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ORIGINAL RESEARCH

Comparison of the Predictive Value of Neutrophil Percentage-to-Albumin Ratio and Modified Glasgow Prognostic Score for the Risk of Stroke-Associated Pneumonia Among Stroke Patients

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Objective: To assess the predicting value of neutrophil percentage-to-albumin ratio (NPAR) and modified Glasgow Prognostic Score (mGPS) for Stroke-Associated Pneumonia (SAP) occurrence among stroke patients.

Methods: We recruited stroke patients (aged 18 years) hospitalized at Tianjin First Central Hospital from January 2022 to February 2023 for this retrospective cohort study. NPAR was categorized into four groups by considering the quartiles: Q1 (<1.38), Q2 (≥1.38 and <1.62), Q3 (≥1.62 and <1.87), Q4 (≥1.87). SAP incident was the primary outcome in this study. Univariate and multivariate logistic regression models were employed to explore the association between NPAR, mGPS and SAP occurrence among individuals with stroke. Besides, we compared the predicting value of NPAR and mGPS for SAP occurrence by the receiver operating characteristic (ROC) curve.

Results: Our study encompassed 851 patients with stroke. One hundred and forty-seven patients (17.27%) developed SAP. After accounting for confounding factors, we observed significant positive association of high NPAR with SAP occurrence [(for the third quartile: odds ratio (OR)=2.35, 95% confidence interval (CI): 1.01–5.47; for the fourth quartile: OR=3.35, 95% CI: 1.44–7.77)]. Additionally, the results also indicated that mGPS 1 (OR=2.26, 95% CI: 1.25–4.08) and mGPS 2 (OR=7.37, 95% CI: 2.63–20.70) were related to the increased probability of SAP, respectively. ROC analysis demonstrated that both the NPAR [area under the curve (AUC) =0.729, 95% CI: 0.687–0.771] and mGPS (AUC=0.671, 95% CI: 0.627–0.716) exhibited good predictive power for SAP occurrence. Based on the DeLong test, the predictive value of NPAR for SAP may be significantly superior to that of mGPS (P<0.05).

Conclusion: Our findings suggest that both NPAR and mGPS serve as reliable biomarker for assessing SAP risk in stroke patients, with NPAR demonstrating superior predictive value for SAP compared to mGPS.

Keywords: NPAR, mGPS, SAP, predictive value, comparison

Introduction

Stroke-Associated Pneumonia (SAP) is frequently occurring complication of stroke, characterized by the development of pneumonia within the initial 7 days following stroke initiation in non-ventilated patients.[1] SAP occurrence can be attributed to the inhalation of oropharyngeal secretions or a systemic inflammatory response triggered by the stroke itself.[2] The incidence of SAP varies from 7% to 38%, and it can significantly exacerbate the condition of stroke patients, leading to an increased risk of severe disability and death, prolonged hospitalization, escalated medical expenses, and imposing a considerable burden on both families and society.[3,4] Therefore, timely identification of risk factors related to SAP and implementation of preventive interventions may contribute to mitigating the likelihood of developing SAP and thereby benefiting patients.

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Most evidence suggests that inflammatory responses could be crucial in the progression of SAP, suggesting the predicting value of clinical biomarkers associated with inflammation for SAP progression.[5,6] Neutrophil percentage-to-albumin ratio (NPAR) serves as a novel index that reflects both systemic inflammatory and immunologic conditions.[7] This ratio is obtained by dividing the neutrophil percentage by the serum albumin concentration.[8] NPAR has been widely utilized in various clinical applications due to its inflammatory properties and has been identified as an independent prognostic factor for SAP in patients diagnosed with intracerebral hemorrhage (ICH),[9] stroke,[10] and acute ischemic stroke (AIS).[11] Similarly, modified Glasgow Prognostic Score (mGPS), an additional novel indicator that accurately reflects the inflammatory and nutritional status of individuals, has also garnered significant attention.[12] The calculation of mGPS was derived from the levels of serum C-reactive protein (CRP) and serum albumin.[13] In the study of Li et al, they found that mGPS may be used to predict the onset of SAP in AIS patients upon admission.[14] However, few previous studies have yet compared the prognostic value of NPAR and mGPS for SAP occurrence in individuals with stroke.

Therefore, our study sought to compare the predicting value of NPAR and mGPS in the occurrence of SAP among individuals with stroke.

