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Original Article

Predictive value of cerebrospinal fluid heparin-binding protein and CD64 expression for postoperative central nervous system infection following intracerebral hemorrhage surgery

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Abstract: Objectives: To explore the association and predictive value of cerebrospinal fluid (CSF) heparin-binding protein (HBP) and cluster of differentiation 64 (CD64) levels with postoperative central nervous system (CNS) infection following hypertensive intracerebral hemorrhage surgery. Methods: A retrospective analysis was conducted on 64 patients who developed postoperative CNS infections (infection group) and 70 patients without infections (non-infection group) after surgical treatment for hypertensive intracerebral hemorrhage at Shangyu People's Hospital of Shaoxing between February 2021 and February 2024. CSF HBP and CD64 levels were measured within 24-48 hours postoperatively. Univariate and multivariate logistic regression analyses were performed to identify risk factors for CNS infection. Receiver operating characteristic curve analysis was used to assess the predictive performance of the biomarkers. Results: Patients in the infection group were significantly older than those in the non-infection group. CSF HBP and CD64 levels were significantly elevated in the infection group (all $P<0.05$). Additionally, peripheral blood levels of procalcitonin, lactate dehydrogenase, and C-reactive protein were higher, whereas albumin levels were lower in the infection group (all $P<0.05$). Multivariate analysis identified elevated CSF HBP and CD64 as independent risk factors for CNS infection. The area under the curve values for predicting CNS infections were 0.745 for CSF HBP alone, 0.709 for CSF CD64 alone, and 0.846 when both markers were combined. Conclusions: Elevated CSF HBP and CD64 levels are closely associated with postoperative CNS infection following hypertensive intracerebral hemorrhage surgery. While each marker alone offers moderate predictive value, their combined use significantly enhances diagnostic accuracy.

Keywords: Cerebrospinal fluid, heparin-binding protein, CD64, hypertension, intracerebral hemorrhage, central nervous system infection, prediction

Introduction

Hypertensive intracerebral hemorrhage is a common and life-threatening neurosurgical emergency, associated with high rates of mortality and disability [1]. Surgical evacuation of hematomas is an effective intervention for reducing brain injury. However, postoperative central nervous system (CNS) infections remain a frequent and challenging complication that significantly impede recovery and negatively impact patients' quality of life [2]. Despite their clinical importance, current predictive tools for CNS infections exhibit notable limitations in accuracy and reliability. Conventional biomarkers, such as C-reactive protein (CRP) and procalcitonin (PCT), have limited sensitivity for detecting CNS infection and are significantly affected by systemic inflammatory responses. Although cerebrospinal fluid (CSF) bacterial culture remains the diagnostic gold standard, its 48-72-hour turnaround time often results in delayed treatment initiation. Consequently, clinicians face a challenging dilemma: either administer potentially unnecessary prophylactic antibiotics or risk a missed diagnosis of delayed-onset infection [3]. Heparin-binding protein (HBP), a novel biomarker of infection,

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has demonstrated superior sensitivity to PCT in the diagnosis of sepsis. However, its application for predicting postoperative CNS infections remains inconclusive [4]. Cluster of differentiation 64 (CD64), a specific marker of immune activation, has also shown diagnostic value in differentiating bacterial meningitis [5]. Nevertheless, existing studies have primarily focused on community-acquired infections, with little evidence available in the context of postoperative or trauma-related infections. Therefore, this study aimed to investigate the association of CSF HBP and CD64 expression with the occurrence of postoperative CNS infections in patients with hypertensive intracerebral hemorrhage, and to evaluate their predictive value for infection risk to inform early clinical intervention.

Materials and methods

Study design and population

This retrospective study reviewed patients who underwent surgical treatment for hypertensive intracerebral hemorrhage at Shangyu People's Hospital of Shaoxing between February 2021 and February 2024. A total of 64 patients who developed postoperative CNS infections were assigned to the infection group, and 70 patients without postoperative CNS infection were included as the non-infection group. This study was approved by the Medical Ethics Committee of Shangyu People's Hospital of Shaoxing.

