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Original Article

Preoperative hemoglobin, albumin, lymphocyte, and platelet (HALP) score for predictive utility in patients undergoing elective supratentorial craniotomy

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Abstract: Background: Elective supratentorial craniotomies may affect short-term prognoses. This study investigates the utility of the preoperative Hemoglobin, Albumin, Lymphocyte, and Platelet (HALP) score for predicting patient outcomes following such procedures. Methods: We retrospectively analyzed patients who underwent elective supratentorial craniotomy at a single center between January 2018 and August 2022. Outcomes were categorized as favorable or unfavorable according to survival and the occurrence of major complications. The HALP score was calculated from preoperative blood samples collected within 24 hours before surgery. Postoperative evaluation encompassed monitoring of complications, cognitive function using the Montreal Cognitive Assessment (MoCA), and neurological status assessed with the Glasgow Coma Scale (GCS). Results: After propensity score matching, 150 patients were analyzed (75 per group). Preoperative HALP scores in the good prognosis group were significantly higher than those of the poor prognosis group (73.24 ± 8.45 vs. 61.67 ± 7.82, $P < 0.001$). Multivariate analysis confirmed that lower values of HALP components independently increased the risk of poor prognosis. The receiver operator characteristic (ROC) analysis showed that the HALP score (AUC = 0.841) was better as a predictor of poor prognosis than its component alone, with an optimal intersection value of 69.42 (sensitivity = 0.84, specificity = 0.747). Patients with a low HALP score also experienced less than ideal perioperative outcomes, including longer surgery times, more blood loss, longer hospital stays, and higher rates of neurological dysfunction, consciousness disorders, and infections. Conclusions: Preoperative HALP score can predict the short-term outcome of patients undergoing elective supratentorial neurosurgery.

Keywords: HALP score, neurosurgery, supratentorial surgery, short-term prognosis, predictive

Introduction

Elective supratentorial neurosurgery is an important intervention for intracranial lesions such as brain tumors, vascular malformations, and intractable epilepsy, aiming to improve the prognosis of the nervous system and the quality of life of patients [1-3]. Despite improvements in surgical technique and perioperative management, these procedures remain associated with significant risks. Complications such as intracranial hemorrhage, new or exacerbated neurological deficits, and systemic events can worsen short-term prognosis and survival [1, 4, 5]. Reliable prediction of postoperative outcomes remains difficult. Therefore, simple and reliable preoperative biomarkers are needed for risk stratification and to guide individualized management.

A patient's preoperative physiological status is important for recovery and postoperative course. In many surgical areas, systemic inflammation and nutritional status are used to predict outcomes, as they reflect response to surgical stress and healing capacity [6-8]. These factors are also critical in neurosurgery, where the brain has high metabolic demand and limited tolerance to secondary injury. The combination of poor metabolism, weak immunity, and increased inflammation may aggravate brain injury and delay neurological recovery. This supports the need for integrated assessment tools [9-11].

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The hemoglobin, albumin, lymphocyte, and platelet (HALP) score is a recently proposed composite marker. It gives an overall measure of nutrition and systemic inflammation [12, 13]. It is a practical and low-cost measure. Hemoglobin and albumin reflect nutrient reserves and organ function. Lymphocytes and platelets are important for immune regulation and inflammatory activity [12, 14, 15]. A low HALP score suggests anemia, hypoalbuminemia, lymphopenia, and a low platelet count. Overall, it points to a reduced ability to cope with major surgery [12, 14].

More studies support the prognostic value of the HALP score. It is linked to survival and recurrence in gastric, pancreatic, colorectal, and bladder cancers [14-16]. It is also useful in other fields, including cardiovascular disease and stroke [12, 17, 18]. This suggests that the HALP score reflects core pathophysiology, including chronic anemia, protein-energy malnutrition, and a procoagulant, pro-inflammatory state. These factors are common drivers of poor outcomes across many conditions [10, 12].

However, the prognostic utility of the preoperative HALP score specifically for short-term outcomes after elective supratentorial craniotomy remains relatively unexplored. This context presents unique physiological challenges, as the brain is highly susceptible to ischemic and inflammatory insults, and pre-existing neurological compromise can compound underlying metabolic and immune dysfunction [9, 19]. This study therefore aims to evaluate whether this simple, composite biomarker of nutritional and inflammatory status, previously validated in other clinical settings, holds predictive value in this distinct neurosurgical population. Establishing its use could provide clinicians with an accessible, objective tool to help identify patients at elevated risk for poor short-term recovery, thereby informing perioperative care.

