), using commercially available kits with well-established performance specifications to ensure valid and reliable results. Complete blood counts were performed using an automated hematology analyzer, which was calibrated regularly to ensure the precision and reliability of the results. Microbiological cultures were conducted following standardized procedures. Blood cultures were collected using specialized blood culture bottles, and the samples were processed using a Bact/ALERT 3D automated blood culture system (bioMérieux, France). The samples were incubated and monitored for bacterial growth, and the results were confirmed by microbiology staff, who validated positive cultures based on colony morphology, Gram staining, and other biochemical tests.

Cardiac Function Assessment

Transthoracic echocardiography (Mindray M-7) was performed within 24 h of admission, to assess cardiac function. The examination was conducted by certified cardiology technicians, who followed standardized protocols for acquiring measurements of key cardiac parameters, including left ventricular ejection fraction (EF) and the E/A ratio.

Statistical Analysis

All statistical analyses were performed using SPSS version 26. For parametric tests (*t* test and Pearson correlation), we assumed that the data were normally distributed. This assumption was validated using the Shapiro-Wilk test, and the data that did not meet the normality assumption were analyzed

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Table 1. Comparison of clinical characteristics, biomarkers, and cardiac function between myocardial injury and non-myocardial injury groups.

Variable	Myocardial injury (n=106)	Non-myocardial injury (n=62)	Z/χ^2/t	*P* value
Male [%, (n)]	67.0 (71)	75.8 (47)	1.458	0.227
APACHE II score [(±SD)]	23.98±8.63	22.84±8.73	-0.763	0.447
Hypertension [%, (n)]	55.7 (59)	56.5 (35)	0.01	0.921
EICU stay [days, M (Q1, Q3)]	6 (2, 11)	7 (3, 12)	-1.581	0.114
28-day mortality [%, (n)]	53.2 (63)	59.4 (33)	0.616	0.433
BAR [M (Q1, Q3)]	0.57 (0.33, 0.97)	0.32 (0.21, 0.72)	-3.297	0.001
PCT [μg/L, M (Q1, Q3)]	12.69 (1.14, 64.68)	4.92 (0.30, 21.42)	-2.781	0.005
CRP [mg/L, M (Q1, Q3)]	106.00 (55.76, 189.85)	100.31 (22.63, 181.73)	-1.631	0.103
Lactate [mmol/L, M (Q1, Q3)]	4.49 (2.20, 6.78)	3.15 (1.63, 4.30)	-2.990	0.003
EF [% M (Q1, Q3)]	57 (48, 59)	58 (55, 60)	-2.781	0.037

APACHE II score – Acute Physiology and Chronic Health Evaluation II score; EICU – Emergency Intensive Care Unit; BAR – blood urea nitrogen-to-albumin ratio; PCT – procalcitonin; CRP – C-reactive protein; EF – ejection fraction.

using non-parametric methods, such as the Mann-Whitney U test and Spearman correlation. Normally distributed continuous variables are expressed as mean±standard deviation, and comparisons between groups were conducted using the independent samples *t* test. Non-normally distributed continuous variables are presented as median (interquartile range), and group comparisons were performed using the Mann-Whitney U test. Categorical variables are reported as counts (%), and comparisons between groups were conducted using the chi-square test. Correlations between BAR and conventional inflammatory indicators were examined using Pearson correlation analysis for normally distributed data and Spearman correlation analysis for data not normally distributed. To handle missing data, we used multiple imputation to ensure that no information was lost during the analysis and that the results remained unbiased. To minimize bias in statistical analysis, we used multiple regression techniques to control for potential confounders, such as comorbidities and age, that could influence the relationship between myocardial injury and various biomarkers. Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive value of BAR for myocardial injury. To further assess the robustness of our findings, we performed sensitivity analyses to explore how different methods of handling missing data or slight variations in model specifications impacted the results. Additionally, MedCalc software was used to compare the prognostic performance of BAR and other inflammatory markers. All tests were 2-sided, with a *P* value <0.05 considered statistically significant.

