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RESEARCH

Admission lactate and short-term mortality in the geriatric ICU: comparison with established severity scores

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Abstract

Aim This study aims to investigate the prognostic value of admission lactate level in predicting 28-day mortality among geriatric patients admitted to the intensive care unit (ICU) and to compare its performance with established severity scores, including APACHE II and SOFA.

Materials and methods In this retrospective cohort study, data of patients aged ≥ 65 years who were admitted to a tertiary ICU between December 2024 and June 2025 were analyzed. Patients with ICU stays < 24 h or incomplete records were excluded. Demographic characteristics, comorbidities, admission lactate, APACHE II, and SOFA scores were recorded. The primary outcome was the association between admission lactate and 28-day mortality. Secondary outcomes included ICU length of stay, mechanical ventilation duration, and comparative prognostic accuracy of lactate versus APACHE II and SOFA.

Results A total of 241 patients were included. The 28-day mortality rate was 32.8%. Non-survivors had significantly higher admission lactate levels compared to survivors (6.29 ± 5.42 vs. 2.44 ± 1.80 mmol/L, $p < 0.001$). In multivariable logistic regression, admission lactate remained an independent predictor of mortality after adjustment for age, sex, comorbidity, and APACHE II (OR 1.29, 95% CI 1.09–1.52, $p = 0.003$). ROC analysis showed that lactate predicted 28-day mortality with an AUC of 0.77, compared to 0.92 for APACHE II and 0.88 for SOFA. Mortality increased across lactate categories: 14.2% (< 2 mmol/L), 27.8% (2–4 mmol/L), and 62.5% (> 4 mmol/L) ($p < 0.001$).

Conclusion Admission lactate is a simple and readily obtainable biomarker that independently predicts short-term mortality in geriatric ICU patients. While not outperforming established severity scores, lactate provides immediate risk stratification at the bedside and may aid clinical decision-making in this vulnerable population.

Keywords Lactate · Geriatric patients · Intensive care unit · APACHE II · SOFA · Mortality · Biomarker

Introduction

Early identification of high-risk patients is a cornerstone of intensive care medicine. Predicting mortality in critically ill individuals allows clinicians to guide therapeutic interventions, optimize resource allocation, and improve outcomes [1]. Several prognostic scoring systems, such as the Acute Physiology and Chronic Health Evaluation II (APACHE II) and the Sequential Organ Failure Assessment (SOFA), are widely used in daily practice to estimate prognosis. Although these scores are well validated, their calculation requires the collection of multiple physiological and laboratory parameters, which may delay risk stratification in urgent clinical settings [2, 3].

Serum lactate has emerged as a simple and rapidly obtainable biomarker that reflects the balance between oxygen delivery and tissue demand. Elevated lactate levels are considered an indicator of impaired cellular oxygen utilization, tissue hypoperfusion, or increased anaerobic metabolism [4, 5]. Numerous studies in heterogeneous ICU populations have demonstrated that admission lactate concentration, as well as lactate clearance, are strongly associated with mortality. Proposed cut-off values of 2 mmol/L and 4 mmol/L

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are frequently cited in the literature as clinically relevant thresholds for risk stratification [6, 7].

However, most of the existing evidence is derived from general or mixed ICU cohorts, with limited data focusing specifically on elderly patients. Geriatric individuals represent a distinct population characterized by diminished physiological reserve, a high prevalence of comorbidities, and different patterns of response to critical illness [8]. These features may alter the prognostic significance of lactate compared with younger patients. As the global population ages and the proportion of elderly ICU admissions rises, there is a growing need to clarify reliable prognostic markers in this vulnerable group [9, 10].

The present study aimed to investigate the association between admission lactate levels and 28-day mortality in geriatric ICU patients. Secondary objectives included the evaluation of the relationship between lactate and ICU length of stay, mechanical ventilation duration, and the comparative prognostic performance of lactate versus established severity scores (SOFA and APACHE II). We hypothesized that higher admission lactate levels would be independently associated with increased 28-day mortality among geriatric ICU patients, and that thresholds at 2 and 4 mmol/L would stratify short-term risk.

