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Association between the lactate-to-albumin ratio and sepsis-associated acute kidney injury: a cross-sectional study

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Abstract

Background Patients who develop sepsis-associated acute kidney injury (SAKI) in the intensive care unit face a significantly elevated mortality risk. The lactate-to-albumin ratio (LAR) has been utilized as an important marker for the occurrence and development of various diseases. Nevertheless, the association between LAR and SAKI remains inadequately explored. This study seeks to investigate the connection between the LAR and SAKI.

Methods Patients identified with SAKI were selected from the Medical Information Mart for Intensive Care-IV (MIMIC-IV) database. LAR was recorded at the time of admission, with the primary endpoint being the development of AKI within 7 days following the sepsis diagnosis. Logistic regression and subgroup analyses were utilized to assess the relationship between LAR and SAKI.

Results The final analysis incorporated data from 4,113 patients retrieved from the MIMIC-IV database. Logistic regression analysis revealed that a 1-unit increase in LAR was linked to a 49% rise in the incidence of SAKI (95% confidence interval, 1.27 to 1.76; $P < 0.001$). These findings were further validated through subgroup analyses, confirming their robustness.

Conclusions Higher LAR at admission was independently associated with an increased risk of SAKI.

Keywords Sepsis-associated kidney injury, Lactate-to-albumin ratio, Sepsis, Novel biomarker, Critically ill patients

Introduction

Sepsis is a life-threatening syndrome marked by organ dysfunction stemming from the body's dysregulated response to infection [1]. The kidneys are among the most frequently affected organs, leading to sepsis-associated acute kidney injury (SAKI), which contributes to the high morbidity and mortality associated with sepsis. In an ancillary analysis of a multicenter randomized controlled trial involving septic shock and including 1243 patients, acute kidney injury (AKI) was present in 50.4% of patients upon enrollment in the emergency department, with an additional 18.7% developing AKI within the subsequent 7 days [2, 3]. SAKI is closely linked to adverse clinical outcomes, including an increased risk of in-hospital mortality and extended hospital stays compared to AKI from other causes [4]. Early detection of SAKI is critical for optimizing treatment and improving patient outcomes. As a result, significant research efforts have been directed toward identifying biomarkers that can aid in the early detection of SAKI.

Serum lactate serves as an indicator of tissue hypoperfusion. Elevated serum lactate levels are considered a surrogate marker for cellular metabolic dysfunction and are independently linked to acute mortality in sepsis patients [5]. On the other hand, albumin has demonstrated the

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ability to counteract the harmful effects of infection-induced inflammatory responses and lower the risk of organ failure. Nevertheless, both lactate and albumin, when used as individual markers, can be influenced by various factors, including physical activity, liver conditions, medications, and nutritional status [6–8].

The lactate-to-albumin ratio (LAR) has emerged as a promising biomarker, garnering increasing attention for its role in the prognostic evaluation of critically ill patients. Research indicates that combining lactate and albumin into the LAR provides a more precise predictive capability for sepsis than lactate alone [9, 10]. Furthermore, recent studies have identified LAR as a reliable predictor of mortality in patients with AKI [11]. However, the association between LAR and SAKI remains unclear. We analyzed data from the Medical Information Mart for Intensive Care IV (MIMIC-IV) database, focusing on sepsis hospitalizations between 2008 and 2019, to explore the relationship between LAR and SAKI.

Materials and methods

Data sources and setting

This research made use of data sourced from the MIMIC-IV database, an extensive repository of electronic health records. MIMIC-IV encompasses a comprehensive collection of de-identified, high-quality data on patients in the Intensive Care Unit (ICU) at Beth Israel Deaconess Medical Center (BIDMC) in Boston, MA, USA, spanning from 2008 to 2019. Access to this dataset was provided under certification number 58844105. The Institutional Review Board at BIDMC granted a waiver for informed consent and approved the use of this dataset for research purposes. This cohort study adhered to the guidelines established by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [12].

Study population

This study comprised ICU patients from the MIMIC-IV database who met the eligibility criteria. We concentrated on adults with a diagnosis of sepsis-3, characterized by at least a two-point increase in the Sequential Organ Failure Assessment (SOFA) score resulting from a dysregulated response to infection. We excluded patients based on the following criteria: (1) age under 18 years; (2) repeated hospital admissions, other than the first ICU admission; (3) ICU stay shorter than 24 h; (4) pre-existing renal disease; and (5) incomplete data on key variables, including lactate and albumin.

Exposure and endpoints

In this study, the LAR was selected as the primary variable of interest. We utilized lactate and albumin measurements obtained within 24 h of ICU admission. When multiple measurements of these parameters were available within this time frame, the earliest recorded value was used. Patients were divided into two groups according to their AKI status: the AKI group ($n = 3234$) and the non-AKI group ($n = 879$).

