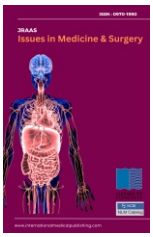
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Research Article

Section: General Medicine

Association of Serum Lactate Dehydrogenase to Albumin Ratio with the Risk of Stroke Associated Pneumonia in Acute Stroke Patients

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HIGHLIGHTS

- LAR predicted stroke-associated pneumonia
- Higher LAR increased SAP risk
- LAR showed strong diagnostic accuracy
- Dysphagia independently predicted SAP
- SAP increased mortality and ICU admission

Key Words:
Stroke-associated pneumonia
Lactate dehydrogenase-to-albumin ratio
Acute stroke
Lactate dehydrogenase
Risk stratification

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ABSTRACT

Introduction: Stroke-associated pneumonia (SAP) is a frequent complication of acute stroke and contributes to increased morbidity, mortality, intensive care requirement, and prolonged hospitalization. The lactate dehydrogenase-to-albumin ratio (LAR) combines markers of cellular injury and systemic inflammatory or nutritional status and may provide a simple indicator for early SAP risk stratification. **Aim & Objective:** To determine the association between serum LAR and SAP in acute stroke patients, assess its diagnostic ability for predicting SAP, and evaluate clinical outcomes according to different LAR levels. **Materials & Methods:** This cross-sectional observational study was conducted in the Department of General Medicine, SRN Hospital, M.L.N. Medical College, Prayagraj, from March 2025 to March 2026. One hundred consecutive adults with acute ischemic or hemorrhagic stroke presenting within seven days were enrolled. Serum LDH and albumin were measured, LAR was calculated, and SAP was diagnosed using modified CDC criteria. Statistical analysis included t-test, chi-square test, Pearson correlation, multivariate logistic regression, and ROC analysis. **Results:** SAP occurred in 26% of patients. Mean LAR was significantly higher in SAP than non-SAP patients (33.65 ± 9.22 vs 19.04 ± 6.33, $p<0.001$). LAR showed strong predictive performance with an AUC of 0.897 and an optimal cutoff of 24.24, providing 84.6% sensitivity, 83.8% specificity, 64.7% positive predictive value, 93.9% negative predictive value, and 84% overall accuracy. Higher NIHSS, dysphagia, mechanical ventilation, and LAR independently predicted SAP. SAP was associated with higher ICU admission and mortality. **Conclusion:** LAR was significantly associated with SAP and remained an independent predictor after adjustment. It may serve as a simple, inexpensive biomarker for early identification of high-risk acute stroke patients in routine clinical stroke care.

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INTRODUCTION

Stroke is a neurological emergency and remains a leading cause of death and long-term disability worldwide. It occurs as a consequence of interruption of cerebral blood flow due to vascular occlusion or rupture, producing acute neuronal injury and neurological dysfunction [1]. The global burden remains substantial. Estimates from the Global Burden of Disease Study 2021 reported approximately 11.9 million incident strokes, 93.8 million prevalent cases, 7.3 million stroke-related deaths, and 160.5 million disability-adjusted life years worldwide in 2021 [2]. Although advances in thrombolysis, mechanical thrombectomy, stroke-unit care, neurocritical care, and rehabilitation have improved outcomes, early medical complications remain important determinants of morbidity, mortality, hospital stay, and functional recovery after acute stroke [3].

Stroke-associated pneumonia (SAP) is one of the most frequent and clinically important infectious complications occurring after acute stroke. The Pneumonia in Stroke Consensus Group recommended the term SAP for lower respiratory tract infection developing within the first seven days after stroke onset and proposed standardized clinical and radiological criteria for its diagnosis [4]. A systematic review and meta-analysis by Badve et al., including 47 studies with 139,432 patients, reported a pooled frequency of post-stroke pneumonia of 12.3%, indicating that approximately one in ten patients experiences pneumonia during the acute period of hospital care. SAP may complicate neurological management, prolong hospitalization, increase supportive-care requirements, and adversely affect recovery [5].