Materials and methods

Study design and setting

This retrospective observational study was conducted in the tertiary intensive care unit (ICU) of a training and research hospital between December 2024 and June 2025. The ICU is a closed, multidisciplinary, level III facility providing advanced critical care management.

Ethical approval

The study protocol was reviewed and approved by the Institutional Ethics Committee (Approval number: 512, Date: June 13, 2025). Owing to the retrospective nature of the study, the requirement for informed consent was waived.

Patient population

Patients aged ≥ 65 years who were admitted to the ICU during the study period were screened for eligibility. During this period, a total of 324 consecutive geriatric ICU admissions were screened. Of these, 48 patients were excluded due to incomplete data and 35 due to an ICU stay shorter than 24 h. Inclusion criteria were: (i) ICU stay of more than 24 h and (ii) complete availability of demographic, clinical, and laboratory data. A total of 241 patients met the inclusion criteria and were analyzed.

Data collection

Demographic characteristics (age, sex), comorbidities, and admission diagnoses were extracted from electronic medical records. Clinical severity scores including APACHE II and SOFA were calculated within the first 24 h of ICU admission. Serum lactate levels measured on admission were recorded as the primary biomarker. Outcome measures included 28-day all-cause mortality, ICU length of stay, and duration of mechanical ventilation.

Frailty was assessed using the Clinical Frailty Scale (CFS) at ICU admission, and comorbidity burden was quantified using the Charlson Comorbidity Index (CCI). In addition to composite scores, individual diagnoses such as hypertension, diabetes mellitus, coronary artery disease, chronic kidney disease, and malignancy were also recorded to ensure detailed characterization of baseline health status. Primary reasons for ICU admission were classified as postoperative follow-up, sepsis, post–cardiac arrest, cerebrovascular event, respiratory or metabolic causes, and other categories, based on electronic medical records and admission notes.

Outcomes

The primary outcome of the study was the association between admission lactate level and 28-day mortality. In addition, several secondary outcomes were evaluated, including the relationship between admission lactate and ICU length of stay, as well as mechanical ventilation duration. The prognostic accuracy of lactate was further compared with established scoring systems, namely SOFA and APACHE II.

Lactate levels were categorized as <2.0, 2.0–4.0, and >4.0 mmol/L, based on prior studies and exploratory ROC analysis in our cohort. Finally, mortality differences were examined across these predefined lactate categories.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation (SD) for normally distributed data or median (interquartile range, IQR) for skewed data. Comparisons between survivors and non-survivors were performed using the Student's t-test or Mann–Whitney U test, as appropriate. Categorical variables were compared using the Chi-square test. Correlations between lactate and ICU or ventilation duration were assessed with Spearman's correlation analysis. Prognostic performance was evaluated by receiver

Table 1 Baseline characteristics of the study population

Variable	Value
Age, mean ± SD (years)	73.8 ± 8.1
Male sex, n (%)	132 (54.8)
Charlson Comorbidity Index, median (IQR)	4 (3–6)
Clinical Frailty Scale, median (IQR)	5 (4–6)
Primary reason for ICU admission, n (%)	
– Postoperative follow-up	61 (25.3)
– Sepsis	51 (21.2)
– Post–cardiac arrest	35 (14.5)
– Cerebrovascular event	26 (10.8)
– Fall-related injury	23 (9.5)
– COPD exacerbation	15 (6.2)
– Acute kidney injury	11 (4.6)
– Other (e.g., pulmonary embolism, traffic accident, gastrointestinal bleeding, decompensated heart failure, status epilepticus)	10 (4.2)
Laboratory parameters on admission	
– Albumin (g/L), median [IQR]	30.0 [25.0–35.0]
– CRP (mg/L), median [IQR]	51.0 [10.9–108.0]
– Creatinine (mg/dL), median [IQR]	1.16 [0.8–1.67]
– Hemoglobin (g/dL), median [IQR]	11.8 [9.7–13.6]