Diagnostic, inclusion, and exclusion criteria

Diagnostic Criteria: (1) The diagnosis of hypertensive intracerebral hemorrhage was made in accordance with the Chinese Multidisciplinary Guidelines for the Diagnosis and Treatment of Hypertensive Intracerebral Hemorrhage [6]. (2) The diagnosis of CNS infections was established according to the Chinese Expert Consensus on the Diagnosis and Treatment of Central Nervous System Infections in Neurosurgery (2021 Edition) [7].

Inclusion Criteria: (1) Age ≥19 years; (2) Underwent surgical treatment for hypertensive intracerebral hemorrhage in the Department of Neurosurgery at Shangyu People's Hospital of Shaoxing; (3) Normal cognitive function prior to surgery; (4) CNS infections confirmed by positive CSF bacterial culture.

Exclusion Criteria: (1) Presence of intracranial tumors; (2) History of traumatic brain injury; (3) Cerebral infarction; (4) Underlying disorders associated with coagulopathy; (5) Preoperative presence of multiple organ infections, systemic infections, or other concurrent infectious diseases; (6) Human immunodeficiency virus infection.

Treatment method

All patients received surgical intervention. The specific procedure, either craniotomy for hematoma evacuation or minimally invasive drainage, was determined based on hematoma size, location, and the patient's clinical condition. Patients with larger hematomas (>30 mL) or those causing significant midline shift underwent craniotomy under general anesthesia. This open procedure employed microsurgical techniques to evacuate the hematoma while minimizing damage to adjacent brain tissue. Smaller hematomas (<30 mL) or cases involving critically ill patients who were unsuitable for prolonged surgery, received minimally invasive drainage. This technique involved CT-guided stereotactic placement of a drainage catheter into the hematoma cavity, followed by the administration of fibrinolytic agents through the catheter to dissolve the clot and facilitate drainage. Postoperatively, all patients received standard care, including anti-infective therapy, blood pressure management, and nutritional support.

General information collection

Demographic and clinical data were retrieved from medical records, including age, sex, body mass index, smoking history, alcohol consumption history, comorbidities (coronary heart disease, diabetes mellitus, hyperlipidemia), and duration of hypertension. Surgery-related parameters included operative time, Glasgow Coma Scale score [8], intraoperative blood loss, surgical site, CSF leakage, duration of drainage tube placement, and prophylactic antibiotic use. All data were cross-checked by two independent reviewers, and key variables were validated for logical consistency before entry.

Detection method of CSF index

At 24-48 hours postoperatively, 200 μL of CSF was collected by lumbar puncture. After cen-

trifugation at 3000 rpm for 10 minutes (centrifugal radius: 12 cm), the supernatant was collected. HBP levels were measured using a fluorescence immunochromatographic assay with kits provided by Tianjin Pengchuang Health Technology Co., Ltd. (registration number: 20202400906). CD64 expression was detected by flow cytometry using kits supplied by BD Rapid Diagnostics (Suzhou) Co., Ltd. (registration number: 20173401489).

Detection method of biochemical index

Peripheral venous blood was collected within 24 hours after surgery using a disposable vacuum blood collection tube. A 5 mL blood sample was divided into two parts. One part was left at room temperature for 30 minutes to allow natural coagulation, then centrifuged at 3000 rpm for 10 minutes (centrifugal radius: 15 cm). The serum was separated for subsequent index detection.