Results

General Clinical Characteristics of Myocardial Injury and Non-Myocardial Injury Groups

A total of 168 elderly patients with sepsis were admitted to the EICU, of whom 106 patients (63.10%) were identified with myocardial injury. The age of patients ranged from 65 to 99 years, with a mean age of 77.56±7.49 years. Among these, 71 patients (67%) were men, and 35 patients (33%) were women, indicating a higher prevalence in men. Cardiac dysfunction was predominantly characterized by diastolic dysfunction (70%), while arrhythmias were less common (4.6%), primarily presenting as atrial fibrillation and sinus tachycardia. The primary causes of sepsis included pulmonary infections in 60 patients (56.60%), followed by intra-abdominal infections in 22 patients (20.75%), mainly attributed to gastrointestinal perforation leading to peritonitis. Additionally, digestive system infections were noted in 13 patients (12.26%), with liver abscesses and biliary infections being the most frequent etiologies. Pathogen detection yielded a positive rate of 31.13% (33 cases). The predominant pathogens were *Klebsiella pneumoniae* (15 cases, 45.5%), followed by *Escherichia coli* (7 cases, 21.2%) and *Acinetobacter baumannii* (6 cases, 18.2%). Multidrug-resistant organisms were identified in 4 cases (12.1%). When comparing the myocardial injury group to the non-myocardial injury group, the myocardial injury group exhibited significantly lower EF values. However, no statistically significant differences were observed between the 2 groups in terms of comorbid conditions, such as hypertension and diabetes (*P*>0.05; **Table 1**).

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Table 2. Correlation analysis between BAR and infection markers and APACHE II score in elderly sepsis patients with myocardial injury within 24 h of admission.

Indicator	Correlation coefficient (r)	*P* value
PCT	0.372	<0.001
CRP	0.274	0.009
Lactate	0.252	0.012
APACHE II Score	0.230	0.018

PCT – procalcitonin; CRP – C-reactive protein; APACHE II Score – Acute Physiology and Chronic Health Evaluation II score; BAR – blood urea nitrogen-to-albumin ratio.

Comparison of BAR, Inflammatory Markers, and EF Between Myocardial Injury and Non-Myocardial Injury Groups Within 24 H of Admission

This study compared key clinical biomarkers between the myocardial injury and non-myocardial injury groups within 24 h of admission to the EICU. The results indicated that the myocardial injury group exhibited significantly higher BAR, procalcitonin levels, and lactate levels, as well as an EF, all of which suggest a more severe inflammatory response and impaired cardiac function. Specifically, the BAR was notably higher in the myocardial injury group (0.57 vs 0.32, *P*=0.001), as were procalcitonin (12.69 μg/L vs 4.92 μg/L, *P*=0.005) and lactate levels (4.49 mmol/L vs 3.15 mmol/L, *P*=0.003). The EF was also significantly lower in the myocardial injury group (57% vs 58%, *P*=0.037). However, CRP levels did not differ significantly between the 2 groups (106.00 mg/L vs 100.31 mg/L, *P*=0.103; **Table 1**).

Correlation Between BAR, Infection Markers, and Severity Scores in Elderly Sepsis Patients with Myocardial Injury Within 24 H of Admission

In elderly sepsis patients with myocardial injury, the BAR demonstrated significant positive correlations with infection markers and disease severity scores within 24 h of EICU admission. BAR was positively correlated with lactate, procalcitonin, and CRP, with the strongest correlation observed between BAR and procalcitonin (r=0.372, *P*=0.000). Additionally, BAR showed a significant positive correlation with the APACHE II score (r=0.230, *P*<0.05), indicating its association with the overall severity of the disease (**Table 2**).

Independent Risk Factors for Myocardial Injury in Elderly Sepsis Patients in the EICU

Logistic regression analysis was performed to identify independent risk factors for myocardial injury in elderly patients with sepsis admitted to the EICU. Variables with statistical significance in univariate analysis, including age, presence of septic shock, EF, BAR, and lactate, were included in the regression model. The results indicated that the presence of septic shock, lower EF, and elevated levels of BAR and lactate were independent risk factors for myocardial injury in this patient population (**Table 3**).

Predictive Value of BAR and Lactate for Myocardial Injury in Elderly Sepsis Patients: ROC Curve Analysis

The ROC curve analysis demonstrated that the BAR had significant predictive value for myocardial injury in elderly patients with sepsis admitted to the EICU, with an AUC of 0.653 (*P*<0.01). Using MedCalc software, the optimal cutoff value for BAR was determined to be 0.33, with a sensitivity of 76.4% and a specificity of 53.2% for predicting myocardial injury. Further analysis revealed that combining BAR with lactate did not provide a statistically significant improvement in predictive value, compared with using BAR alone (*P*>0.05). When stratified by the cutoff value of 0.33, patients in the myocardial injury group with BAR <0.33 had a mortality rate of 34.6%, while those with BAR ≥0.33 had a significantly higher mortality rate of 67.5% (χ^2=8.801, *P*=0.003; **Table 4, Figure 1**).