Patients methods

Research design

We conducted a retrospective study to evaluate whether preoperative HALP scores were able to predict the short-term prognosis of patients undergoing elective supratentorial craniotomy. The study population included continuous patients who underwent such surgery at Peking University International Hospital from January 2018 to August 2022. An initial review of electronic records identified 264 potential candidates. The research program complied with the ethical guidelines contained in the Helsinki Declaration and has been approved by the Peking University International Hospital Ethics Committee. Given the retrospective nature of the study and the use of anonymized data, the requirement for informed consent of the individual was exempted.

Patient selection

Eligible participants were adults 18 years of age and older who had undergone elective cranial surgery for an intracranial disease such as a brain tumor, vascular abnormalities or refractory epilepsy and needed to be diagnosed through preoperative imaging and clinical evaluation. We required complete and accessible clinical, laboratory and follow-up data to be available in electronic medical record systems. To minimize the impact of confounding factors, we applied specific exclusion criteria: 23 patients were excluded because the active malignancy may systematically alter nutritional and inflammatory markers; Fifteen patients were excluded because of severe psychological or cognitive impairment that might interfere with the evaluation of the outcome; Another 13 patients were ruled out because they were treated with antibiotics or immunosuppressive drugs within three months of surgery, which could affect immune parameters such as lymphocyte count. After applying these criteria, a total of 213 patients were eligible for initial analysis.

Grouping criteria

Patients were divided into two groups based on short-term outcomes recorded during the hospital stay. The main endpoint is a comprehensive indicator of survival and quality of life. The good prognosis group included patients who survived for more than three months after surgery without major disabling complications and did not require long-term or unplanned intensive care. The poor prognosis group included patients who died or had serious problems within three months after surgery, such as clear neurological decline, lower consciousness, or major systemic infection [20]. From an initial cohort of 213 patients (134 with good out-

comes and 79 with poor outcomes), we performed a 1:1 propensity score matching (PSM) to balance baseline variables. Propensity scores were estimated using a logistic regression model that included age, gender, BMI, and length of surgery. The caliper width was set to 0.02 standard deviation. This procedure produced a matched cohort of 150 patients (75 in each group) for all subsequent HALP score analyses. For external validation, we included an additional 80 consecutive patients (48 with good prognosis and 32 with poor prognosis) who underwent elective supratentorial craniotomy at the same institution from September 2022 to December 2023. This group used the same inclusion and exclusion criteria as the main cohorts. The external validation cohort was managed under consistent diagnostic protocols and received equivalent standard-of-care treatment, including surgical approache and perioperative management guidelines, as the primary cohort. This consistency ensured that the prognostic biomarker was evaluated in a clinically comparable setting.

Data collection and evaluation methodology

We systematically collected data by reviewing the hospital's electronic medical records. We extracted baseline demographics and clinical variables, age, sex, body mass index (BMI), smoking status, operative time, perioperative steroid use, prophylactic antibiotic administration, use of retained drains, and improved preoperative Rankin Scale (Mrs-RRB-grade were included as baseline functional status indicators.

Key haematologic indices - hemoglobin (g/L), albumin (g = L), absolute lymphocyte count (× 10^9/L) and platelet count (× 10^9, L) - were obtained from routine venous blood samples taken within 24 hours of admission. These parameters were analyzed by the hospital's clinical laboratory using a standard automated analyzer. The HALP score is calculated using the formula: Hemoglobin (g/L) × Albumin (g/L) × Lymphocyte count (× 10^9/L)/Platelet count (× 10^9/L), as described previously [21].

Postoperative outcomes were evaluated through objective clinical data and documented complications. We recorded the length of hospital stay (from surgery to discharge), the number of surgeries and the estimated amount of blood lost during surgery. We also monitored the occurrence of predefined postoperative complications, including cerebrospinal fluid leakage, new or aggravated neurological impairments, significant consciousness impairments and hospital-acquired infections such as surgical site infections, pneumonia or bloodstream infections [22].