Materials and Methods

Study Population

In this retrospective cohort study, we recruited stroke individuals (aged 18 years) hospitalized at Tianjin First Central Hospital from January 2022 to February 2023. The research protocol received ethical approval from the Ethical Committee of the Tianjin First Central Hospital (No. 20240618–1).

Inclusion criteria: (1) aged ≥18 years; (2) diagnosed with stroke;[15] (3) admitted to the hospital within 24 hours of the onset of stroke. Exclusion criteria: (1) stroke patients with mechanical ventilation; (2) patients with immunosuppression status (including HIV-positive, undergone bone marrow stem cell transplantation or solid organ transplant, and currently undergoing glucocorticoid shock therapy or immunosuppressive therapy, or radiation or chemotherapy); (3) patients with acute brain injury; (4) patients with blood system diseases; (5) patients with advanced stage malignant tumor; (6) patients with inability to assess National Institute of Health Stroke Scale (NIHSS); (7) patients with missing information of CRP; (8) patients with hemorrhagic stroke; (9) patients without liver function test and kidney function test available; (10) patients with missing information about SAP, diabetes, and history of stroke. The patient selection flow chart was depicted in Figure 1.

Exposure Variable

Within the first 24 hours of admission, blood routine examination, serum CRP level and albumin level of patients were assessed. The NPAR was calculated using the following formula: neutrophil percentage (%)/albumin concentration (g/L).[16] In line with previous research,[17–19] NPAR was categorized into four groups by considering the quartiles: Q1 (<1.38), Q2 (≥1.38 and <1.62), Q3 (≥1.62 and <1.87), Q4 (≥1.87). The mGPS score was determined using the following criteria: mGPS 0=CRP ≤10 mg/L and albumin ≥3.5 g/dL; mGPS 1 = CRP >10 mg/L or albumin <3.5 g/dL; mGPS 2=CRP >10 mg/L and albumin <3.5 g/dL.[20]

Outcome Variable

SAP incident was the primary outcome in this study. Based on the criteria set by the Centers for Disease Control and Prevention criteria, SAP was characterized as a range of lower respiratory tract infections, which occurred within 7 days following the onset of stroke.[1] Diagnosis relied on clinical and laboratory indicators of respiratory tract infection (including fever, new purulent sputum, cough, bronchial breath sounds or worsening gas exchange), in conjunction with characteristic findings on chest radiograph.[21]

Other Study Variables

The extracted data included age, hemoglobin (g/L), white blood cell (WBC, 10^9/L), red blood cell count (RBC, 10^{12}/L), lymphocyte (10^9/L), monocyte (10^9/L), eosinophil (10^9/L), platelet (10^9/L), basophilic (10^9/L), mean platelet volume