The main endpoint was the occurrence of AKI within 7 days following the diagnosis of sepsis. AKI was assessed based on the Kidney Disease Improving Global Outcomes (KDIGO) criteria: which include: (1) an increase in serum creatinine by ≥ 0.3 mg/dL within 48 h; (2) an increase in serum creatinine to ≥ 1.5 times the baseline within the prior 7 days; or (3) a urine output of < 0.5 mL/kg/h for 6 h [1, 13]. In this study, baseline serum creatinine was defined as the lowest serum creatinine within 7 days after diagnosis of sepsis. Secondary endpoints included mortality rates at 28 and 90 days, in-hospital mortality, and ICU-free days until 28 days.

Covariates

The study incorporated several variables for analysis. Demographic and admission data included age, sex, and race. Additional admission-related measures included the Charlson Comorbidity Index, the Simplified Acute Physiology Score II (SAPS II), and the Sequential Organ Failure Assessment (SOFA) score. Vital signs recorded at ICU admission included heart rate, mean blood pressure (MBP), and oxygen saturation (SpO2). The interventions assessed encompassed mechanical ventilation, vasopressor administration, renal replacement therapy (RRT), and the use of antibiotics within the initial 24 h of ICU admission. The laboratory tests included measurements of potassium, sodium, chloride, bicarbonate, anion gap, hemoglobin, phosphate, total calcium, creatinine, blood–urea–nitrogen (BUN), glucose, platelet count, and white blood cell (WBC) count. Comorbidities evaluated were myocardial infarction, cerebrovascular disease, congestive heart failure, chronic pulmonary disease, diabetes, peripheral vascular disease, malignant cancer, and liver disease, with comorbidity data extracted using the International Classification of Diseases (ICD) coding systems.

Statistical analysis

Given the retrospective design of this study, we did not develop a predefined statistical analysis plan or perform a power calculation. The sample size was determined based on the available data in the database. The proportion of missing values for covariates was less than 2%. Therefore, we opted to exclude these missing values directly.

We present categorical variables as counts with percentages, while continuous variables are summarized as

means with standard deviations (SD) or medians with interquartile ranges (IQR). The analysis of continuous data utilized either the Student's *t* test or the Wilcoxon rank-sum test, depending on data distribution, whereas categorical data were analyzed using either Pearson's chi-squared test or Fisher's exact test.

Variable selection was guided by clinical relevance and existing literature. In addition, variables with *p* values < 0.1 in univariate analysis also were included. We employed a tenfold cross-validation in conjunction with least absolute shrinkage and selection operator (LASSO) regression to analyze variables with *p* values below 0.1 from the initial comparison of basic information. This approach was used to identify variables associated with the onset of SAKI, with lambda (λ) calculated at the first standard error (SE), referred to as λ.1se. Logistic regression was then utilized to evaluate the association between LAR and SAKI in both unadjusted and adjusted models. The findings were reported as odds ratios (OR) with 95% confidence intervals (CI). The regression model analysis methods used for the secondary outcomes are detailed in the Supplementary Material. In addition, subgroup analyses were conducted to examine potential interactions and verify the robustness of the results.

Analyses were conducted using R Statistical Software (Version 4.2.2, http://www.R-project.org, The R Foundation) and the Free Statistics analysis platform (Version 2.0, Beijing, China). Statistical significance was determined by a *p* value of less than 0.05 in a two-tailed test.

Results

Study cohort and patients' characteristics

This study included 4,113 eligible patients (see Fig. 1). Of these, 3,234 patients (78.6%) developed SAKI within 7 days following the diagnosis of sepsis. Individuals with SAKI were significantly older than those without ($P < 0.001$). In addition, the SAKI group had a higher proportion of males and exhibited lower MBP and SpO2