Discussion

Sepsis is a common critical condition in the EICU, characterized by high morbidity and mortality. Global studies have reported

Table 3. Logistic regression analysis of risk factors for myocardial injury in elderly sepsis patients.

Variable	Regression coefficient	Odds ratio	95% Confidence interval	*P* value
Age	0.022	1.022	0.996-1.049	0.101
Presence of shock	0.960	2.612	1.371-4.977	0.003
EF (%)	-0.070	0.932	0.886-0.981	0.007
BAR	0.821	2.272	1.061-4.863	0.035
Lactate	0.135	1.145	1.033-1.269	0.010

EF (%) – ejection fraction (%); BAR – blood urea nitrogen-to-albumin ratio.

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Table 4. Receiver operating characteristic curve analysis of BAR, lactate, and combined BAR and lactate for predicting myocardial injury in elderly sepsis patients.

Indicator	AUC	SE	95% Confidence interval (CI)
BAR	0.653	0.0474	0.573-0.728
Lactate	0.644	0.0456	0.563-0.719
Combined BAR & Lac	0.657	0.0443	0.577-0.731

AUC – area under the curve; SE – standard error; BAR – blood urea nitrogen-to-albumin ratio.

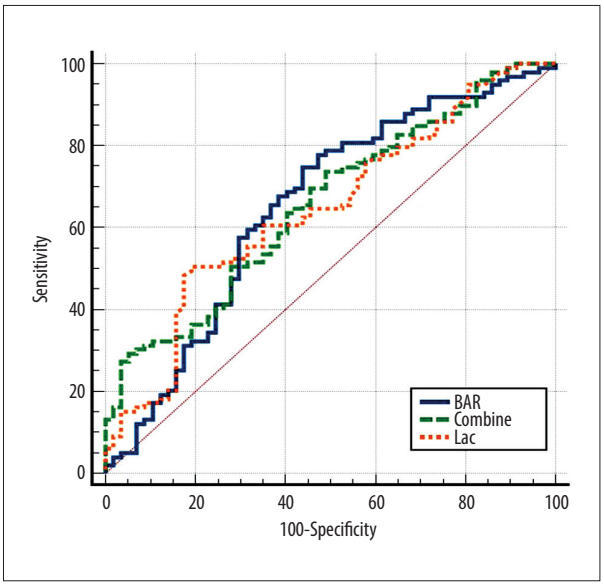

Figure 1. Receiver operating characteristic curves for blood urea nitrogen-to-albumin ratio (BAR), lactate levels (Lac), and combined BAR and Lac in predicting myocardial injury in elderly patients with sepsis in the Emergency Intensive Care Unit.

an annual increase of approximately 9% in sepsis cases, with the elderly population showing a disproportionately higher growth rate [14]. Among patients with severe sepsis, myocardial injury is a frequent complication, affecting up to two-thirds of cases [15]. Sepsis-induced myocardial injury can lead to a spectrum of cardiac dysfunction, ranging from isolated diastolic dysfunction to combined severe diastolic and systolic failure, with some cases progressing to cardiogenic shock. Studies have shown that cTnI levels can increase within 1 h of endotoxin exposure, serving as a marker for non-ischemic myocardial injury in sepsis [15,16]. Our present study showed that elevated BAR is not only predictive of myocardial injury but also serves as an indicator of poor prognosis in elderly patients with sepsis. Specifically, we found that patients with BAR ≥0.33 had significantly higher mortality rates (67.5%) than did those with BAR <0.33 (34.6%, P=0.003). This is consistent with previous research that has highlighted the utility of BAR as a simple, cost-effective biomarker in sepsis and other critical conditions [17]. Elevated lactate levels, in conjunction with BAR, also predicted myocardial injury. However, the combination of BAR and lactate did not provide significantly greater predictive value, likely due to the multifactorial nature of sepsis and myocardial injury. The lack of improvement in predictive accuracy when combining these markers can suggest that additional biomarkers or clinical parameters should be incorporated to enhance predictive models in the future. The findings regarding BAR align with studies that have demonstrated its association with adverse outcomes in critically ill patients, such as those with pneumonia [18]. Lactate has been extensively validated as a marker of sepsis severity and prognosis, and our results reinforce its role in myocardial injury prediction in this context [19]. The integration of BAR and lactate into clinical practice could offer an accessible and actionable approach for early identification of patients at high risk. However, further investigation is needed to refine their combined utility and determine optimal cutoff values in diverse patient populations.