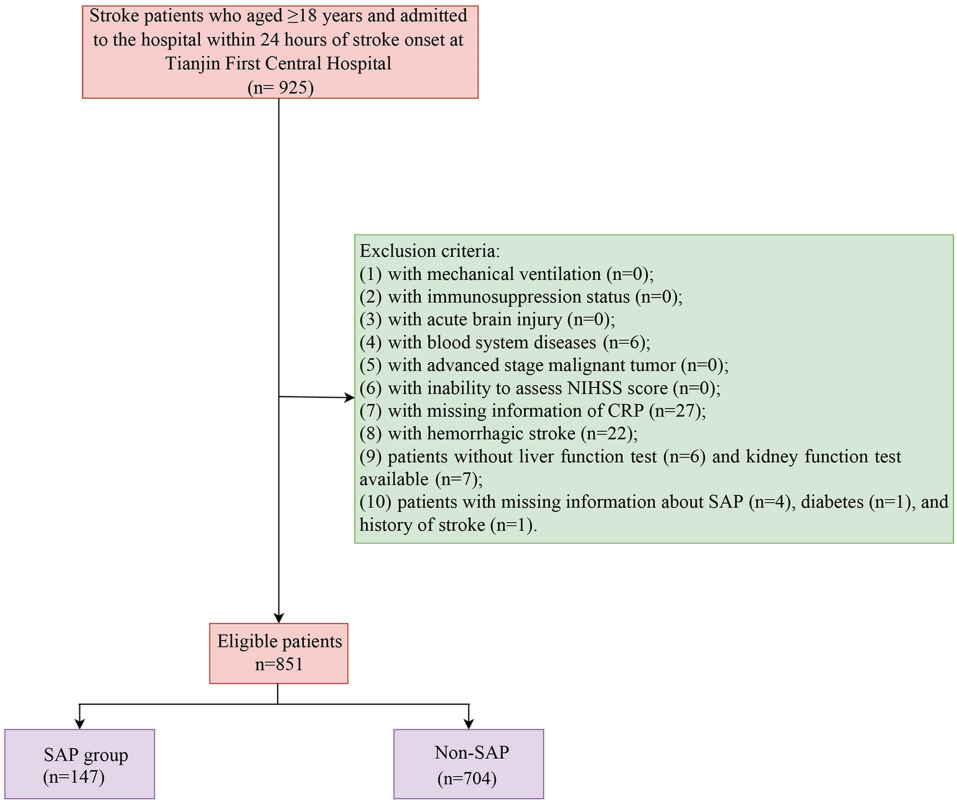

Figure 1 The flowchart of participants.
Abbreviations: NIHSS, National Institute of Health Stroke Scale; CRP, C-reactive protein; SAP, Stroke-Associated Pneumonia.

(MPV, fl), red cell distribution width (RDW), alanine aminotransferase (ALT, U/L), gamma-glutamyl transpeptidase (GGT, U/L), aspartate aminotransferase (AST, U/L), alkaline phosphatase (ALP, U/L), total protein (g/L), total bilirubin (TBIL, μmol/L), direct bilirubin (DBIL, μmol/L), indirect bilirubin (IBIL, μmol/L), globulin (GLB, g/L), AGR (albumin/globulin), uric acid (UA, μmol/L), blood urea nitrogen (BUN, mmol/L), creatinine (Cr, μmol/L), activity of daily living (ADL), gender, smoking, drinking, intemperance, history of stroke, hypertension, atrial fibrillation, diabetes, heart failure, coronary heart disease, chronic lung disease, stroke subtype, stroke severity, level of consciousness, dysphagia, impaired mobility, thrombolysis, place nasogastric tube and acid suppressor.

Statistical Analysis

Missing data of variables (below 5%) were filled using random forest interpolation method. Sensitivity analyses before and after interpolation are presented in Supplementary Table 1. In order to present normally distributed continuous variables, we utilized means ± standard deviations (SD), whereas for non-normally distributed continuous variables, medians along with interquartile ranges [M (Q1, Q3)] were employed. Categorical variables were presented in terms of frequencies and percentages. The *t*-test was utilized to compare continuous variables that followed a normal distribution, while the Wilcoxon rank sum test was employed for assessing continuous variables that did not follow a normal distribution. Fisher's exact test or Chi-square test were used to compare categorical variables. Univariate logistic regression analysis and bidirectional stepwise regression were employed to identify potential confounding variables linked to SAP. Then, we employed univariate and multivariate logistic regression models to investigate the association between NPAR, mGPS and SAP risk among individuals with stroke. Two models were employed: Model 1 (crude model), Model 2 (adjusted for age, WBC, DBIL, stroke severity, ADL, atrial fibrillation, and dysphagia). Odds ratio (OR) and 95% confidence interval (CI) were estimated. We also compared the predicting value of NPAR and mGPS for SAP

occurrence using receiver operating characteristic (ROC) curve and calibration curve. $P<0.05$ is regarded as statistical significance. All statistical analyses were conducted using software SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Participant Characteristics

Our study encompassed a cohort of 851 stroke patients, with an average age of 68.56 ± 11.85 years. Among these, 147 patients (17.27%) were identified with SAP, while the remaining 704 patients (82.73%) were classified as non-SAP. The characteristics of both SAP and non-SAP patients are described in Table 1. Patients in the SAP group were elder, higher levels of WBC, monocyte, RDW, AST, GGT, TBIL, DBIL, BUN, and Cr, lower levels of hemoglobin, lymphocyte, eosinophil, total protein, and AGR, had a higher prevalence of history of stroke, atrial fibrillation,