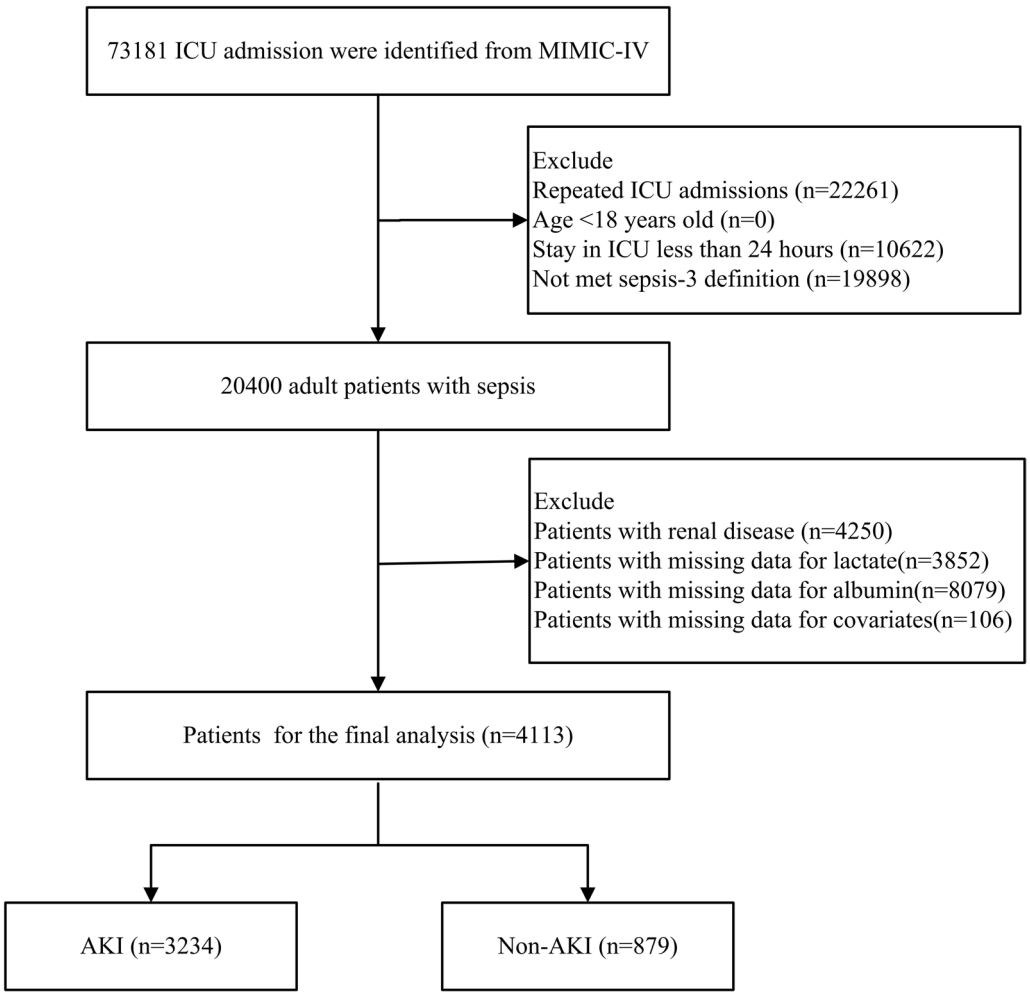

Fig. 1 Flow chart of patient selection. *Note* ICU, Intensive Care Unit; MIMIC-IV, Medical Information Mart in Intensive Care-IV; AKI: acute kidney injury