Neurological and cognitive function is assessed by the Montreal Cognitive Assessment (MoCA), which covers multiple cognitive domains with an overall score on a scale of 0 to 30. MoCA Cronbach's Alpha in this study is 0.839 [23]. The level of consciousness is measured using the Glasgow Coma Scale (GCS), which assesses eye, speech and motor responses with a total score of 3 to 15. GCS has a Cronbach's alpha of 0.78, indicating that reliability is acceptable [24].

Statistical analysis

All analyses were performed using SPSS version 27.0 (IBM, Armonk, NY, USA). Continuous variables test for normality. Data from a normal distribution were presented as mean ± standard deviation and compared using an independent t-test. Categorical variables are expressed in numbers and percentages, and comparisons between groups were made using a Chi Square test or Fisher's exact test. Univariate and multivariate logistic regression analysis was used to identify factors independently associated with short-term poor prognosis. Variables that were meaningful or clinically relevant in single-variate analyses were included in multivariate models. The goodness-of-fit of the final multivariate logistic regression model was assessed using the Hosmer-Lemeshow test, which indicated a good fit ($P > 0.05$). The predictive performance of the HALP score and its components was assessed by receiver operating characteristic (ROC) curve analysis. We calculated the area under the curve (AUC), optimal cut-off value, sensitivity, specificity, and Youden index. A 2-sided *P* value < 0.05 was considered significant.

Results

Baseline patient characteristics before and after propensity score matching

Preliminary comparisons of the good prognosis group and the poor prognosis group before propensity score matching (PSM) sh-

Table 1. Comparison of baseline characteristics and HALP scores before propensity score matching

Clinical indicator		Before PSM		t/χ^2	P
		Good prognosis groups (n = 134)	Poor prognosis group (n = 79)		
Age (years)		54.48 ± 6.54	56.72 ± 6.02	2.484	0.014
Gender [n (%)]	Male	71 (52.99%)	51 (64.56%)	2.72	0.099
	Female	63 (47.01%)	28 (35.44%)		
BMI (kg/m^2)		23.87 ± 3.24	22.18 ± 3.41	3.607	< 0.001
Smoking [n (%)]	YES	41 (30.60%)	31 (39.24%)	1.659	0.198
	NO	93 (69.40%)	48 (60.76%)		
Surgical time [n (%)]	< 7 h	108 (80.60%)	49 (62.03%)	8.846	0.003
	≥ 7 h	26 (19.40%)	30 (37.97%)		
Perioperative steroid use [n (%)]	YES	62 (46.27%)	41 (51.90%)	0.631	0.427
	NO	72 (53.73%)	38 (48.10%)		
Use of prophylactic antibiotics [n (%)]	YES	121 (90.30%)	70 (88.61%)	0.153	0.695
	NO	13 (9.70%)	9 (11.39%)		
Indwelling drainage tube [n (%)]	YES	79 (58.96%)	61 (77.22%)	7.356	0.007
	NO	55 (41.04%)	18 (22.78%)		
mRS		3.19 ± 0.78	3.37 ± 0.74	1.684	0.094

BMI: Body Mass Index; mRS: modified Rankin Scale.

Table 2. Comparison of baseline characteristics and HALP scores after propensity score matching

Clinical indicator		After PSM		t/χ^2	P
		Good prognosis groups (n = 75)	Poor prognosis group (n = 75)		
Age (years)		54.05 ± 5.77	54.79 ± 6.21	0.765	0.446
Gender [n (%)]	Male	41 (54.67%)	39 (52.00%)	0.107	0.743
	Female	34 (45.33%)	36 (48.00%)		
BMI (kg/m^2)		23.06 ± 2.94	22.78 ± 3.02	0.563	0.574
Smoking [n (%)]	YES	24 (32.00%)	26 (34.67%)	0.120	0.729
	NO	51 (68.00%)	49 (65.33%)		
Surgical time [n (%)]	< 7 h	59 (78.67%)	61 (81.33%)	0.167	0.683
	≥ 7 h	16 (21.33%)	14 (18.67%)		
Perioperative steroid use [n (%)]	YES	34 (45.33%)	36 (48.00%)	0.107	0.743
	NO	41 (54.67%)	39 (52.00%)		
Use of prophylactic antibiotics [n (%)]	YES	68 (90.67%)	67 (89.33%)	0.074	0.785
	NO	7 (9.33%)	8 (10.67%)		
Indwelling drainage tube [n (%)]	YES	44 (58.67%)	46 (61.33%)	0.111	0.739
	NO	31 (41.33%)	29 (38.67%)		
mRS		3.26 ± 0.61	3.32 ± 0.63	0.606	0.545