The pathogenesis of SAP is complex and cannot be explained by aspiration alone. Acute stroke can impair consciousness, swallowing, cough, airway protection, and mobility. Dysphagia facilitates aspiration of oropharyngeal secretions and gastric contents, while reduced cough strength and immobility interfere with pulmonary clearance [6]. In parallel, cerebral injury produces interactions between the nervous and immune systems. Stroke initially activates inflammatory pathways but may subsequently induce systemic immunosuppression. Faura et al. described stroke-induced immunosuppression as involving reduced circulating lymphocytes and natural killer cells, a shift in T-helper responses, and impaired antimicrobial functions of neutrophils and monocytes. These abnormalities can diminish host defense and increase susceptibility to post-stroke infections, particularly pneumonia [7].

Because SAP frequently develops early after stroke, timely identification of high-risk patients is clinically important. Traditional clinical risk factors, including advanced age, dysphagia, impaired consciousness, neurological severity, nasogastric tube use, and associated comorbidities, are useful but do not fully explain individual susceptibility [8]. Laboratory biomarkers capable of reflecting tissue injury, inflammation, immune dysfunction, and physiological reserve may therefore contribute to early risk stratification. However, the PISCES consensus noted limited evidence for commonly used markers such as white blood cell count and C-reactive protein and insufficient evidence for several other biomarkers, highlighting the need for simple and reproducible indicators of SAP risk [4].

Lactate dehydrogenase (LDH) is a widely distributed intracellular enzyme involved in the interconversion of lactate and pyruvate during cellular energy metabolism. Serum LDH can rise when cellular membranes are damaged and intracellular contents are released, and elevated values may accompany tissue hypoxia, ischemic injury, inflammation, or systemic illness. In acute stroke, neuronal and systemic tissue injury may therefore contribute to an increased LDH concentration [9]. Nevertheless, LDH alone is nonspecific because its concentration may be influenced by injury in several tissues and organs. Its significance

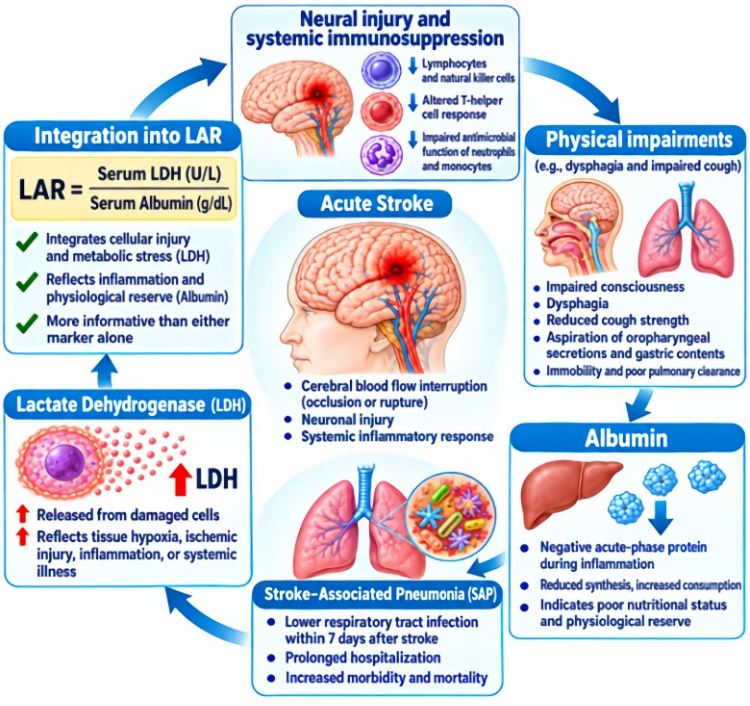


Figure 1: Mechanistic Pathway of LAR in stroke associated pneumonia (SAP)

may be strengthened when interpreted with another marker reflecting a different component of systemic illness [10].