One of the key findings in our study is the significant difference in EF between the myocardial injury and non-myocardial injury groups, with the myocardial injury group demonstrating lower EF values. This raises the important question of whether lower EF causes more myocardial injury or whether myocardial injury leads to a lower EF. Based on the existing literature and our findings, it is likely that myocardial injury contributes to a reduction in EF, rather than the reverse. Myocardial injury, particularly in the context of sepsis, often leads to impaired cardiac function. The inflammatory response in sepsis, including elevated levels of inflammatory markers, such as procalcitonin and lactate, can result in myocardial dysfunction, which ultimately leads to a decrease in EF. Moreover, myocardial injury can result from ischemia, oxidative stress, and microvascular dysfunction, all of which are common in patients with sepsis and can cause long-term impairment of the heart's contractile ability. On the other hand, while lower EF is a well-established indicator of heart failure and myocardial dysfunction, it is not typically the direct cause of myocardial injury. Instead, a decreased EF may be a consequence or indicator of more severe underlying myocardial injury. Therefore, in our study, we suggest that myocardial injury is likely the

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primary driver of the observed decrease in EF, and EF serves as a reflection of the severity of myocardial injury in elderly patients with sepsis [7,20].

The pathophysiology of sepsis-induced myocardial injury is linked to systemic inflammatory responses triggered by infection. Notably, myocardial dysfunction in sepsis is often reversible, with recovery typically occurring within 7 to 10 days following resolution of the underlying cause. Effective management requires a dual approach of myocardial protection and aggressive anti-inflammatory therapy, with targeted antimicrobial treatment based on the identified infection source. Sepsis can originate from infections in various anatomical locations, with common causes including pneumonia, peritonitis, cellulitis, meningitis, and cholecystitis. Consistent with previous research, pulmonary infections were the most frequent cause in the present study (56.6%), followed by intra-abdominal infections (20.75%), primarily due to gastrointestinal perforation, and digestive tract infections such as liver abscesses, biliary infections, and pancreatitis (12.26%). The blood culture positivity rate in patients with sepsis is reportedly higher than in patients without sepsis, with rates reaching approximately 45% in septic shock [21]. In this study, blood cultures were positive in 31.13% (33 cases), with *Klebsiella pneumoniae* (45.5%), *Escherichia coli* (21.2%), and *Acinetobacter baumannii* (18.2%) as the predominant pathogens. Multidrug-resistant organisms accounted for 12.1% of cases. The relatively low culture positivity rate can be attributed to factors such as the timing and frequency of sampling, the time-consuming nature of culture processes (48-72 h), and the attenuated systemic response in elderly patients, which can lead to delayed diagnosis and treatment [22,23]. In this study, over half of the patients progressed to septic shock within 48 h of admission, reflecting the rapid disease progression in this population. The overall in-hospital mortality was 55.5%, with 32% of patients dying during hospitalization. These findings emphasize the critical need for early recognition and intervention to improve outcomes in elderly sepsis patients with myocardial injury [24].

In 2003, the PIRO (predisposition, infection, response, and organ dysfunction) concept emphasized the importance of using accessible biological markers to assess sepsis severity and predict mortality risk [25]. Recent studies and expert consensus have recommended lactate as a critical inflammatory marker for evaluating sepsis progression. Consistent with this, our findings indicated that lower EF values within 24 h of admission, alongside elevated BAR and lactate levels, were independent risk factors for myocardial injury in elderly sepsis patients. BAR, calculated as the ratio of BUN to albumin, has recently emerged as a reliable predictor of mortality in conditions such as pneumonia [17]. Its simplicity, low cost, and applicability across various healthcare settings make it a practical biomarker. Elevated BUN levels reflect increased protein catabolism and renal dysfunction, both of which are common in sepsis, due to accelerated metabolic demands [18]. Conversely, albumin, synthesized in the liver, plays critical roles in neutralizing free radicals, stabilizing vascular membranes, and providing anticoagulant effects. During sepsis, albumin levels decrease due to increased consumption during systemic inflammation and stress. Thus, elevated BAR reflects a combined impact of metabolic derangements and inflammatory responses, making it a useful marker in sepsis. Consistent with prior studies, serum lactate levels have been identified as independent predictors of 30-day mortality in sepsis and septic shock patients [19]. Similarly, procalcitonin, a marker of bacterial and fungal infections, correlates with sepsis-related inflammatory activity and is a reliable indicator of multi-organ dysfunction [26]. In our study, procalcitonin, lactate, and BAR levels were significantly higher in elderly sepsis patients with myocardial injury than in those without ($P<0.05$). Correlation analysis revealed a strong positive association between BAR and inflammatory markers, such as lactate, procalcitonin, and CRP. The strongest correlation was observed between BAR and procalcitonin (r=0.372, $P=0.000$). Logistic regression further confirmed BAR as an independent risk factor for myocardial injury, highlighting its potential as a prognostic marker in elderly patients with sepsis. Although the correlation is statistically significant, it is not particularly strong, likely due to the multifactorial nature of sepsis and myocardial injury, where various biomarkers contribute to the inflammatory response. Despite this, BAR was identified as an independent risk factor for myocardial injury, highlighting its potential as a prognostic marker in this patient population. Further research is needed to explore the clinical utility and mechanisms underlying the association between BAR and myocardial injury in sepsis.