Table 1 Baseline characteristics of participants

Patient characteristic	Total ($n = 4113$)	Non-AKI ($n = 879$)	AKI ($n = 3234$)	p
Age (years), Mean ± SD	61.7 ± 17.0	58.7 ± 18.3	62.5 ± 16.5	< 0.001
Sex, *n* (%)				0.027
Female	1835 (44.6)	421 (47.9)	1414 (43.7)	
Male	2278 (55.4)	458 (52.1)	1820 (56.3)	
Race, *n* (%)				0.070
White	2509 (61.0)	513 (58.4)	1996 (61.7)	
Other	1604 (39.0)	366 (41.6)	1238 (38.3)	
Vital signs				
Heart rate (bpm), Mean ± SD	91.5 ± 17.5	91.0 ± 16.4	91.7 ± 17.8	0.345
MBP (mmHg), Mean ± SD	77.1 ± 10.4	78.3 ± 10.8	76.8 ± 10.3	< 0.001
SpO_2 (%), Mean ± SD	96.8 ± 2.6	97.0 ± 2.2	96.8 ± 2.7	0.011
Comorbidity disease, *n* (%)				
Myocardial infarction	603 (14.7)	95 (10.8)	508 (15.7)	< 0.001
Congestive heart failure	925 (22.5)	119 (13.5)	806 (24.9)	< 0.001
Peripheral vascular disease	358 (8.7)	44 (5.0)	314 (9.7)	< 0.001
Cerebrovascular disease	464 (11.3)	90 (10.2)	374 (11.6)	0.271
Chronic pulmonary disease	1000(24.3)	188(21.4)	812(25.1)	0.023
Diabetes	981 (23.9)	176 (20)	805 (24.9)	0.003
Malignant cancer	675 (16.4)	140 (15.9)	535 (16.5)	0.662
Liver disease	1203 (29.2)	189 (21.5)	1014 (31.4)	< 0.001
Score system				
Charlson comorbidity index, Median (IQR)	5.0 (3.0, 7.0)	4.0 (2.0, 6.0)	5.0 (4.0, 7.0)	< 0.001
SOFA score, Median (IQR)	3.0 (2.0, 5.0)	3.0 (2.0, 4.0)	4.0 (2.0, 6.0)	< 0.001
SAPS II, Mean ± SD	42.8 ± 15.6	34.5 ± 12.0	45.1 ± 15.7	< 0.001
Laboratory parameters				
Sodium (mmol/L), Mean ± SD	138.4 ± 6.0	138.8 ± 5.5	138.3 ± 6.2	0.064
Potassium (mmol/L), Mean ± SD	4.2 ± 0.8	4.0 ± 0.7	4.2 ± 0.9	< 0.001
Chloride(mmol/L), Mean ± SD	104.3 ± 7.3	105.5 ± 7.0	104.0 ± 7.3	< 0.001
Bicarbonate (mmol/L), Mean ± SD	21.3 ± 5.2	21.7 ± 4.7	21.2 ± 5.4	0.036
Anion gap(mEq/L), Mean ± SD	16.0 ± 5.1	14.7 ± 4.0	16.3 ± 5.3	< 0.001
Hemoglobin (g/dL), Mean ± SD	10.8 ± 2.4	10.6 ± 2.2	10.9 ± 2.4	0.006
Phosphate (mg/dL), Median (IQR)	3.9 ± 1.7	3.3 ± 1.3	4.0 ± 1.8	< 0.001
Total calcium (mg/dL), Mean ± SD	8.0 ± 1.0	7.9 ± 0.9	8.0 ± 1.1	0.021
Creatinine (mg/dL), Median (IQR)	1.0 (0.7, 1.5)	0.9 (0.7, 1.2)	1.1 (0.8, 1.6)	< 0.001
BUN (mg/dL), Median (IQR)	21.0 (14.0, 34.0)	17.0 (11.0, 27.5)	22.0 (14.0, 35.0)	< 0.001
Glucose (mg/dL), Median (IQR)	133.0 (106.0, 177.0)	123.0 (102.0, 157.0)	137.0 (108.2, 183.0)	< 0.001
Platelets (K/uL), Median (IQR)	176.0 (113.0, 252.0)	177.0 (115.5, 248.0)	175.0 (111.0, 253.0)	0.762
WBC(K/uL), Median (IQR)	12.5 (8.2, 18.1)	12.0 (7.7, 17.5)	12.6 (8.3, 18.2)	0.008
LAR, Median (IQR)	0.7 (0.4, 1.2)	0.6 (0.4, 0.9)	0.7 (0.5, 1.3)	< 0.001
Interventions				
Ventilator (day 1), n (%)	2888 (70.2)	398 (45.3)	2490 (77.0)	< 0.001
Antibiotic (day 1), n (%)	3669 (89.2)	819 (93.2)	2850 (88.1)	< 0.001
Vasoactive agent (day 1), n (%)	2152 (52.3)	344 (39.1)	1808 (55.9)	< 0.001
RRT (day 1), n (%)	235 (5.7)	8 (0.9)	227 (7.0)	< 0.001
Los in hospital (day), Median (IQR)	10.5 (5.9, 18.7)	7.7 (4.8, 12.7)	11.6 (6.4, 20.3)	< 0.001
Los in icu (day), Median (IQR)	4.2 (2.2, 8.7)	2.5 (1.7, 4.0)	5.0 (2.7, 9.7)	< 0.001

Note AKI, acute kidney injury; bpm, beats per minute; SD, standard deviation; MBP, mean blood pressure; SpO_2, peripheral capillary oxygen saturation; IQR, interquartile range; SAPS II, simplified acute physiology score; SOFA, Sequential Organ Failure Assessment; BUN, blood–urea–nitrogen; WBC, white blood cell; LAR, lactate-to-albumin ratio; RRT, renal replacement therapy

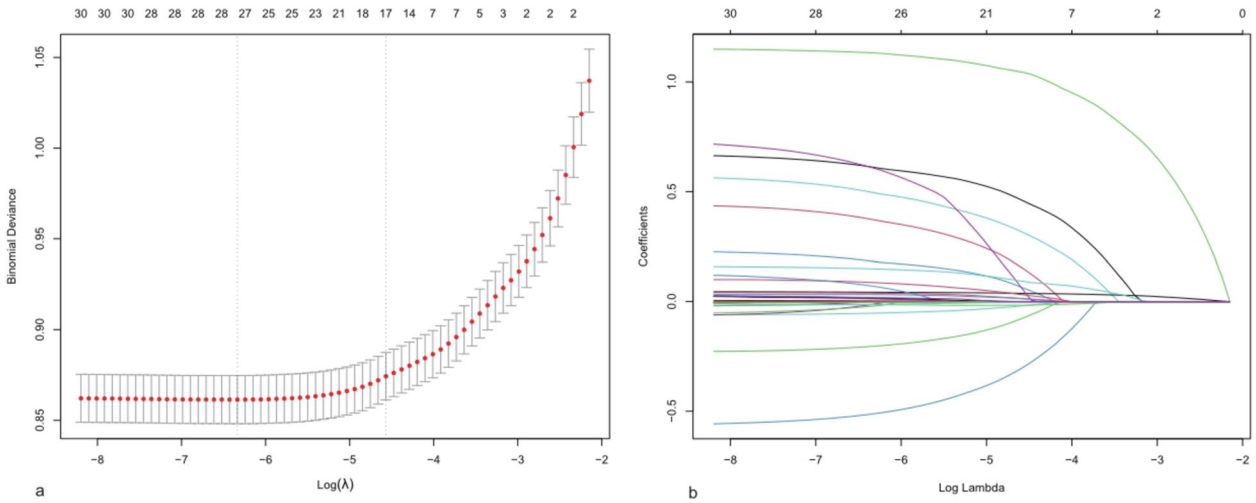

Fig. 2 **a** Selection process of the value of lambda by cross validation. **b** Selection process of variables of sepsis-associated acute kidney injury by least absolute shrinkage and selection operator (LASSO) regression