White blood cell (WBC) count was measured using the BK-WBC cell counter manufactured by Tianjin Purui Instrument Co., Ltd. (registration number: 20192220188). PCT was measured using a dry fluorescence immunoassay with kits from Boditech (Guangxi) Biotechnology Co., Ltd. (registration number: 20192400082). Lactate dehydrogenase (LDH) was detected using the Deutsche Gesellschaft für Klinische Chemie und Laboratoriumsmedizin recommended method with reagents from Qingdao Baimei Biotechnology Co., Ltd. (registration number: 20192400182). CRP was measured by latex-enhanced immunoturbidimetric assay using kits from Shenzhen Mindray Bio-Medical Electronics Co., Ltd. (registration number: 20202400893). Albumin (ALB) was detected using the bromocresol green method with kits provided by Wuhan Bettericon Biotechnology Co., Ltd. (registration number: 20202402979). Total bilirubin was determined by the chemical oxidation method with kits from Nanjing Aolin Biotechnology Co., Ltd. (registration number: 20172402491).

Statistical processing

Data were analyzed using SPSS version 21.0. Measured data, such as CSF HBP and CD64 levels, that followed a normal distribution, were expressed as mean ± standard deviation ($\bar{x} \pm s$), with comparisons between two groups performed using the t-test. Categorical data, such as sex, smoking, and alcohol consumption, were expressed as percentages (%), and comparisons between groups were conducted using the chi-square (χ^2) test. Univariate and multivariate logistic regression analyses were used to identify risk factors for postoperative CNS infection in patients with hypertensive cerebral hemorrhage. Receiver operating characteristic (ROC) curve analysis was applied to evaluate the predictive value of each risk factor. A P value of <0.05 was considered significant.

Result

Intergroup comparison of population characteristics

The age of patients in the infection group was significantly higher than that of the control group (P<0.05). There were no statistically significant differences between the infection and control groups in terms of body mass index, sex distribution, smoking status, alcohol consumption, comorbidities, or duration of hypertension (all P>0.05). See **Table 1**.

Intergroup comparison of expression levels of CSF HBP and CD64

The levels of CSF HBP and CD64 expression in the infection group were significantly higher than those of the control group (both P<0.001) (**Table 2**). Flow cytometric analysis further confirmed these findings, as illustrated in **Figure 1**. The figure clearly demonstrates a distinct difference in CD64 expression between the two groups. In the control group (**Figure 1A**), the median CD64 expression was 0.27%, while in the infection group (**Figure 1B**), it was significantly elevated to 0.84%.

Intergroup comparison of surgery-related indicators

The volume of cerebral hemorrhage in the infection group was significantly greater than that in the control group (P<0.05). There were no significant differences between the infection and control groups in terms of Glasgow Coma Scale score, length of hospital stay, duration of surgery, surgical site, incidence of CSF

Table 1. Intergroup comparison of population characteristics

Group	n	Age (years old)	BMI (kg/m^2)	Gender (%)		Smoking (%)	Drinking (%)	Comorbidities (%)			Hypertension course (year)
				Male	Female			Coronary heart disease	Diabetes	Hyperlipidemia	
Infection group	64	71.4±6.2	23.88±1.80	38 (59.38)	26 (40.63)	24 (37.5)	21 (32.81)	13 (20.31)	15 (23.44)	47 (73.44)	11.7±3.6
Control group	70	67.9±6.9	23.54±2.08	44 (62.86)	26 (37.14)	32 (45.71)	27 (38.57)	10 (14.29)	24 (34.29)	56 (80.00)	12.6±3.9
t/χ^2		3.078	1.007	0.171		0.927	0.482	0.854	1.907	0.810	-1.384
P		0.003	0.316	0.679		0.336	0.487	0.355	0.167	0.368	0.169

BMI: Body Mass Index.

Table 2. Intergroup comparison of expression levels of CSF HBP and CD64

Disease data	Infection group (n=64)	Control group (n=70)	t	*P*
HBP (μg/L)	33.71±8.14	9.20±2.55	23.947	<0.001
CD64 (%)	0.78±0.16	0.35±0.09	19.384	<0.001

CSF: Cerebrospinal fluid; HBP: Heparin-binding protein; CD64: Cluster of differentiation 64.