owed significant differences in several baseline characteristics, including age, BMI, length of surgery, and use of retained trachea tubes (all P < 0.05), as shown in **Table 1**. To reduce these differences, 1:1 PSM was performed, resulting in a matched cohort of 150 patients (75 in each group). Matched analyses confirmed baseline profiles between the two groups (including age, sex, BMI, smoking status, length of surgery, perioperative steroid use, prophylactic antibiotic use, residual drainage tube use, and mRS score) were well balanced and no statistically significant differences were observed (all P > 0.05, **Table 2**).

Table 3. Comparison of hematologic indices and HALP score between good and poor prognosis groups

Clinical indicator	Good prognosis group (n = 75)	Poor prognosis group (n = 75)	t	P
Hemoglobin (g/L)	145.73 ± 8.62	137.44 ± 7.34	6.336	< 0.001
Albumin (g/L)	44.12 ± 3.28	39.87 ± 3.51	7.659	< 0.001
Lymphocyte (× 10^9/L)	1.94 ± 0.42	1.58 ± 0.33	5.903	< 0.001
Platelet (× 10^9/L)	231.13 ± 30.12	208.79 ± 28.63	4.656	< 0.001
HALP	73.24 ± 8.45	61.67 ± 7.82	8.707	< 0.001

HALP: Hemoglobin, Albumin, Lymphocyte, and Platelet.

Table 4. Multivariate logistic regression analysis of factors associated with poor short-term prognosis

Factor	Coefficient	Std. Error	Wald	P	OR	95% CI
Hemoglobin (g/L)	-0.246	0.067	-3.665	< 0.001	0.782	0.686-0.892
Albumin (g/L)	-0.630	0.167	-3.764	< 0.001	0.533	0.384-0.739
Lymphocyte (× 10^9/L)	-5.934	1.828	-3.246	0.001	0.003	0.001-0.095
Platelet (× 10^9/L)	-0.050	0.016	-3.121	0.002	0.951	0.922-0.982

Table 5. Receiver operating characteristic (ROC) analysis of hematologic indices and HALP score for predicting poor prognosis

Factor	Best threshold	Sensitivities	Specificities	AUC	Youden index
Hemoglobin (g/L)	140.15	0.667	0.773	0.771	0.440
Albumin (g/L)	41.825	0.693	0.813	0.802	0.560
Lymphocyte (× 10^9/L)	1.645	0.627	0.760	0.749	0.387
Platelet (× 10^9/L)	222.400	0.707	0.613	0.697	0.320
HALP	69.420	0.840	0.747	0.841	0.587

AUC: Area Under The Curve.

Association between hematological parameters, HALP score, and postoperative prognosis

A comparison of hematologic indices showed that preoperative hemoglobin, albumin, lymphocyte counts, and platelet counts in the good prognostic group were significantly higher than in the poor prognostic group (all P < 0.001) (**Table 3**). Thus, the calculated HALP score was also significantly higher in the good outcome group (73.24 ± 8.45 vs. 61.67 ± 7.82, P < 0.001) (**Table 3**). Multivariate logistic regression analysis determined that preoperative low hemoglobin, albumin, lymphocyte count, and platelet count were independent predictors of short-term poor prognosis (all P < 0.01, **Table 4**).

Predictive performance of the HALP score for poor prognosis

The ability of hematologic indices to predict poor outcome was assessed by receiver operating characteristic (ROC) analysis. Of the markers assessed, the HALP score showed the strongest differentiating ability, with an area under the curve (AUC) of 0.841, exceeding the performance of its individual components. The sensitivity of the HALP score to predict poor short-term outcome was 0.840 and 0.747 for specificity (**Table 5**; **Figure 1A**). To further evaluate the clinical utility of the HALP score, decision curve analysis (DCA) was performed. The DCA demonstrated that the HALP score provided a positive net benefit across a range of threshold probabilities in the main cohort, supporting its value in clinical decision-making (**Figure 1B**).