Table 1 Participant Characteristics

Variables	Total (n=851)	Non-SAP Group (n=704)	SAP Group (n=147)	*P*
Age, years, Mean ± SD	68.56 ± 11.85	66.88 ± 11.38	76.63 ± 10.67	<0.001
Hemoglobin, g/L, Mean ± SD	138.21 ± 18.31	139.08 ± 17.25	134.05 ± 22.33	0.011
RBC, 10^{12}/L, Mean ± SD	4.56 ± 0.61	4.57 ± 0.58	4.49 ± 0.73	0.234
WBC, 10^9/L, M (Q_1, Q_3)	7.24 (5.87, 9.03)	7.16 (5.82, 8.69)	8.10 (6.24, 11.07)	<0.001
Platelet, 10^9/L, M (Q_1, Q_3)	204.00 (160.00, 251.00)	206.00 (162.50, 251.00)	196.00 (143.00, 244.00)	0.129
Lymphocyte, 10^9/L, M (Q_1, Q_3)	1.69 (1.17, 2.41)	1.75 (1.20, 2.42)	1.38 (0.88, 2.31)	0.001
Monocyte, 10^9/L, M (Q_1, Q_3)	0.51 (0.39, 0.72)	0.50 (0.38, 0.69)	0.59 (0.44, 1.00)	<0.001
Eosinophil, 10^9/L, M (Q_1, Q_3)	0.09 (0.03, 0.19)	0.09 (0.04, 0.19)	0.06 (0.01, 0.20)	0.004
Basophilic, 10^9/L, M (Q_1, Q_3)	0.03 (0.02, 0.05)	0.03 (0.02, 0.05)	0.03 (0.02, 0.05)	0.195
MPV, fl, Mean ± SD	9.42 ± 1.16	9.40 ± 1.12	9.54 ± 1.31	0.242
RDW, %, Mean ± SD	12.45 ± 1.01	12.42 ± 0.97	12.63 ± 1.17	0.040
ALT, U/L, M (Q_1, Q_3)	19.00 (13.90, 26.00)	19.00 (14.00, 26.00)	19.00 (13.00, 26.00)	0.832
AST, U/L, M (Q_1, Q_3)	22.40 (17.60, 28.00)	22.00 (17.30, 27.50)	25.00 (18.00, 34.00)	0.002
GGT, U/L, M (Q_1, Q_3)	25.00 (17.00, 48.00)	24.00 (17.00, 46.00)	30.00 (17.00, 61.00)	0.039
ALP, U/L, M (Q_1, Q_3)	82.00 (64.00, 98.00)	81.00 (64.00, 97.00)	83.00 (66.00, 105.00)	0.127
TBIL, μmol/L, M (Q_1, Q_3)	11.22 (7.82, 15.20)	11.00 (7.72, 14.80)	11.90 (8.80, 17.30)	0.009
DBIL, μmol/L, M (Q_1, Q_3)	3.50 (2.32, 4.90)	3.42 (2.30, 4.70)	4.10 (2.70, 5.80)	<0.001
IBIL, μmol/L, M (Q_1, Q_3)	7.09 (4.50, 11.00)	6.90 (4.48, 11.00)	7.50 (4.80, 12.20)	0.241
Total protein, g/L, Mean ± SD	70.96 ± 8.46	71.35 ± 8.41	69.05 ± 8.48	0.003
GLB, g/L, Mean ± SD	29.61 ± 5.88	29.47 ± 5.81	30.29 ± 6.19	0.123
AGR, g/L, Mean ± SD	1.44 ± 0.30	1.47 ± 0.29	1.31 ± 0.30	<0.001
BUN, mmol/L, M (Q_1, Q_3)	5.65 (4.68, 7.02)	5.62 (4.68, 6.88)	6.03 (4.72, 7.86)	0.009
Cr, μmol/L, Mean ± SD	74.76 ± 22.70	73.53 ± 21.71	80.61 ± 26.26	0.003
UA, μmol/L, M (Q_1, Q_3)	319.50 (250.10, 384.70)	320.70 (254.25, 384.40)	314.80 (238.70, 393.40)	0.575
ADL, n (%)				<0.001
Impaired	297 (34.90)	173 (24.57)	124 (84.35)	
Normal	554 (65.10)	531 (75.43)	23 (15.65)	
Gender, male, n (%)	508 (59.69)	426 (60.51)	82 (55.78)	0.288
Smoking, yes, n (%)	368 (43.24)	312 (44.32)	56 (38.10)	0.166
Drinking, yes, n (%)	283 (33.25)	236 (33.52)	47 (31.97)	0.717
Intemperance, yes, n (%)	98 (11.52)	84 (11.93)	14 (9.52)	0.405
History of stroke, yes, n (%)	285 (33.49)	213 (30.26)	72 (48.98)	<0.001
Hypertension, yes, n (%)	597 (70.15)	490 (69.60)	107 (72.79)	0.442
Diabetes, yes, n (%)	296 (34.78)	243 (34.52)	53 (36.05)	0.722
Atrial fibrillation, yes, n (%)	101 (11.87)	51 (7.24)	50 (34.01)	<0.001
Coronary heart disease, yes, n (%)	217 (25.50)	163 (23.15)	54 (36.73)	<0.001
Heart failure, yes, n (%)	35 (4.11)	20 (2.84)	15 (10.20)	<0.001

(*Continued*)

Table 1 (Continued).