Albumin is the major circulating plasma protein synthesized by the liver and contributes to oncotic pressure, transport functions, antioxidant activity, and physiological homeostasis. Serum albumin is influenced by nutritional status, inflammation, hepatic synthesis, vascular permeability, and severity of acute illness. During systemic inflammation, albumin behaves as a negative acute-phase protein and its circulating concentration may decline. In acute stroke patients, reduced albumin may therefore indicate diminished physiological reserve or greater inflammatory stress, which may increase vulnerability to infection. Evaluation of LDH and albumin together may consequently provide more comprehensive information than either biomarker alone [11]

The lactate dehydrogenase-to-albumin ratio (LAR) integrates a marker associated with cellular injury and metabolic stress with a marker influenced by inflammation and physiological reserve. Yan et al. evaluated 3,173 patients with acute ischemic stroke, among whom 417 developed SAP. Mean LAR was significantly higher in patients who developed SAP than in those who did not, at 8.75 ± 4.58 versus 6.10 ± 2.55. After adjustment for potential confounding factors, an LAR greater than 6.75 was associated with increased odds of SAP, with an odds ratio of 2.80 and a 95% confidence interval of 2.18 to 3.59. LAR also demonstrated better discriminatory performance than LDH or albumin considered separately [12]. Mechanistic Pathway Linking LAR to Stroke-Associated Pneumonia (SAP) (**Figure 1**)

These findings provide a biologically plausible and clinically practical basis for evaluating LAR in acute stroke. LDH and albumin are inexpensive, routinely available laboratory parameters that can be measured soon after admission. Their ratio may complement clinical assessment and help identify patients needing closer respiratory surveillance, swallowing evaluation, aspiration precautions, oral care, and mobilization. However, evidence linking LAR with stroke-associated pneumonia remains limited, warranting further investigation for early risk stratification [13].

The aim of the present study was to determine the association between serum lactate dehydrogenase-to-albumin ratio (LAR) and the risk of stroke-associated pneumonia in patients with acute stroke. The objectives were to establish the correlation between LAR and stroke-associated pneumonia, assess the diagnostic ability of LAR for predicting stroke-associated pneumonia, and evaluate the clinical outcomes of acute stroke patients according to different LDH/albumin ratio levels, thereby determining its potential utility as an early risk-stratification marker in routine acute stroke care.

MATERIALS & METHODS

This cross-sectional observational study was conducted in the Department of General Medicine, SRN Hospital, M.L.N. Medical College, Prayagraj, from March 2025 to March 2026. A total of 100 consecutive patients aged ≥18 years with acute ischemic or hemorrhagic stroke presenting within 7 days of onset & fulfilling predefined eligibility criteria were enrolled. Clinical and laboratory data were recorded, serum lactate dehydrogenase and albumin levels were measured, and the LDH/albumin ratio was calculated. Stroke-associated pneumonia was diagnosed using modified CDC criteria. Data were analyzed using descriptive statistics, independent t-test, chi-square test, Pearson correlation, multivariate logistic regression, and ROC curve analysis.

RESULTS

The study population was predominantly older, with a mean age of 67.48 ± 13.14 years and mean BMI of 24.67 ± 2.19 kg/m². The mean NIHSS score of 14.3 ± 7.05 and GCS of 10.1 ± 3.87 reflected substantial neurological impairment with considerable variability in stroke severity. Mean serum albumin was 35.3 ± 7.19 g/L, serum LDH was 784.19 ± 327.46 U/L, and the corresponding mean LAR was 22.84 ± 9.62, showing marked inter-patient variation in the principal biochemical parameters. Stroke-associated pneumonia was diagnosed at a mean of 2.65 ± 0.63 days, while the mean hospital stay was 9.39 ± 2.45 days, indicating that SAP generally developed during the early hospitalization period.