Correlation between HALP score and perioperative outcome

We further analyzed the results by splitting patients into low and high HALP groups using established cut-off values. Patients in the low HALP group had significantly longer operative time, greater intraoperative blood loss, and longer hospital stay than those in the high

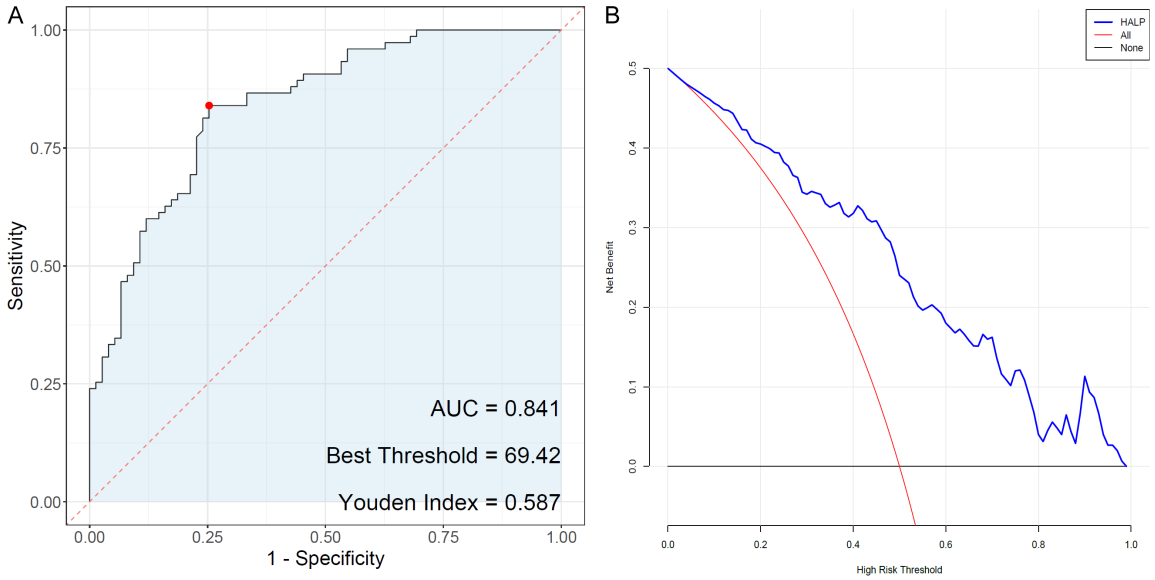

Figure 1. Predictive performance of the HALP score in the main cohort. A. Receiver operating characteristic (ROC) curve for predicting short-term poor prognosis. B. Decision curve analysis for the predictive model. The y-axis shows the net benefit. The 'All' curve represents the net benefit if all patients were predicted as having a poor prognosis. The analysis is presented for threshold probabilities ranging from 0.1 to 0.8. The 'None' curve represents the net benefit if no patients were predicted as having a poor prognosis. AUC: Area Under The Curve.

Table 6. Comparison of perioperative outcomes between low and high HALP score groups

Clinical indicator	Low HALP Group (n = 82)	High HALP Group (n = 68)	t	P
Operation time (h)	4.38 ± 1.24	3.92 ± 1.18	2.32	0.022
Number of operations (times)	1.26 ± 0.43	1.18 ± 0.39	1.273	0.205
Intraoperative blood loss (ml)	312.47 ± 78.36	268.54 ± 72.91	3.527	< 0.001
Hospital stay (days)	12.63 ± 3.27	10.84 ± 2.96	3.474	< 0.001

Table 7. Incidence of postoperative complications in low vs. high HALP score groups [n (%)]

Clinical indicator	Low HALP Group (n = 82)	High HALP Group (n = 68)	χ^2	P
Neurologic impairment	28 (34.15%)	12 (17.65%)	5.175	0.023
Disturbance of consciousness	22 (26.83%)	8 (11.76%)	5.273	0.022
Cerebrospinal fluid leakage	14 (17.07%)	5 (7.35%)	3.175	0.075
Infection	19 (23.17%)	7 (10.29%)	4.302	0.038

HALP group (all P < 0.05, **Table 6**). In addition, the incidence of major postoperative comorbidities (e.g., neurological dysfunction, cognitive impairment, and infection) was significantly higher in the low HALP group (all P < 0.05, **Table 7**). Consistently, the low HALP group had poorer functional outcomes, as evidenced by the Montreal Cognitive Assessment (MoCA) score (23.47 ± 2.86 vs. 24.82 ± 2.43, P = 0.003). And Glasgow Coma Scale (GCS) scores (11.38 ± 1.72 vs. 12.34 ± 1.32, P < 0.001) were significantly reduced, as shown in **Figure 2**.