Table 2 Comparison of survivors and non-survivors

Variable	Survivors	Non-survivors	*p*-value
Age (years)	78.1 ± 8.2	79.7 ± 8.9	0.202
APACHE II	15.2 ± 5.5	27.3 ± 5.6	< 0.001
SOFA	6.3 ± 2.7	10.7 ± 2.2	< 0.001
Lactate (mmol/L)	2.44 ± 1.80	6.29 ± 5.42	< 0.001

Table 3 ROC analysis of predictors for 28-day mortality

Predictor	AUC	95% CI
Lactate	0.777	0.717–0.840
APACHE II	0.933	0.898–0.963
SOFA	0.887	0.846–0.923

operating characteristic (ROC) curve analysis, with the area under the curve (AUC) reported and optimal cut-off values determined using the Youden index. Independent predictors of 28-day mortality were identified using multivariable logistic regression analysis including age, sex, comorbidity, APACHE II, and lactate. A two-sided p-value < 0.05 was considered statistically significant. All analyses were performed using SPSS software (version 25, IBM Corp., Armonk, NY, USA).

Results

Among 241 geriatric ICU patients included in the study, the mean age was 78.6 ± 8.4 years and 128 (53.1%) were female. A total of 78 patients (32.4%) died within 28 days, while 163 (67.6%) survived. The median ICU length of stay was 6 days (IQR 3–12), and the median duration of mechanical ventilation was 1 day (IQR 0–11). Baseline characteristics, including frailty, comorbidity, admission diagnoses, and laboratory parameters on admission, are summarized in Table 1. The most frequent admission diagnoses were postoperative follow-up (25.3%), sepsis (21.2%), and post-cardiac arrest (14.5%).

Lactate levels were also significantly associated with frailty and comorbidity.

Patients with ≥ 2 comorbidities had higher admission lactate values (median 2.41 [1.68–4.25] mmol/L) than those with ≤ 1 comorbidity (1.92 [1.44–3.10] mmol/L, $p = 0.041$).

Similarly, lactate increased across frailty strata: 1.88 [1.45–3.25] for CFS ≤ 4, 2.16 [1.54–3.60] for CFS 5–6, and 2.56 [1.83–4.72] mmol/L for CFS ≥ 7 ($p = 0.036$, Kruskal–Wallis).

Compared with the survival group, non-survivors had significantly higher admission lactate values (6.29 ± 5.42 vs. 2.44 ± 1.80 mmol/L; median 4.05 vs. 1.95; $p < 0.001$). Mortality rates increased across lactate categories, from 13.5% in patients with lactate < 2 mmol/L to 29.2% in those with lactate 2–4 mmol/L, and 70.9% in those with lactate > 4 mmol/L (Chi-square test = 53.15, $p < 0.001$).

The discriminatory ability of admission lactate for predicting 28-day mortality was moderate, with an AUC of 0.777 (95% CI 0.717–0.840). The optimal cut-off value was 4.16 mmol/L, corresponding to a sensitivity of 50.0% and a specificity of 90.7%. Detailed ROC analysis results are presented in Table 3. In contrast, both APACHE II (AUC 0.933, 95% CI 0.898–0.963) and SOFA (AUC 0.887, 95% CI 0.846–0.923) demonstrated superior prognostic accuracy (Fig. 1).

In the multivariable logistic regression model adjusted for age, sex, and comorbidity (Model A), lactate remained an independent predictor of mortality (OR 1.43 per mmol/L, 95% CI 1.25–1.64; $p < 0.001$). When APACHE II was added (Model B), both lactate (OR 1.14, 95% CI 1.00–1.29; $p = 0.049$) and APACHE II (OR 1.36, 95% CI 1.25–1.49; $p < 0.001$) were independently associated with 28-day mortality (Table 4).