Variables	Total (n=851)	Non-SAP Group (n=704)	SAP Group (n=147)	*P*
Chronic lung disease, yes, n (%)	7 (0.82)	6 (0.85)	1 (0.68)	1.000
Stroke subtype, n (%)				<0.001
Great artery disease	590 (69.33)	501 (71.16)	89 (60.54)	
Small vessel occlusion	106 (12.46)	103 (14.63)	3 (2.04)	
Cardiac embolism	86 (10.11)	47 (6.68)	39 (26.53)	
Other	2 (0.24)	2 (0.28)	0 (0.00)	
Unknown	67 (7.87)	51 (7.24)	16 (10.88)	
Stroke severity, n (%)				<0.001
Mild	564 (66.27)	534 (75.85)	30 (20.41)	
Moderate	223 (26.20)	154 (21.88)	69 (46.94)	
Severe	64 (7.52)	16 (2.27)	48 (32.65)	
Level of consciousness, n (%)				<0.001
Clear	783 (92.01)	690 (98.01)	93 (63.27)	
Disturbance	32 (3.76)	11 (1.56)	21 (14.29)	
Stun	36 (4.23)	3 (0.43)	33 (22.45)	
Dysphagia, yes, n (%)	136 (15.98)	37 (5.26)	99 (67.35)	<0.001
Impaired mobility, yes, n (%)	292 (34.31)	171 (24.29)	121 (82.31)	<0.001
Thrombolysis, yes, n (%)	269 (31.61)	238 (33.81)	31 (21.09)	0.003
Place nasogastric tube, yes, n (%)	130 (15.28)	32 (4.55)	98 (66.67)	<0.001
Acid suppressor, yes, n (%)	649 (76.26)	512 (72.73)	137 (93.20)	<0.001
NPAR, ratio, M (Q_1, Q_3)	1.62 (1.38, 1.87)	1.57 (1.36, 1.80)	1.91 (1.67, 2.23)	<0.001
NPAR, n (%)				<0.001
<1.62	425 (49.94)	398 (56.53)	27 (18.37)	
≥1.62	426 (50.06)	306 (43.47)	120 (81.63)	
NPAR, n (%)				<0.001
<1.47	284 (33.37)	263 (37.36)	21 (14.29)	
≥1.47 and <1.79	283 (33.25)	251 (35.65)	32 (21.77)	
≥1.79	284 (33.37)	190 (26.99)	94 (63.95)	
NPAR, n (%)				<0.001
<1.38	213 (25.03)	198 (28.13)	15 (10.20)	
≥1.38 and <1.62	213 (25.03)	201 (28.55)	12 (8.16)	
≥1.62 and <1.87	212 (24.91)	169 (24.01)	43 (29.25)	
≥1.87	213 (25.03)	136 (19.32)	77 (52.38)	
mGPS, n (%)				<0.001
0	646 (75.91)	573 (81.39)	73 (49.66)	
1	166 (19.51)	119 (16.90)	47 (31.97)	
2	39 (4.58)	12 (1.70)	27 (18.37)	

Abbreviations: SAP, Stroke-Associated Pneumonia; RBC, red blood cell count; WBC, white blood cell; MPV, mean platelet volume; RDW, red cell distribution width; ALT, alanine aminotransferase; AST, aspartate aminotransferase; GGT, gamma-glutamyl transpeptidase; ALP, alkaline phosphatase; TBIL, total bilirubin; DBIL, direct bilirubin; IBIL, indirect bilirubin; GLB, globulin; AGR, albumin/globulin; BUN, blood urea nitrogen; Cr, creatinine; UA, uric acid; ADL, activity of daily living; NPAR, neutrophil percentage-to-albumin ratio; mGPS, modified Glasgow Prognostic Score.

coronary heart disease, heart failure, and more severe stroke, dysphagia. The SAP group exhibited higher NPAR and higher proportion of mGPS 2 in comparison to the non-SAP group (P<0.05). Additionally, the result may indicate a higher incidence of SAP in the high-level NPAR group (81.63%, classify NPAR by median; 63.95%, classify NPAR by tertiles; 52.38%, classify NPAR by quartiles).