External validation of the HALP score

To further assess the predictive utility of the HALP score, 80 patients in an independent external validation cohort were analyzed. Baseline hematologic parameters and HALP scores for this cohort by prognosis are summarized in **Table 8**. Consistent with the results of the main cohort, the good prognosis group (n = 48) showed significantly higher preoperative hemoglobin, albumin, and gonoblastoma counts, combined with a lower platelet count,

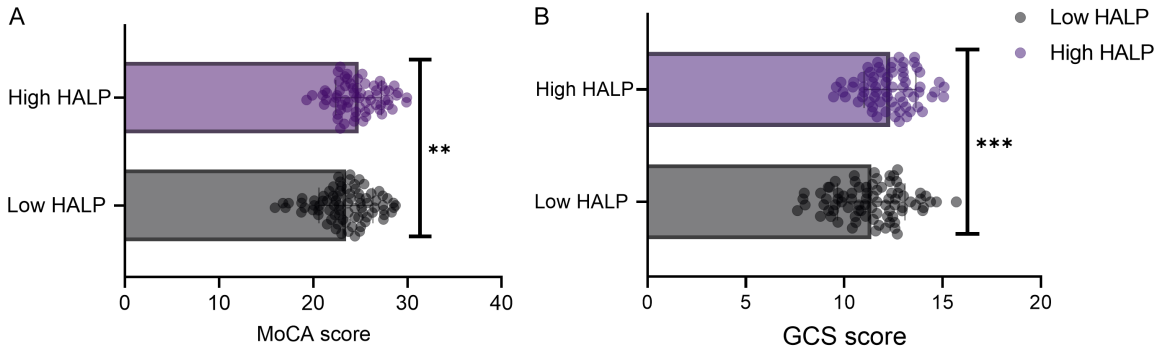

Figure 2. Neurologic and consciousness assessment scores in low vs. high HALP score groups. A. MoCA score; B. GCS score. MoCA: Montreal Cognitive Assessment; GCS: Glasgow Coma Scale; HALP: Hemoglobin, Albumin, Lymphocyte, and Platelet. **P < 0.01; ***P < 0.001.

Table 8. Baseline characteristics of the external validation cohort

Clinical indicator	Good prognosis group (n = 48)	Poor prognosis group (n = 32)	t	P
Hemoglobin (g/L)	143.91 ± 8.51	136.34 ± 8.22	3.949	< 0.001
Albumin (g/L)	43.92 ± 3.53	40.41 ± 3.63	4.312	< 0.001
Lymphocyte (× 10^9/L)	1.91 ± 0.39	1.66 ± 0.38	2.772	0.007
Platelet (× 10^9/L)	233.47 ± 28.71	210.82 ± 30.44	3.376	0.001
HALP	73.89 ± 8.12	62.45 ± 8.01	6.206	< 0.001

Table 9. ROC analysis of hematologic indices and HALP score for predicting poor prognosis in the external validation cohort

Factor	Best threshold	Sensitivities	Specificities	AUC	Youden index
Hemoglobin (g/L)	138.89	0.625	0.792	0.732	0.417
Albumin (g/L)	40.530	0.562	0.875	0.761	0.437
Lymphocyte (× 10^9/L)	1.785	0.750	0.604	0.680	0.354
Platelet (× 10^9/L)	208.010	0.562	0.812	0.717	0.374
HALP	69.435	0.812	0.708	0.838	0.520

resulted in a significantly higher HALP score (73.89 ± 8.12) relative to the poor prognostic group (n = 32) vs. 62.45 ± 8.01, P < 0.001).