Discussion

In this study of geriatric ICU patients, we demonstrated that admission lactate level is significantly associated with 28-day mortality and remains an independent predictor after adjusting for age, sex, comorbidity, and APACHE II score. Mortality increased progressively across lactate categories, with patients in the highest group (> 4 mmol/L) showing the worst outcomes. Although APACHE II and SOFA scores

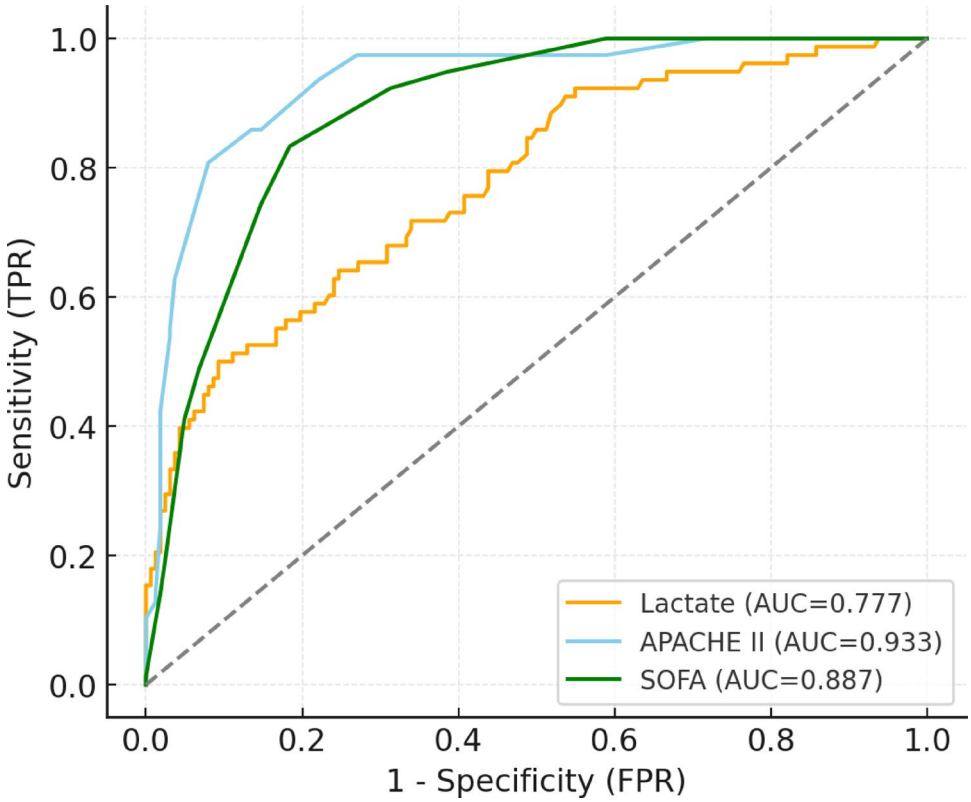

Fig. 1 ROC curves for 28-day mortality

Table 4 Multivariable logistic regression models for 28-day mortality

Variable	OR	95% CI	*p*-value
Lactate	1.14	1.00–1.29	0.049
Age	1.03	0.98–1.08	0.191
Male sex	1.39	0.59–3.26	0.446
APACHE II	1.36	1.25–1.49	<0.001

Model A: unadjusted logistic regression; Model B: adjusted for age, sex, comorbidity (CCI), and APACHE II score

provided stronger overall discrimination, lactate still offered valuable and readily obtainable prognostic information.