Association Between NPAR, mGPS and SAP Occurrence

Table 2 shows the associations between NPAR, mGPS and SAP occurrence using both univariate and multivariate logistic regression models. In the univariate logistic regression model, with the first quartile serving as the reference, we

Table 2 Association Between NPAR, mGPS and SAP Occurrence

Variables	Model 1		Model 2	
	OR (95% CI)	*P*	OR (95% CI)	*P*
NPAR				
<1.38	Ref		Ref	
≥1.38 and <1.62	0.79 (0.36–1.73)	0.552	0.68 (0.24–1.89)	0.459
≥1.62 and <1.87	3.36 (1.80–6.26)	<0.001	2.35 (1.01–5.47)	0.046
≥1.87	7.47 (4.12–13.55)	<0.001	3.35 (1.44–7.77)	0.005
mGPS				
0	Ref		Ref	
1	3.10 (2.04–4.70)	<0.001	2.26 (1.25–4.08)	0.007
2	17.66 (8.57–36.35)	<0.001	7.37 (2.63–20.70)	<0.001

Notes: Model 1: not adjusted. Model 2: adjusted for age, white blood cell, direct bilirubin, stroke severity, activity of daily living, atrial fibrillation, and dysphagia.
Abbreviations: SAP, Stroke-Associated Pneumonia; NPAR, neutrophil percentage-to-albumin ratio; mGPS, modified Glasgow Prognostic Score; Ref, Reference; OR, odd ratio; CI, confidence interval.

found significantly positive associations between NPAR in the third (Model 1: OR=3.36, 95% CI: 1.80–6.26) and fourth (Model 1: OR=7.47, 95% CI: 4.12–13.55) quartile and SAP occurrence. After controlling for age, WBC, DBIL, stroke severity, ADL, atrial fibrillation, and dysphagia (Model 2), the association between NPAR and SAP remained unchanged (for the third quartile: OR=2.35, 95% CI: 1.01–5.47; for the fourth quartile: OR=3.35, 95% CI: 1.44–7.77). Additionally, both univariate and multivariate logistic regression models demonstrated that mGPS 1 (Model 1: OR=3.10, 95% CI: 2.04–4.70; Model 2: OR=2.26, 95% CI: 1.25–4.08) and mGPS 2 (Model 1: OR=17.66, 95% CI: 8.57–36.35; Model 2: OR=7.37, 95% CI: 2.63–20.70) were related to increased probability of SAP, respectively.

Predicting Value of NPAR and mGPS for SAP Occurrence

We used ROC curves to evaluate the value of NPAR and mGPS indicators. As shown in Table 3 and Figure 2A, ROC analysis demonstrated that both the NPAR [area under the curve (AUC)= 0.729, 95% CI: 0.687–0.771] and mGPS (AUC=0.671, 95% CI: 0.627–0.716) exhibited good predictive capabilities for SAP occurrence. Based on the DeLong test, the predictive value of NPAR for SAP may be significantly superior to that of mGPS ($P<0.05$). For NPAR, the sensitivity for recognizing SAP was 0.816 (95% CI: 0.754–0.879), with a specificity of 0.567 (95% CI: 0.530–0.603), offering a positive predictive value (PPV) of 0.282 (95% CI: 0.240–0.325) and negative predictive value (NPV) of 0.937 (95% CI: 0.913–0.960). For mGPS, the sensitivity for recognizing SAP was 0.184 (95% CI: 0.121–0.246), with a specificity of 0.983 (95% CI: 0.973–0.993), offering a PPV of 0.692 (95% CI: 0.547–0.837) and NPV of 0.852 (95% CI: 0.828–0.877). In addition, the calibration curves also show a good concordance between the actual and predicted probabilities of SAP occurrence (Figure 2B).