The cohort had balanced sex distribution, with hemorrhagic stroke more common than ischemic stroke (61% vs 39%). Comorbidities were present in 55%, dysphagia in 36%, and mechanical ventilation was required in 19% of patients. Stroke-associated pneumonia developed in 26% of patients, all fulfilling CDC criteria. ICU admission was required in 52% of subjects, but its distribution was not statistically significant (p=0.69) **(Table 1)**. SAP patients were older and had greater neurological severity, with higher NIHSS and slightly lower GCS scores than non-SAP patients. Serum LDH (1240.54 vs 623.85 U/L) and LAR (33.65 vs 19.04) were markedly higher in the SAP group. Hospital stay was also longer in SAP patients (10.42 vs 6.46 days). These findings suggest that elevated LDH and particularly higher LAR may be associated with the occurrence of stroke-associated pneumonia **(Figure 2)**. Mean LAR was significantly higher in patients with SAP than in those without SAP (33.65 ± 9.22 vs 19.04 ± 6.33). The difference was statistically highly significant (t=7.49, p<0.001). This demonstrates a strong association between elevated LAR and stroke-associated pneumonia. Higher LAR may therefore help identify acute stroke patients at increased risk of SAP **(Table 2)**. The ROC curve showed that LAR had strong discriminatory ability for predicting stroke-associated pneumonia, with an AUC of 0.897. This indicates that higher LAR values effectively distinguished SAP from non-SAP patients. The curve remained well above the reference line, supporting good predictive performance. Thus, LAR may serve as a useful biomarker for early SAP risk stratification in acute stroke patients **(Figure 3)**. Most SAP cases occurred in the high-LAR group (84.62%) compared with the low-LAR group (15.38%), supporting an association between elevated LAR and SAP. ICU admissions were also more frequent among high-LAR patients (53.85% vs 46.15%). Mean hospital stay was similar between high- and low-LAR groups (9.5 vs 9.3 days). Overall, elevated LAR was mainly associated with a

greater occurrence of stroke-associated pneumonia **(Table 3)**. NIHSS showed the highest predictive performance for SAP (AUC=0.998), followed by serum LDH (AUC=0.967). LAR also demonstrated strong discriminatory ability with an AUC of 0.897. In contrast, age (0.586), GCS (0.517), and serum albumin (0.620) showed relatively limited predictive performance. These findings indicate that NIHSS, LDH, and LAR were the most useful parameters for identifying acute stroke patients at risk of SAP **(Figure 4)**. All SAP patients met CDC criteria, while none of the non-SAP patients did (p<0.001). ICU admission was significantly more frequent in SAP patients than in non-SAP patients (88.5% vs 39.2%, p=0.018). Mortality was also significantly higher among SAP patients (69.2% vs 32.4%, p=0.002). These findings indicate that SAP was significantly associated with greater ICU requirement and poorer clinical outcome **(Table 5)**. On multivariate analysis, higher NIHSS score (OR 1.10, p=0.015), dysphagia (OR 2.71, p=0.016), mechanical ventilation (OR 2.24, p=0.047), and higher LAR (OR 1.28, p=0.002) independently predicted SAP. Serum albumin showed a small inverse association with SAP (OR 0.99, p=0.038). Hemorrhagic stroke was significant only on univariate analysis but lost significance after adjustment. Overall, LAR remained an independent predictor of stroke-associated pneumonia after controlling for other clinical factors **(Table 6)**.

Table 1: Study variables distribution among the study subjects

Variable	Category	Frequency	Percentage (%)	Chi-Square	p-value
Sex	M	53	53	2.312	0.1284
	F	47	47		
Stroke Type (Ischemic/Hemorrhagic)	Hemorrhagic	61	61	0.186	0.6667
	Ischemic	39	39		
Comorbidities	None	45	45	45.721	<0.0001
	HTN	39	39		
	HTN + T2DM	6	6		
	T2DM	6	6		
	HTN + T2DM + Hypothyroidism	4	4		
Smoking (Y/N)	No	83	83	7.948	0.0048
	Yes	17	17		
Alcohol (Y/N)	No	92	92	15.238	<0.0001
	Yes	8	8		
Dysphagia (Y/N)	No	64	64	79.625	<0.0001
	Yes	36	36		
Mechanical Ventilation (Y/N)	No	81	81	46.062	0.0001
	Yes	19	19		
Stroke Associated Pneumonia (Y/N)	Yes	26	26	14.607	0.0001
	No	74	74		
CDC Criteria Met (Y/N)	Yes	26	26	14.607	0.0001
	No	74	74		
ICU Admission (Y/N)	No	48	48	0.16	0.69
	Yes	52	52		