The prognostic value of lactate as a predictor of mortality has been increasingly recognized in recent critical care literature. A 2021 study by Liu et al. found that admission lactate levels >4 mmol/L were strongly associated with 28-day mortality in ICU patients with sepsis (OR 1.23, 95% CI 1.10–1.38), a threshold closely aligning with our optimal cut-off of 4.16 mmol/L [11]. Similarly, Ryoo et al. reported that lactate levels ≥ 2 mmol/L predicted mortality in septic shock patients defined by Sepsis-3, with an AUC of 0.70 for 28-day outcomes, highlighting its prognostic utility in severe sepsis [12]. More recently, Zhang et al. demonstrated in a large multicenter cohort of elderly sepsis patients that lactate and 28-day mortality were associated in a non-linear fashion, with risk markedly increasing above ~ 3.7 mmol/L, further emphasizing the importance of lactate in geriatric critical illness [13]. Our study extends these findings by confirming lactate's utility across a broader geriatric ICU population, including diverse diagnoses such as cardiovascular emergencies and respiratory failure. These consistent findings underscore lactate's reliability as a rapid prognostic marker in critical care, particularly for elderly patients.

These findings highlight the importance of lactate as a simple, rapid, and cost-effective biomarker in critically ill elderly patients. Unlike complex severity scoring systems that require the integration of multiple variables, lactate measurement can be performed immediately at the bedside, allowing early risk stratification and timely clinical decision-making [4, 6]. In line with this perspective, Uluç and colleagues recently demonstrated that simple indices such as the HALP score, CRP/albumin ratio, and platelet/lymphocyte ratio also have prognostic value in geriatric ICU patients, underscoring the increasing relevance of accessible biomarkers [14]. Our results suggest that lactate thresholds of 2 mmol/L and 4 mmol/L, which have been emphasized in previous research, may also hold prognostic relevance in the geriatric ICU population [7].

Even among patients with admission lactate < 2.0 mmol/L, 13.5% died within 28 days. This may reflect non-hypoperfusion causes of death (e.g., respiratory or neurological failure), delayed lactate rise, or impaired hepatic clearance. Advanced age and comorbidities may also contribute independently of lactate. Thus, while lactate remains a practical and valuable marker, it should be interpreted in the broader clinical context [6, 7].