($P < 0.05$). The prevalence of comorbid conditions was notably higher among SAKI patients, with the exception of cerebrovascular disease and malignant cancer, which did not show significant differences ($P > 0.05$). Laboratory parameters were also worse in the SAKI group. A greater number of SAKI patients required mechanical ventilation, vasoactive drugs, and RRT (all $P < 0.001$). Furthermore, patients with SAKI had elevated SAPS II, SOFA scores, and Charlson comorbidity index scores (all $P < 0.001$). LAR was higher in the SAKI group compared to the non-SAKI group (0.6 [0.4, 0.9] vs. 0.7 [0.5, 1.3], $P < 0.001$) (Table 1).

Association between LAR and SAKI

Using AKI as the dependent variable and the 35 variables with p values less than 0.1 from Table 1 as independent variables, we performed a tenfold cross-validation LASSO regression analysis. λ.1se was determined to be 0.01. This analysis ultimately identified 20 variables for inclusion, including the LAR, age, race, SpO2, SOFA score, SAPS II, potassium, chloride, hemoglobin, bicarbonate, phosphate, BUN, total calcium, and comorbidities, such as congestive heart failure, peripheral vascular disease, diabetes, and liver disease. In addition, variables related to initial treatment, such as mechanical ventilation (day 1), antibiotic use (day 1), and RRT (day 1) were selected, as depicted in Fig. 2. Both the full set of variables and these 20 selected variables were subsequently included in separate logistic regression analyses, detailed in Table 2.

Higher LAR was associated with the risk of SAKI. In the initial model, the OR for the relationship between LAR and SAKI was 1.94 (95% CI, 1.70 to 2.22; $P < 0.001$). This association remained robust in the fully adjusted model, where each one-unit increase in LAR was associated with a 49% increase in the likelihood of SAKI occurrence (adjusted OR in model 4, 1.49; 95% CI, 1.27 to 1.76; $P < 0.001$). Consistent results were observed in logistic regression analyses using variables selected by LASSO. Even after accounting for confounding variables, a high LAR continued to be associated with the risk of SAKI (adjusted OR in model 5, 1.46; 95% CI, 1.25 to 1.71; $P < 0.001$).

To further assess the impact of LAR, patients were divided into three equal groups based on their LAR values: T1, T2, and T3. The analysis across these strata confirmed that individuals in the highest LAR group had a significantly increased risk of developing SAKI compared to those in the lowest LAR group (adjusted OR 1.53; 95% CI, 1.19 to 1.97; $P = 0.001$). In addition, a trend test indicated a statistically significant trend ($P < 0.05$) toward higher risk with increasing LAR levels (Table 2).

Subgroup analyses

We performed subgroup analyses to examine how factors such as age, sex, race, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, chronic pulmonary disease, diabetes, malignant cancer, and liver disease might influence the relationship between LAR and the incidence of SAKI. No statistically significant interactions were found in any subgroups (P for interaction > 0.05, Fig. 3). These findings suggest a consistent effect of

Table 2 Association between LAR and SAKI in different models

	n. total	n. event(%)	Model 1		Model 2		Model 3		Model 4		Model 5*	
			OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*
LAR	4113	3234 (78.6)	1.94 (1.70 ~ 2.22)	< 0.001	1.95 (1.71 ~ 2.24)	< 0.001	1.90 (1.62 ~ 2.22)	< 0.001	1.49 (1.27 ~ 1.76)	< 0.001	1.46(1.25 ~ 1.71)	< 0.001
LAR. Tertiles												
T1	1367	1006 (73.6)	1 (Ref)		1 (Ref)		1 (Ref)		1 (Ref)		1 (Ref)	
T2	1373	1034 (75.3)	1.09 (0.92 ~ 1.30)	0.303	1.08 (0.91 ~ 1.28)	0.379	1.12 (0.93 ~ 1.34)	0.247	1.02 (0.83 ~ 1.24)	0.884	0.99(0.81 ~ 1.20)	0.912
T3	1373	1194 (87.0)	2.39 (1.96 ~ 2.92)	< 0.001	2.43 (2.00 ~ 2.97)	< 0.001	2.12 (1.68 ~ 2.66)	< 0.001	1.53 (1.19 ~ 1.97)	0.001	1.50(1.18 ~ 1.90)	0.001
P for trend				< 0.001		< 0.001		< 0.001		0.002		0.002