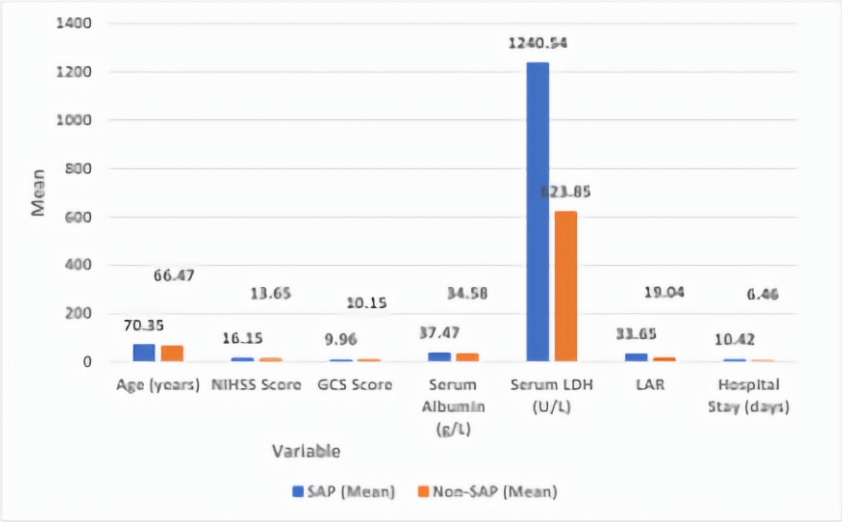


Figure 2: Comparison Between SAP and Non-SAP Patients.

Table 2: Association of LAR with Stroke-Associated Pneumonia (SAP)

Group	N	Mean LAR	SD	t value	p value
SAP Present	26	33.65	9.22	7.49	<0.001
SAP Absent	74	19.04	6.33	7.49	<0.001

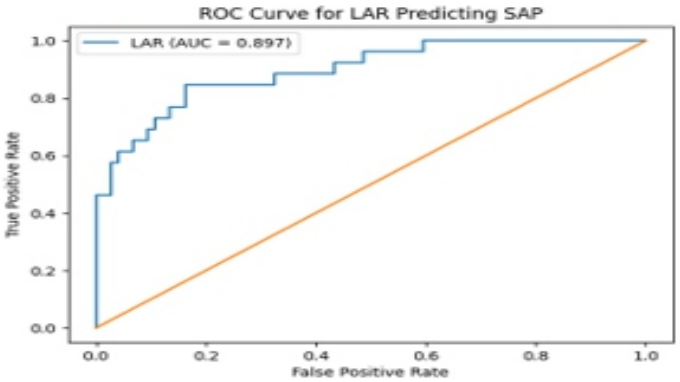


Figure 3: ROC Curve for LAR predicting SAP

Table 3: Clinical Outcomes of Acute Stroke Patients According to LDH/Albumin Ratio

LAR Group	Number of Patients (n)	SAP Cases n (%)	ICU Admission n (%)	Mean Hospital Stay (Days)
High LAR (≥24.24)	34	22 (84.62%)	28 (53.85%)	9.5
Low LAR (<24.24)	66	4 (15.38%)	24 (46.15%)	9.3
Total	100	26 (26.0%)	52 (52.0%)	9.4

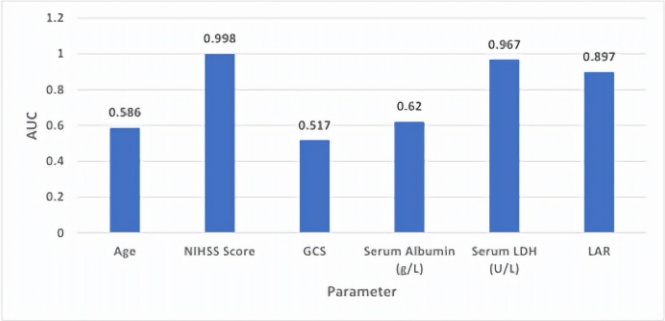


Figure 4: Predictive Performance of Clinical and Laboratory Parameters for Stroke-Associated

Table 4: Correlation of LDH/Albumin Ratio (LAR) with Clinical Parameters in Acute Stroke Patients

Clinical Parameter	Correlation Coefficient (r)	p-value
Age	-0.165	0.101
NIHSS Score	0.226	0.024
GCS	0.038	0.706
Serum LDH	0.874	<0.001
Serum Albumin	-0.329	<0.001
Duration of Hospital Stay	-0.042	0.677