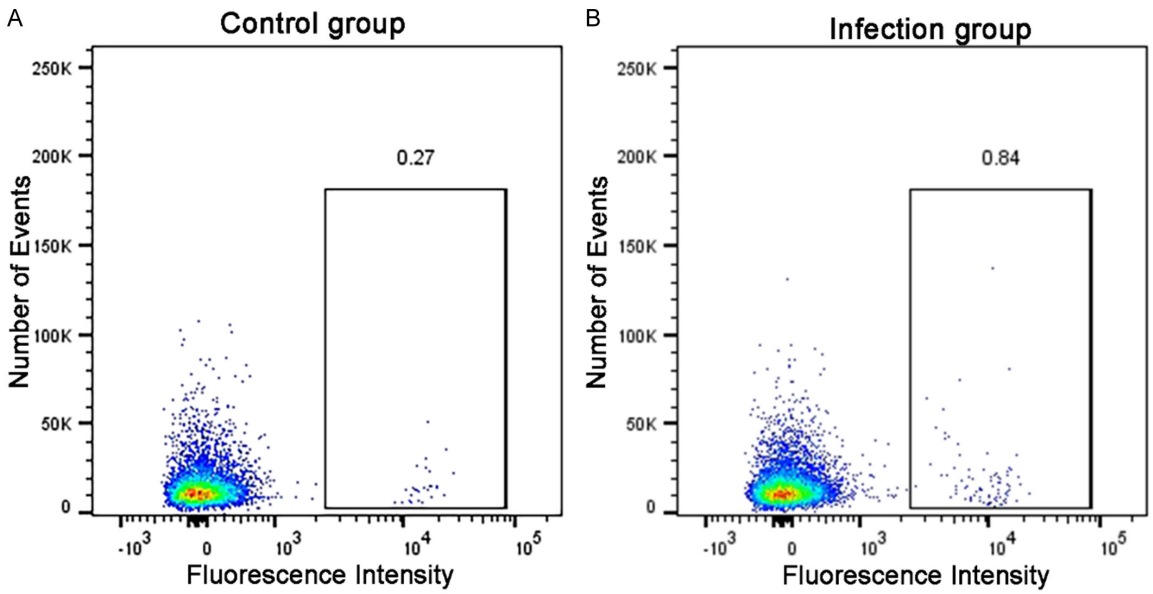


Figure 1. Flow cytometric analysis of CSF CD64. A: Control group; B: Infection group. CSF: Cerebrospinal fluid; CD64: Cluster of differentiation 64.

Table 3. Intergroup comparison of surgery-related indicators

Disease data	Infection group (n=64)	Control group (n=70)	t/χ^2	*P*
Operation time (min)	98.5±14.2	96.0±12.7	1.076	0.284
GCS score (point)	7.33±1.20	7.61±1.32	-1.281	0.203
Hospitalization time (d)	18.3±2.4	17.6±2.7	1.580	0.116
Blood loss (mL)	46.4±6.0	43.8±7.1	2.279	0.024
Surgical location			0.856	0.355
On-screen type	39 (60.94)	48 (68.57)		
Off-screen type	25 (39.06)	22 (31.43)		
Leakage of cerebrospinal fluid			3.516	0.061
Yes	22 (34.38)	14 (20)		
No	42 (65.63)	56 (80)		
Indwelling drainage tube time			2.205	0.138
≥2 d	21 (32.81)	15 (21.43)		
<2 d	43 (67.19)	55 (78.57)		
Prophylactic antibiotics			2.994	0.084
Yes	56 (87.5)	67 (95.71)		
No	8 (12.5)	3 (4.29)		

GCS: Glasgow Coma Scale.

leakage, duration of drainage tube placement, or prophylactic antibiotic use (all *P*>0.05) (**Table 3**).

Intergroup comparison of blood biomarkers

The levels of PCT, LDH, and CRP were significantly higher in the infection group compared to the control group, while the ALB level was significantly lower (all *P*<0.05). There were no significant differences between the infection and control groups in terms of peripheral WBC count, neutrophil count, or total bilirubin level (all *P*>0.05) (**Table 4**).