* Variables screened by LASSO were included in the Logistic regression analysis

Model 1: unadjusted

Model 2: adjusted for sex, age, race

Model 3: adjusted for model 2 + heart rate, MBP, SpO_2, potassium, sodium, chloride, bicarbonate, anion gap, hemoglobin, phosphate, total calcium, creatinine, BUN, glucose, platelets, WBC

Model 4: adjusted for model 3 + Charlson comorbidity index, SOFA, SAPS II, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, chronic pulmonary disease, diabetes, malignant cancer, liver disease, ventilator(day 1), antibiotic(day 1), vasoactive agent (day 1), RRT (day 1)

Model 5: adjusted for age, race, SpO_2, SOFA, SAPS II, potassium, chloride, hemoglobin, bicarbonate, phosphate, BUN, total calcium, congestive heart failure, peripheral vascular disease, diabetes, liver disease, ventilator (day 1), antibiotic (day 1), RRT (day 1)

Note LAR, lactate-to-albumin ratio; SAKI, sepsis-associated acute kidney injury; OR, odds ratio; CI: confidence intervals; MBP, mean blood pressure; SpO2, peripheral capillary oxygen saturation; SAPS II, simplified acute physiology score; SOFA, Sequential Organ Failure Assessment; BUN, blood–urea–nitrogen; WBC, white blood cell; RRT, renal replacement therapy; LASSO, least absolute shrinkage and selection operator

(See figure on next page.)

Fig. 3 Subgroup analyses for the association of lactate-to-albumin ratio with sepsis-associated acute kidney injury. *Note* Logistic regression analysis was adjusted for heart rate, mean blood pressure, peripheral capillary oxygen saturation, potassium, sodium, chloride, bicarbonate, anion gap, hemoglobin, phosphate, total calcium, creatinine, blood–urea–nitrogen, glucose, platelets, white blood cell count, Charlson comorbidity index, sequential organ failure assessment score, simplified acute physiology score II, ventilator(day 1), antibiotic(day 1), vasoactive agent (day 1), renal replacement therapy (day 1)

LAR on the risk of SAKI, irrespective of age, race, sex, or comorbidities.

Secondary outcomes

An elevated LAR was associated with an increased risk of in-hospital mortality (adjusted hazard ratio [HR], 1.09; 95% CI, 1.03 to 1.16; $P = 0.002$), 28-day mortality (adjusted HR, 1.10; 95% CI, 1.04 to 1.16; $P = 0.001$), and 90-day mortality (adjusted HR, 1.11; 95% CI, 1.06 to 1.17; $P < 0.001$). In addition, each one-unit increase in LAR was associated with a reduction of 0.87 days in ICU-free days within 28 days (95% CI, − 1.22 to − 0.52) (Table 3).

Discussion

This study established that elevated LAR is significantly linked to the risk of SAKI. To enhance the reliability of our findings, we used LASSO analysis to identify relevant variables and subsequently applied logistic regression for additional adjustment. Consequently, each one-unit increase in LAR corresponded to a 49% higher risk of SAKI. The robustness of these findings was further validated through subgroup analyses. In addition, an inverse L-shaped relationship and threshold effect between LAR and the risk of SAKI offered new insights into their complex interaction.

AKI is a prevalent condition with a high mortality rate, posing significant global medical challenges. Its incidence has been rising over recent years. According to the global AKI–EPI study, 57.3% of critically ill patients developed AKI within 7 days of ICU admission across 97 sites [14]. In this study, 78.6% of septic patients experienced AKI within 7 days of ICU admission based on KDIGO diagnostic criteria. Furthermore, AKI is linked to higher mortality rates, extended hospital stays, and an increased risk of chronic kidney disease [15, 16]. While earlier studies primarily focused on prognostic indicators of AKI, such as the neutrophil-to-lymphocyte ratio and platelet-to-lymphocyte ratio [17, 18], recent research has expanded to include systemic inflammatory biomarkers, such as serum phosphate [19], procalcitonin [20], and the prognostic nutritional index [21], for predicting AKI in critically ill patients.

LAR, an easily accessible marker, has been linked to various conditions, such as sepsis, acute pancreatitis, and acute septic myocardial injury [22–24]. Although research on LAR and AKI is limited, most studies have examined its role in predicting AKI prognosis. Recent research revealed a notable increase in 30-day and 360-day all-cause mortality among AKI patients with elevated LAR [11]. In addition, LAR has been identified as an independent predictor of both in-hospital and ICU mortality in critically ill AKI patients [25]. Despite this, there has been limited systematic investigation into the relationship between LAR and the risk of SAKI. This study found that higher LAR levels were significantly associated with an increased risk of SAKI (adjusted OR, 1.49; 95% CI, 1.27 to 1.76; $P < 0.001$). These findings provide compelling evidence validating the use of LAR as an effective biomarker for the risk of SAKI.