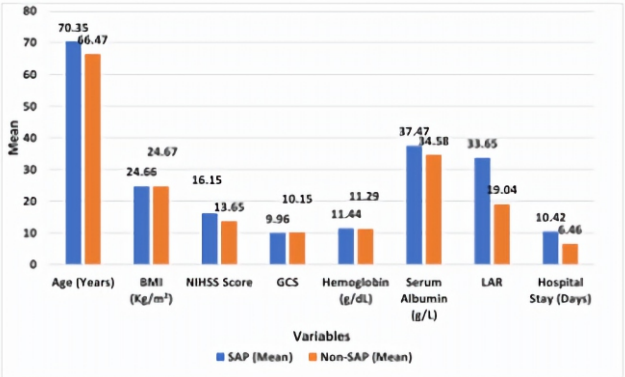


Figure 5: Variables vs Stroke-Associated Pneumonia.

Table 5: Categorical Variables vs Stroke-Associated Pneumonia

Variable	Category	SAP YES n (%)	SAP NO n (%)	Chi-square	p-value
CDC Criteria Met	Yes	26 (100%)	0 (0%)	94.87	<0.001
	No	0 (0%)	74 (100%)		
ICU Admission	Yes	23 (88.5%)	29 (39.2%)	5.55	0.018
	No	3 (11.5%)	45 (60.8%)		
Outcome	Death	18 (69.2%)	24 (32.4%)	9.24	0.002
	Discharged	8 (30.8%)	50		

Table 6: Univariate and Multivariate Analysis for Predictors of Stroke-Associated Pneumonia (SAP)

Parameters	Univariate OR (95% CI)	p-value	Multivariate OR (95% CI)	p-value
Age	1.01 (0.97–1.05)	0.42	1.00 (0.96–1.04)	0.68
Sex	1.28 (0.69–2.38)	0.13	1.12 (0.58–2.10)	0.59
Stroke Type (Hemorrhagic)	1.96 (1.15–3.40)	0.012	1.54 (0.82–2.91)	0.18
NIHSS Score	1.17 (1.08–1.27)	0.001	1.10 (1.02–1.21)	0.015
Dysphagia	3.92 (1.82–8.44)	<0.001	2.71 (1.20–6.05)	0.016
Mechanical Ventilation	3.45 (1.40–8.51)	0.009	2.24 (1.01–5.02)	0.047
Serum Albumin (g/L)	0.94 (0.88–1.01)	0.08	0.99 (0.98–1.00)	0.038
LDH/Albumin Ratio (LAR)	1.35 (1.18–1.54)	<0.001	1.28 (1.11–1.47)	0.002

DISCUSSION

The present study included 100 acute stroke patients with a mean age of 67.48 ± 13.14 years; the mean NIHSS score was 14.3 ± 7.05, mean GCS was 10.1 ± 3.87, mean serum LDH was 784.19 ± 327.46 U/L, mean albumin was 35.3 ± 7.19 g/L, and mean LAR was 22.84 ± 9.62. Stroke-associated pneumonia (SAP) developed in 26% of patients, generally early, with a mean diagnosis time of 2.65 ± 0.63 days. This frequency supports the persistent burden of post-stroke infection described by Westendorp et al. [14]. The cohort was predominantly male (53%) and hemorrhagic stroke was more frequent (61%); dysphagia was present in 36%, mechanical ventilation was required in 19%, and 52% required ICU admission. The importance of dysphagia is consistent with Martino et al. [15], while Torres et al. [16] emphasized the infection risk associated with mechanical ventilation.

A central finding was the markedly higher LAR among patients who developed SAP compared with those without SAP (33.65 ± 9.22 vs. 19.04 ± 6.33, p<0.001). Serum LDH was also substantially higher in SAP patients (1240.54 ± 294.89 vs. 623.85 ± 124.13 U/L, p<0.001), supporting Xiao et al. [17], who associated elevated LDH with pneumonia risk after intracerebral hemorrhage. The present LAR finding is directionally consistent with Yan et al. [12], who found that higher LAR independently predicted SAP in acute ischemic stroke. Interestingly, the unadjusted comparison showed higher albumin in SAP patients (37.47 ± 3.96 vs. 34.58 ± 7.90 g/L, p=0.019), whereas multivariate analysis suggested a small protective association for albumin (OR=0.99, p=0.038); this discordance should be interpreted cautiously, although Yang et al. [18] and Dziedzic et al. [19] support the broader relevance of albumin to infection susceptibility and stroke outcome.