The ROC analysis again confirmed the score's strong ability to predict short-term adverse outcomes, with an AUC of 0.838 (**Table 9**). At a cut-off value of 69.435, the HALP score maintained high sensitivity (0.812) and satisfactory specificity (0.708) in this independent patient group (**Figure 3A**). Additionally, decision curve analysis (DCA) was conducted in the external validation cohort, that showed that the HALP score had a consistent net benefit across threshold probabilities, validating its clinical utility in an independent population (**Figure 3B**).

Discussion

In this retrospective analysis, we examined the ability of preoperative HALP scores to predict short-term outcomes in patients undergoing elective supratentorial neurosurgery. Our results show that a lower preoperative HALP score is linked to a higher rate of poor short-term outcome. This combined index predicts outcomes better than any single component. Patients with a good prognosis had higher preoperative hemoglobin, albumin, lymphocyte, and platelet levels, so their HALP scores were also higher. Multivariate logistic regression, the fit of which was validated (Hosmer-Lemeshow test, P > 0.05), showed that lower values of each component independently increased the

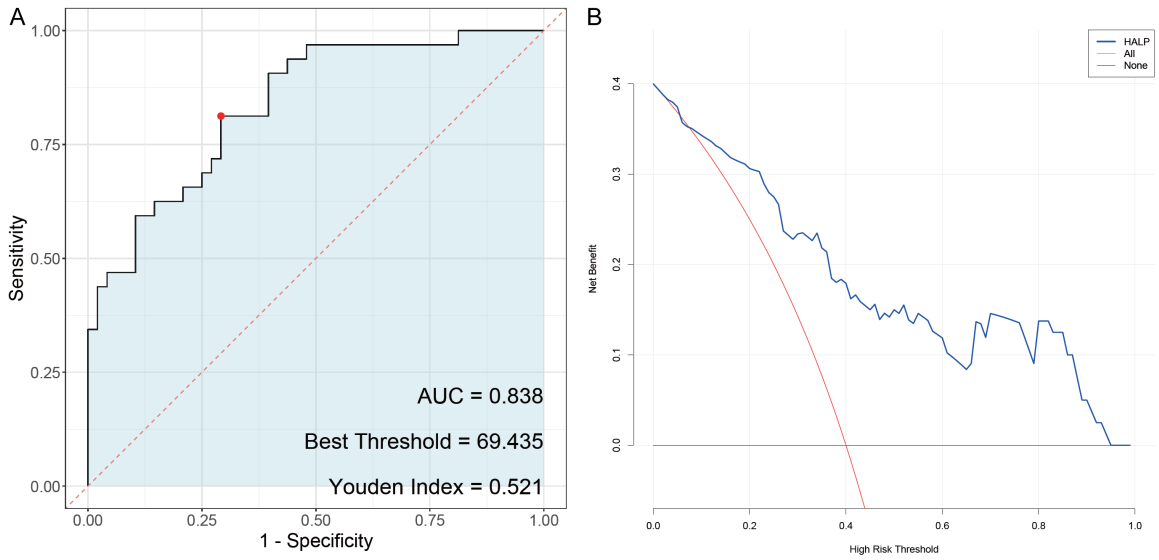

Figure 3. External validation of the HALP score predictive utility. A. ROC curve analysis in the independent validation cohort. B. Decision curve analysis for the predictive model. The y-axis shows the net benefit. The 'All' curve represents the net benefit if all patients were predicted as having a poor prognosis. The analysis is presented for threshold probabilities ranging from 0.1 to 0.8.

risk of a poor short-term outcome, suggests that while these factors collectively contribute to the risk, their individual effects in this model are primarily additive rather than synergistic concerning the studied endpoint. These results show that the blood and nutrition levels before surgery affect recovery after elective surgery.