The underlying mechanisms through which LAR influences the occurrence of SAKI remain unclear. It is well-established that inflammation significantly contributes to the development and progression of AKI. The release of inflammatory mediators and the infiltration of inflammatory cells can cause renal tissue damage and impair kidney function [26]. Elevated lactate levels are indicative of heightened inflammatory activity and can exacerbate the inflammatory response [27]. Conversely, albumin contributes to the regulation of inflammation and the immune system by boosting the production of anti-inflammatory agents, such as lipoxins, solubilizers, and protectins, which aid in tissue repair [23]. Therefore, the impact of LAR on the risk of SAKI patients may involve two distinct inflammatory mechanisms: one related to lactate's promotion of inflammation and the other related to albumin's modulation of inflammatory processes.

Several limitations must be acknowledged when interpreting our results. First, while we have made efforts to account for confounding factors, the retrospective design of this study means that there may be unidentified variables affecting our findings. Second, the nature of this study does not enable us to establish a causal relationship between LAR and SAKI. In addition, given that LAR can fluctuate, a single measurement may not fully capture its association with SAKI over time. Thus, further research

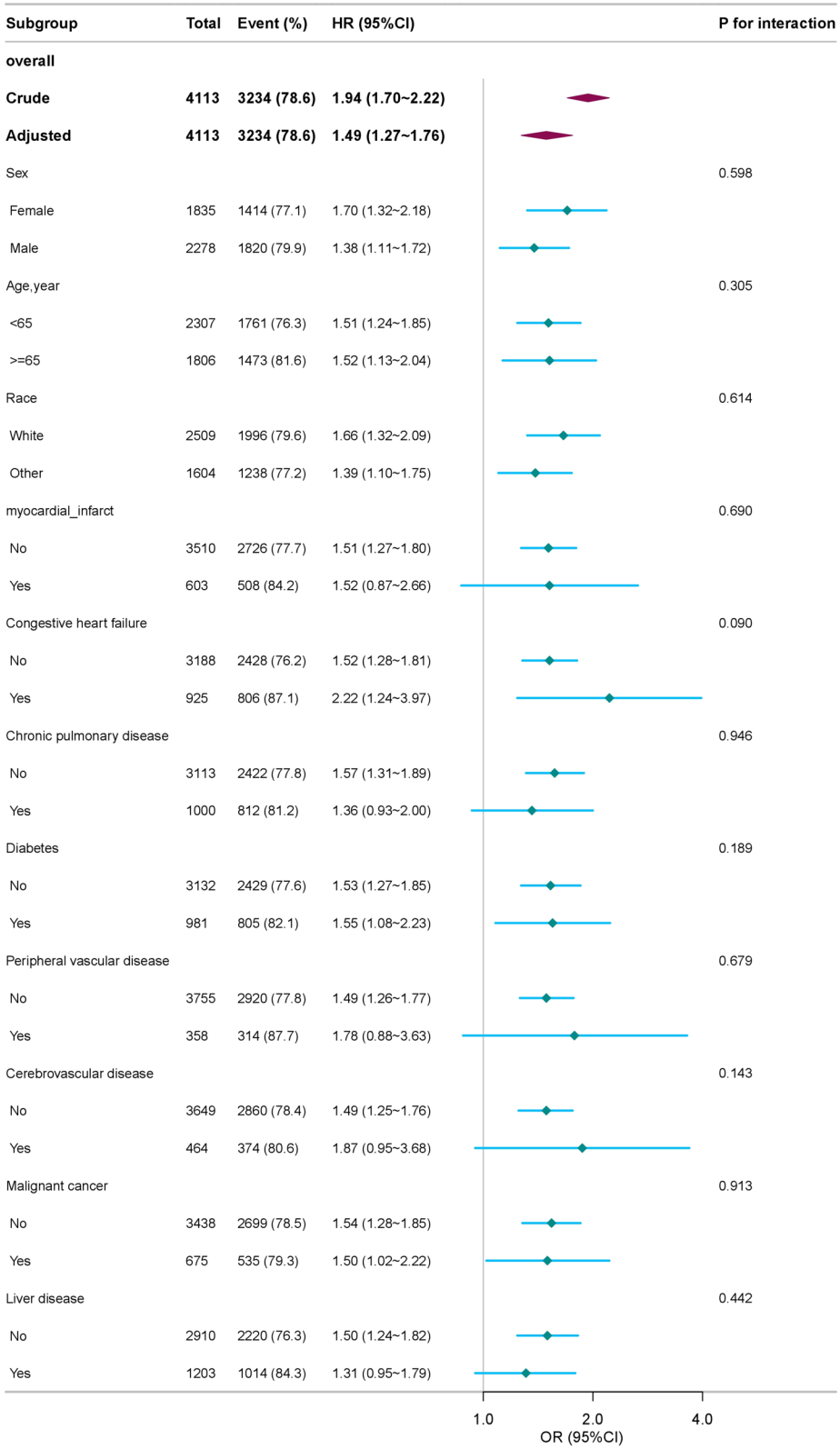

Fig. 3 (See legend on previous page.)