Table 3 Predicting Value of NPAR and mGPS for SAP Occurrence

Variables	AUC (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	NPV (95% CI)	PPV (95% CI)	Accuracy (95% CI)
NPAR	0.691 (0.654–0.727)	0.816 (0.754–0.879)	0.565 (0.529–0.602)	0.936 (0.913–0.960)	0.282 (0.239–0.324)	0.609 (0.576–0.641)
mGPS	0.671 (0.627–0.716)	0.184 (0.121–0.246)	0.983 (0.973–0.993)	0.852 (0.828–0.877)	0.692 (0.547–0.837)	0.845 (0.821–0.869)
NPAR+ mGPS	0.754 (0.711–0.796)	0.463 (0.382–0.543)	0.876 (0.852–0.901)	0.886 (0.863–0.910)	0.439 (0.361–0.517)	0.805 (0.778–0.832)

Abbreviations: SAP, Stroke-Associated Pneumonia; NPAR, neutrophil percentage-to-albumin ratio; mGPS, modified Glasgow Prognostic Score; CI, confidence interval; AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value.

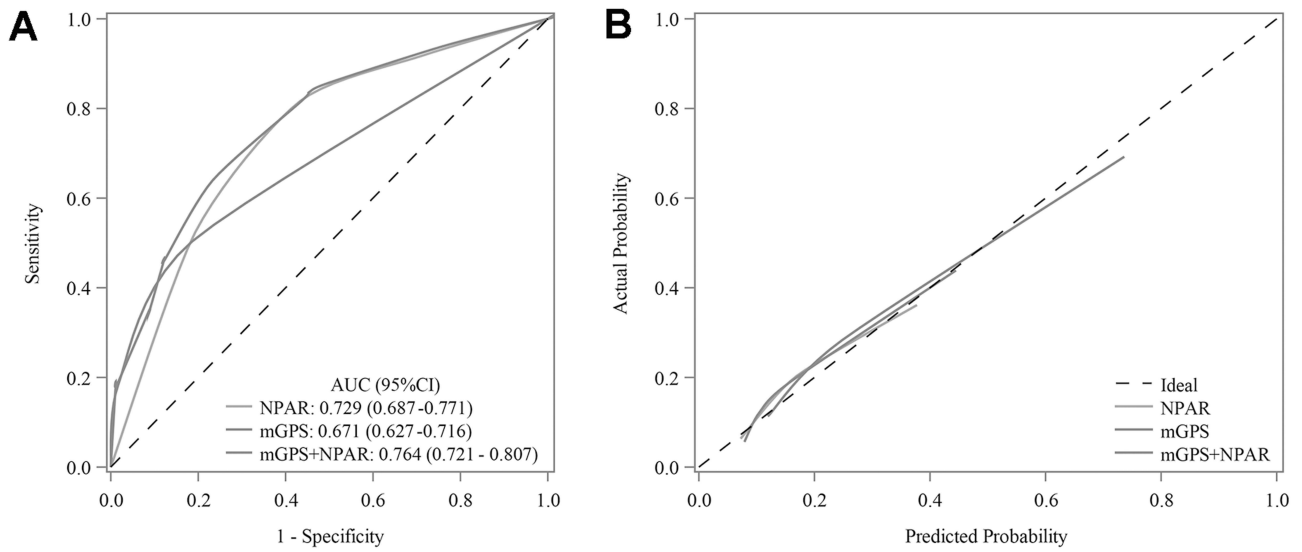

Figure 2 Predicting value of NPAR and mGPS for SAP occurrence. (**A**) The predicting value of NPAR and mGPS for SAP occurrence using receiver operating characteristic curve; (**B**) The predicting value of NPAR and mGPS for SAP occurrence using receiver operating calibration curve.
Abbreviations: NPAR, neutrophil percentage-to-albumin ratio; mGPS, modified Glasgow Prognostic Score; SAP, Stroke-Associated Pneumonia.

Discussion

This retrospective analysis examined clinical data from 851 stroke patients who were admitted to the hospital and compared the predicting value of NPAR and mGPS for SAP occurrence in individuals with stroke. The prevalence of SAP in this population was 17.27%. In the fully adjusted model, a significant association was observed between increased levels of NPAR and mGPS with a higher occurrence of SAP. Additionally, we also observed that both NPAR and mGPS exhibited significant predictive power for the occurrence of SAP, and it should be noted that the predictive value of NPAR for SAP can be considered superior to that of mGPS.