These connections are biologically plausible considering the roles of each component. Hemoglobin is essential for oxygen transport and tissue oxygenation; preoperative anemia can lead to reduced oxygen delivery, slow wound healing, hinder neurological recovery, and worsen outcome [19, 25, 26]. Albumin levels indicate nutritional status and protein synthesis; low albumin may suggest malnutrition or inflammation, reducing the body's ability to withstand surgical stress and recover [17, 27, 28]. Lymphocytes are vital for immune response; a low lymphocyte count can indicate weakened immunity, increasing the risk of postoperative infections and adverse outcome [29, 30]. Platelets play a role in clotting and inflammation; abnormal platelet levels may signal inflammatory conditions or clotting disorders that complicate recovery [31-33]. It is important to note that the HALP score values presented as group means represent the average of the individually calculated scores for all patients within that group. This approach, rather than applying the formula to the average values of the individual components (hemoglobin, albumin, lymphocytes, platelets), is the correct method for summarizing a composite index and accounts for the covariance between its constituents. Therefore, the HALP score combines measures of oxygenation, nutrition, immunity, and inflammation into one index reflecting physiologic resilience. This integrative approach is supported by studies in other clinical contexts. For instance, in patients with acute ischemic stroke, Ramesh et al. [17] demonstrated that a lower HALP score was significantly correlated with poorer functional outcome, suggesting its role in reflecting the systemic burden of ischemia and inflammation. Similarly, Zuo et al. [18] found that a low HALP score increased the risk of post-stroke cognitive impairment, highlighting the possible link between the composite markers of HALP and cerebral vulnerability. In the context of cancer, Xu et al. [21] conducted a meta-analysis concluding that the HALP score robustly predicted survival, reinforcing the notion that the interplay of anemia, malnutrition, and inflammation captured by HALP represents a common pathway influencing prognosis across diverse pathologies. Our findings align with these studies, extending the applicability of the HALP score to elective neurosurgery and suggesting that the mechanisms such as compromised oxygen delivery, impaired

immune surveillance, and a pro-inflammatory state may similarly underpin the increased risk of poor short-term recovery after supratentorial craniotomy.

We evaluated the predictive performance of HALP using ROC analysis. HALP was the strongest predictor of poor short-term outcomes (AUC = 0.841), outperforming each individual component. At an optimal cutoff of 69.42, it achieved a favorable balance of sensitivity and specificity. These findings indicate that the composite score surpasses single indices, likely because it better reflects the interplay between nutritional status and systemic inflammation.

Analysis of secondary outcomes further supports the prognostic utility of the HALP score. Using the optimal cutoff to define low versus high HALP, the low HALP group had longer operative times, greater intraoperative blood loss, and prolonged hospitalization. In addition, the low HALP group had more major postoperative complications, including new or worse neurological deficits, impaired consciousness, and hospital-acquired infections. These findings were supported by lower MoCA and GCS scores in the low HALP group. A similar pattern across different perioperative measures supports the idea that the HALP score can identify patients with lower physiologic reserve, who are more likely to have a complex recovery and worse functional outcomes after surgery.

Our results agree with growing evidence that combined inflammatory and nutritional biomarkers have prognostic value in surgical settings. For example, Matsuda et al. [34] showed that several hematologic ratios and indices could predict survival in patients undergoing brain metastasectomy. The HALP score fits this idea but uses a simple, easy-to-get combination of indices. Its prognostic value has been reported in several oncology and general medical settings [35-37] and our study extends its use to elective neurosurgery. This suggests that the processes reflected by the HALP score - chronic anemia, malnutrition, and systemic inflammation - may be common mechanisms of poor prognosis across different diseases, including those needing neurosurgery [38, 39].

Despite these encouraging results, several limitations warrant consideration. First, this single-center retrospective design is susceptible to selection bias and unmeasured confounding. Although propensity score matching balanced key baseline variables, including the preoperative mRS score which reflects baseline functional status, residual confounding may persist due to the lack of incorporation of other possible confounders, such as detailed tumor characteristics (e.g., size, location, and pathological grade) and specific comorbidities (e.g., diabetes, hypertension), into the PSM mode. Second, the sample size, while adequate for an exploratory analysis, was relatively small, potentially limiting generalizability and statistical robustness. Consequently, large prospective multicenter studies with broader clinical data are needed to validate the predictive value of the HALP score. Its performance should be examined across supratentorial lesion types and baseline disease severities. Future work should also assess subgroup effects, interactions with other prognostic factors (including surgical techniques and detailed complications), and its incremental effect on outcome to refine risk stratification models.

Conclusion

The preoperative HALP score predicts short-term outcome in patients undergoing elective supratentorial neurosurgery. HALP is simple, low-cost, readily obtainable, and reflects nutritional and inflammatory status. Incorporating HALP scores into preoperative evaluation can help clinicians identify high-risk patients, thereby promoting more informed decision-making, personalized perioperative management, and optimized resource allocation, ultimately improving outcome.

Disclosure of conflict of interest

None.

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