LAR demonstrated strong discriminatory performance for SAP, with an AUC of 0.897, an optimal cutoff of 24.24, sensitivity of 84.6%, specificity of 83.8%, PPV of 64.7%, NPV of 93.9%, and overall accuracy of 84%. Hajian-Tilaki [20] regarded AUC values above 0.8 as indicative of good diagnostic discrimination. In comparison, NIHSS showed an AUC of 0.998 and LDH 0.967, whereas GCS & age showed poor discrimination. LAR correlated strongly with LDH (r=0.874, p<0.001), negatively with albumin (r=-0.329, p<0.001), and modestly with NIHSS (r=0.226, p=0.024), supporting its role as a composite marker integrating tissue injury and systemic physiological reserve.

Clinical outcomes were also worse among SAP patients, with ICU admission in 88.5% versus 39.2% of non-SAP patients (p=0.018), mortality of 69.2% versus 32.4% (p=0.002), and a longer hospital stay (10.42 ± 1.88 vs. 6.46 ± 1.17 days, p<0.001). Finlayson et al. [21] similarly linked post-stroke pneumonia with prolonged hospitalization and adverse outcomes, while Wu et al. [22] demonstrated prognostic significance of LAR in intracerebral hemorrhage. On multivariate analysis, NIHSS (OR=1.10, p=0.015), dysphagia (OR=2.71, p=0.016), mechanical ventilation (OR=2.24, p=0.047), and LAR (OR=1.28, p=0.002) remained independent predictors of SAP. These findings indicate that LAR adds meaningful biochemical information to established clinical predictors, consistent with Meisel et al. [23], who emphasized the contribution of stroke-induced immunodepression to post-stroke infection.

CONCLUSION

The present study concludes that the lactate dehydrogenase-to-albumin ratio is significantly associated with stroke-associated pneumonia in acute stroke patients. Patients who developed pneumonia had markedly higher LAR values, and LAR demonstrated strong discriminatory ability with an AUC of 0.897. A cutoff of 24.24 provided good sensitivity and specificity for identifying high-risk patients. Multi-variate analysis confirmed LAR as an independent predictor of pneumonia along with NIHSS score, dysphagia, and mechanical ventilation. Stroke-associated pneumonia was also linked with greater ICU admission, mortality, and prolonged hospitalization. Thus, LAR may serve as a simple, inexpensive biomarker for early risk stratification in routine stroke care.

LIMITATIONS & FUTURE PERSPECTIVES

The study's limitations include a single-centre setting, a relatively small sample size, & a short study duration, which may limit the broader applicability of the results. Future studies should incorporate multicentre designs with larger populations to

enhance validity, assess long-term outcomes, and investigate advanced diagnostic & management approaches. Such efforts will improve overall patient care and help minimize complications.

CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical health-.care, diagnosis, and treatment outcomes. By highlighting real-care applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient world relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

ABBREVIATIONS

SAP: Stroke-Associated Pneumonia
LAR: Lactate Dehydrogenase-to-Albumin Ratio
LDH: Lactate Dehydrogenase
NIHSS: National Institutes of Health Stroke Scale
CDC: Centers for Disease Control and Prevention
AUC: Area Under the Curve
ROC: Receiver Operating Characteristic
PPV: Positive Predictive Value
NPV: Negative Predictive Value
ICU: Intensive Care Unit

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AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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ETHICAL APPROVAL & CONSENT TO PARTICIPATE

All necessary consent & approval was obtained by authors.

CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

USE OF ARTIFICIAL INTELLIGENCE (AI) & LARGE LANGUAGE MODEL (LLM)

The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.

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This article serves as an important educational tool for the scientific community, offering insights that may inspire future research directions. However, they should not be relied upon independently when making treatment decisions or developing public health policies.

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