SAP, as the most prevalent complications among patients with stroke, may lead to increased mortality, prolonged hospitalization and increased economic burden.[22] In recent years, SAP has attracted growing attention. Neutrophils play a critical role in safeguarding the body against diverse pathogenic microbial infections.[23] Moreover, neutrophils play a crucial role in the innate immune system and serve as the primary target for antigens to initiate an immune response, and they also possess the ability to activate other immune cells and elicit cellular as well as humoral immunity.[24] Several studies have provided evidence that stroke induces neuronal cell death and elicits the release of injury-related molecules, which in turn trigger local inflammation within the affected brain region.[25,26] This leads to infiltration of neutrophils and other peripheral inflammatory cells, resulting in an elevation of circulating neutrophil counts, secretion of numerous inflammatory mediators, and a diffuse inflammatory response throughout the brain to prevent further damage to brain tissue and neurons. Serum albumin plays a vital role in assessing the nutritional status of patients, and its correlation with SAP was found to be significant.[27,28] NPAR, a newly developed marker for assessing systemic inflammation based on the ratio of neutrophil percentage to albumin levels, has demonstrated significant associations with disease prognosis across various medical conditions.[29,30] In a retrospective cohort study, it was found that elevated levels of NPAR were associated with an increased likelihood of SAP, and NPAR has also superior predictive performance in predicting SAP compared to neutrophil-lymphocyte ratio (NLR) monocyte-lymphocyte ratio (MLR).[10] This study was similar to our findings. In our study, after adjusting for age, WBC, DBIL, stroke severity, ADL, atrial fibrillation, and dysphagia, the third and fourth quartile of NPAR were significantly linked with an increased SAP risk. It is important to note that we also conducted an analysis of NPAR categorized by various classification criteria and investigated their relationship with SAP risk. As shown in Supplementary Table 2, we stratified NPAR levels by median (<1.62 and ≥1.62), higher NPAR was still significantly associated with SAP risk compared with the low NPAR levels (Model 1: OR=5.78, 95% CI: 3.71–9.01; Model 2: OR=3.35, 95% CI: 1.78–6.32). When dividing NPAR into tertiles (tertile 1: <1.47; tertile 2: ≥1.47

and <1.79; tertile 3: ≥1.79), high tertile of NPAR (≥1.79) was found to be linked with SAP risk (Model 1: OR=6.19, 95% CI: 3.73–10.30; Model 2: OR=2.87, 95% CI: 1.39–5.95). Overall, stroke patients with higher NPAR were more likely to develop SAP. The calculation of mGPS involves assessing the concentrations of C-reactive protein and albumin, which are then categorized into three groups: 0, 1, and 2.[13] The prognostic value of mGPS has been widely verified in several diseases.[31–33] Our study found that mGPS 1 and mGPS 2 were related to increased risk of SAP, respectively.

Importantly, this study compared the predicting value of NPAR and mGPS for SAP occurrence in individuals with stroke using ROC curves. The results indicated that NPAR may exhibit a good predictive capability for SAP occurrence than mGPS (P<0.05). Furthermore, we also explored the potential of integrating NPAR and mGPS scores to predict SAP risk (Table 3). The findings indicate that combining NPAR and mGPS scores (AUC=0.764, 95% CI: 0.721–0.807) could potentially enhance the predictive power for predicting SAP risk; however, further research is necessary to validate these findings.

This study pioneers the investigation of the relationship between NPAR, mGPS, and SAP. As readily accessible novel inflammatory indicators, both NPAR and mGPS demonstrate significant predictive value for SAP occurrence in individuals with stroke. Early intervention in these patients may improve their prognosis. However, it is important to acknowledge certain limitations. First, this study was conducted at a single center and thus may have been influenced by selection bias. Second, although we have made considerable efforts to account for confounding variables, it is possible that numerous other unidentified factors may still influence our results, such as procalcitonin (PCT). Finally, the assessments of NPAR and mGPS were solely based on data collected on admission, thus failing to capture their dynamic changes over time. Further large-scale prospective research is necessary to validate our findings.

Conclusion

In conclusion, our study provides evidence supporting the associations between higher levels of NPAR, mGPS and SAP. Our findings suggest that both NPAR and mGPS serve as reliable biomarker for assessing SAP risk in stroke patients, with NPAR demonstrating superior predictive value for SAP compared to mGPS.

Data Sharing Statement

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Ethics Approval

This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethical Committee of the Tianjin First Central Hospital (No. 20240618-1).

Consent for Publication

Written informed consent was obtained from the participants.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declare that they have no conflicts of interests.

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