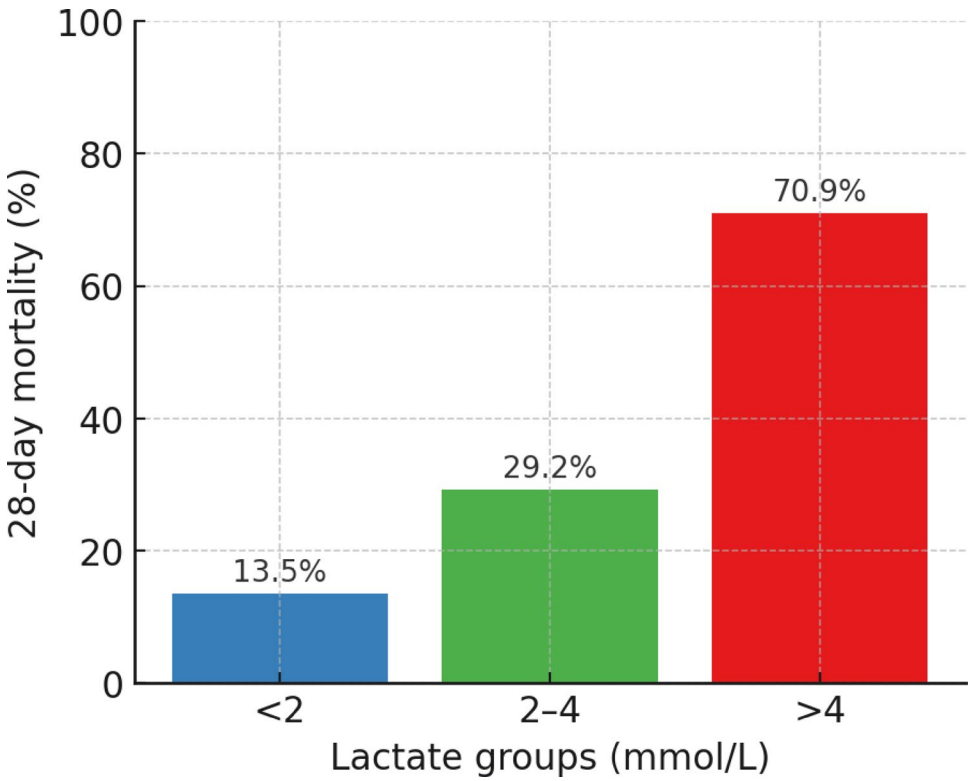

Fig. 2 Mortality by lactate categories

In our cohort, both frailty and comorbidity were evaluated to capture chronic vulnerability in elderly ICU patients. The observed rise in lactate across frailty and comorbidity strata suggests that its elevation reflects not only acute circulatory stress but also limited physiological reserve related to aging and chronic disease burden [11–13]. Frail or highly comorbid patients may have impaired perfusion, mitochondrial dysfunction, and reduced lactate clearance [15–17], leading to persistent hyperlactatemia even without overt shock. This interaction between acute metabolic stress and chronic vulnerability likely underlies the strong prognostic role of lactate in this population [16, 17]. Therefore, lactate should be interpreted in the context of frailty and comorbidity rather than as an isolated marker of severity.

The prognostic utility of lactate in elderly patients can be explained by several pathophysiological mechanisms. With advancing age, diminished cardiovascular reserve, impaired tissue perfusion, and reduced capacity for lactate clearance may amplify the adverse prognostic implications of even moderate lactate elevations [15]. In this context, a raised lactate level may serve not only as a marker of acute illness severity but also as a reflection of underlying frailty and vulnerability. Thus, admission lactate could be particularly valuable in identifying elderly patients at high risk of poor outcomes who may otherwise appear clinically stable [16, 17].

Our analysis further demonstrated that lactate alone does not outperform established severity scores such as APACHE II and SOFA. This was expected, since these scores encompass multi-organ dysfunction and provide a more comprehensive assessment of critical illness [2]. However, lactate offers a rapid and easily obtainable indicator of metabolic stress that may serve as an early adjunct to these complex scoring systems [11, 12, 18]. Combining lactate with APACHE II or SOFA could potentially enhance predictive accuracy, but this approach was beyond the scope of the present study and warrants validation in future prospective research. Nonetheless, lactate can complement these scores by providing an immediate estimate of risk at the time of ICU admission, particularly in situations where calculating composite indices is delayed or not feasible [18].

The clinical implications of our findings are significant. Admission lactate measurement should be considered routine in geriatric ICU patients, with values >4 mmol/L serving as a potential trigger for intensified monitoring and early therapeutic interventions. Incorporating lactate into existing decision-making frameworks could improve triage and optimize the allocation of resources in high-burden critical care environments [7, 9, 18].

Several limitations must be acknowledged.

First, its retrospective single-center design may limit the generalizability of our findings. Nevertheless, the homogeneous patient population and standardized ICU protocols across the study period increase the internal validity of the results. Future multicenter prospective studies involving

diverse ICU settings are warranted to confirm the applicability of these findings.

Second, only admission lactate was assessed; serial measurements and lactate clearance, which are known to improve prognostic accuracy, were not evaluated.

Third, although we included only patients with complete data and ICU stays longer than 24 h, residual selection bias cannot be excluded.

Finally, we did not account for potential confounders such as the timing of lactate sampling relative to initial resuscitation efforts. Although the association between lactate and mortality remained statistically significant in multivariable analysis ($p = 0.049$), the borderline value indicates limited statistical robustness. However, the consistency of this finding with prior literature suggests that the observed association is clinically meaningful despite modest statistical strength.

In conclusion, admission lactate is a robust predictor of short-term mortality in geriatric ICU patients and provides useful complementary information to established severity scores. Future multicenter prospective studies with larger cohorts and serial lactate measurements are warranted to validate these findings and refine cut-off thresholds for risk stratification in this vulnerable population.

Author contributions A.D. conceived and designed the study, collected and analyzed the data, and drafted the manuscript. B.S.K. contributed to data analysis, prepared the tables and figures, and assisted in manuscript editing. All authors reviewed and approved the final version of the manuscript.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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