Table 3 Secondary outcome analysis

Variable	*n* total	*n* event(%)	Model 1		Model 2		Model 3*	
			HR/β (95%CI)	*p*	HR/β(95%CI)	*p*	HR/β(95%CI)	*p*
28-day mortality	4113	1051 (25.6)	1.36 (1.32 ~ 1.41)	< 0.001	1.10 (1.04 ~ 1.16)	0.001	1.32 (1.21 ~ 1.43)	< 0.001
90-day mortality	4113	1313(39.1)	1.34 (1.30 ~ 1.39)	< 0.001	1.11 (1.06 ~ 1.17)	< 0.001	1.32 (1.21 ~ 1.44)	< 0.001
In hospital mortality	4113	917 (22.3)	1.39 (1.35 ~ 1.44)	< 0.001	1.09 (1.03 ~ 1.16)	0.002	1.33 (1.21 ~ 1.45)	< 0.001
ICU free day until 28 days	4113		−2.46 (−2.76 ~ −2.17)	< 0.001	−0.87 (−1.22 ~ −0.52)	< 0.001	−1.20 (−1.53 ~ −0.87)	< 0.001

* Variables screened by LASSO were included in the Logistic regression analysis

Model 1: unadjusted

Model 2: adjusted for sex, age, race, heart rate, MBP, SpO_2, potassium, sodium, chloride, bicarbonate, anion gap, hemoglobin, phosphate, total calcium, creatinine, BUN, glucose, platelets, WBC, Charlson comorbidity index, SOFA, SAPS II, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, chronic pulmonary disease, diabetes, malignant cancer, liver disease, ventilator (day 1), antibiotic (day 1), vasoactive agent (day 1), RRT (day 1)

Model 3: adjusted for age, race, SpO_2, SOFA, SAPS II, potassium, chloride, hemoglobin, bicarbonate, phosphate, BUN, total calcium, congestive heart failure, peripheral vascular disease, diabetes, liver disease, ventilator(day 1), antibiotic(day 1), RRT (day 1)

Note HR, hazard ratio; CI: confidence intervals; ICU, intensive care unit; MBP, mean blood pressure; SpO_2, peripheral capillary oxygen saturation; SAPS II, simplified acute physiology score; SOFA, Sequential Organ Failure Assessment; BUN, blood–urea–nitrogen; WBC, white blood cell; RRT, renal replacement therapy

involving large, multicenter, prospective studies is needed to thoroughly investigate the impact of LAR on SAKI.

Conclusion

Elevated LAR at the time of ICU admission was associated with the risk of SAKI. It is crucial for clinicians to evaluate the prognosis of these patients promptly.

Abbreviations

SAKI	Sepsis-associated acute kidney injury
LAR	Lactate-to-albumin ratio
MIMIC-IV	Medical Information Mart for Intensive Care-IV
AKI	Acute kidney injury
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
ICU	Intensive Care Unit
BIDMC	The Beth Israel Deaconess Medical Center
SOFA	Sequential Organ Failure Assessment
KDIGO	Kidney Disease: Improving Global Outcomes
SQL	Structured Query Language
SAPS II	The Simplified Acute Physiology Score II
MBP	Mean blood pressure
SpO2	Peripheral capillary oxygen saturation
RRT	Renal replacement therapy
WBC	White blood cell count
BUN	Blood–urea–nitrogen
ICD	International Classification of Diseases
SD	Standard deviations
IQR	Interquartile ranges
OR	Odds ratios
CI	Confidence interval
HR	Hazard ratio
LASSO	Least absolute shrinkage and selection operator

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40001-025-02760-8.

Additional file1

Additional file2

Additional file3

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Author contributions

TA: Data curation, Methodology, Software, Writing—original draft, review & editing. YH: Data curation, Methodology Writing—review. ZP: Supervision, Methodology. MH: Project administration, Writing—review & editing.

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Data availability

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://mimic.mit.edu/.

Declarations

Ethics approval and consent to participate

The research involving human subjects was granted approval from the Institutional Review Boards (IRBs). Specifically, the IRB of the Beth Israel Deaconess Medical Center provided consent under the reference number De2001-P-001699/14, and the Massachusetts Institute of Technology offered approval with the designation No. 0403000206. The first author, Ting Ao, was given access to the MIMIC-IV database following successful completion of an online course and test (Certificate ID: 58844105 Ting Ao). The research conducted adhered to local legislation and institutional requirements. Furthermore, written informed consent from participants or their legal guardians/next of

kin was also waived by the ethics committee/institutional review board, as the database did not contain protected health information.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

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