ROC curve analysis showed that BAR had a sensitivity of 76.4% and a specificity of 53.2% for predicting myocardial injury, with an optimal cutoff value of 0.33. Patients with BAR ≥0.33 had significantly higher mortality rates (67.5%) than did those with BAR <0.33 (34.6%, $\chi^2=8.801$, $P=0.003$). These findings suggest that elevated BAR is not only predictive of myocardial injury but may also serve as an indicator of poor prognosis in elderly patients with sepsis. Although BAR and lactate were independent predictors of myocardial injury, their combination did not provide significantly greater predictive value. This could be attributed to the single-center design, relatively small sample size, and lack of stratification by infection etiology. Further research involving larger, multicenter cohorts with detailed stratification is warranted to better evaluate the combined utility of these biomarkers. BAR is a simple, cost-effective biomarker that can be readily incorporated into routine clinical practice for risk assessment in elderly patients with sepsis. Clinicians should remain vigilant for myocardial injury in patients with elevated BAR levels, particularly when combined with elevated lactate. Early identification and intervention in

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this high-risk population may improve outcomes and reduce mortality. Further studies are needed to confirm these findings and explore the long-term prognostic implications of elevated BAR in elderly sepsis patients.

This study has several limitations that need to be acknowledged. First, the single-center design and relatively small sample size limit the generalizability of the findings. A larger, multicenter cohort study would provide more robust data and enhance the external validity of the results. Furthermore, the absence of a non-sepsis control group introduces the possibility of confounding factors. Including such a group in future research could help establish more precise associations between biomarkers and myocardial injury, independent of sepsis. The study also relied on single-point measurements of biomarkers, such as cTnI, lactate, and BAR. Longitudinal monitoring of these biomarkers, especially during the first 7 to 10 days of sepsis progression, would offer a more comprehensive understanding of the dynamics and reversibility of myocardial injury over time. Such an approach could help identify early therapeutic windows for intervention, allowing for more targeted treatment strategies. Dehydration, commonly observed in critically ill patients during the first 24 h, could elevate BAR due to increased BUN levels associated with prerenal azotemia. Although we excluded patients with severe renal dysfunction, to minimize the impact of dehydration on BAR levels, future studies should consider the potential effects of fluid balance and renal function on the interpretation of BAR and its relationship with myocardial injury. Addressing these variables in a more controlled manner could improve the accuracy of BAR as a prognostic marker in sepsis.

Conclusions

Septic shock, reduced EF, and elevated levels of BAR and lactate were found to be independent risk factors for myocardial injury in elderly patients with sepsis. Elevated BAR can serve as a valuable early warning marker for predicting myocardial injury in EICU patients, offering clinicians a practical tool for risk assessment and timely intervention. However, the single-center design and relatively small sample size of this study limit the generalizability of these conclusions. Additionally, the absence of a non-sepsis control group may have introduced potential confounders, affecting the interpretation of the findings. To address these limitations, future studies should incorporate multicenter data and include a more diverse patient population, to confirm these findings across broader settings.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Hengshui People's Hospital. All study procedures complied with the ethical standards of our institutional and national research committees, adhering to the 1964 Helsinki declaration and its subsequent amendments. Informed consent was obtained from all individual participants involved in the study or from their legal guardians.

Consent for Publication

Written informed consent for publication was obtained from all patients and/or their families included in this retrospective analysis.

Availability of Data and Materials

Under reasonable requirements, the correspondence author can provide data.

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Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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