Screening of risk factors for postoperative CNS infections in patients with hypertensive cerebral hemorrhage

Variables that showed statistical significance in univariate analysis were included in the logistic regression model. Specifically, univariate logis-

Table 4. Intergroup comparison of blood biomarkers

Disease data	Infection group (n=64)	Control group (n=70)	t	*P*
WBC (×10^9/L)	14.38±2.81	13.90±2.67	1.014	0.313
PCT (ng/mL)	0.89±0.22	0.45±0.13	14.237	<0.001
LDH (U/L)	254.8±29.8	237.6±27.5	3.475	0.001
Neutrophilic granulocyte (%)	82.6±8.1	84.0±7.5	-1.039	0.301
CRP (mg/L)	15.72±3.90	12.80±3.74	4.423	<0.001
ALB (g/L)	38.59±2.41	40.82±2.96	-4.755	<0.001
TB (g/L)	65.40±5.21	67.15±5.84	-1.824	0.070

WBC: White blood cell; PCT: Procalcitonin; LDH: Lactate dehydrogenase; CRP: C-reactive protein; ALB: Albumin; TB: Total bilirubin.

Table 5. Univariate logistic regression analysis of risk factors for postoperative CNS infections

Indicator	β	SE	Walds	*P*	OR	95% *CI*	
Age	0.409	0.247	2.742	0.134	1.505	0.928	2.443
HBP	0.511	0.226	5.112	0.032	1.667	1.070	2.596
CD64	0.602	0.283	4.525	0.045	1.826	1.048	3.179
Blood loss	0.417	0.186	5.026	0.034	1.517	1.054	2.185
PCT	0.488	0.227	4.622	0.044	1.629	1.044	2.542
LDH	0.503	0.271	3.445	0.098	1.654	0.972	2.813
CRP	0.414	0.186	4.954	0.037	1.513	1.051	2.178
ALB	-0.611	0.297	4.232	0.047	0.543	0.303	0.972
Constant term	1.209	0.408	8.781	<0.001	3.350	1.506	7.453

HBP: Heparin-binding protein; CD64: Cluster of differentiation 64; PCT: Procalcitonin; LDH: Lactate dehydrogenase; CRP: C-reactive protein; ALB: Albumin; CI: Confidence interval.

Table 6. Multivariate logistic regression analysis of risk factors for postoperative CNS infections

Indicator	β	SE	Walds	*P*	OR	95% *CI*	
Age	0.273	0.211	1.644	0.211	1.317	0.773	2.236
HBP	0.974	0.345	8.215	0.004	2.654	1.452	4.854
CD64	1.326	0.354	14.221	<0.001	3.756	1.959	7.208
Blood loss	0.785	0.313	6.317	0.013	2.182	1.227	3.90
PCT	0.818	0.322	6.452	0.011	2.254	1.268	4.057
LDH	0.647	0.299	4.853	0.029	1.892	1.109	3.242
CRP	-0.602	0.298	4.286	0.038	0.558	0.324	0.946
ALB	0.251	0.257	1.004	0.324	1.282	0.799	2.094
Constant term	-1.209	0.416	8.788	0.003	0.305	0.135	0.688

HBP: Heparin-binding protein; CD64: Cluster of differentiation 64; PCT: Procalcitonin; LDH: Lactate dehydrogenase; CRP: C-reactive protein; ALB: Albumin; CI: Confidence interval.

tic regression analysis, detailed in **Table 5**, identified several significant predictors of postoperative CNS infections, including CSF levels of HBP and CD64, blood loss, peripheral blood levels of PCT, CRP, and ALB (all $P<0.05$). Further multivariate logistic regression analysis, presented in **Table 6**, confirmed that higher CFS levels of HBP and CD64 remained significant independent risk factors (both $P<0.05$).

Predictive value of CSF HBP and CD64 for CNS infections in patients with hypertensive cerebral hemorrhage

ROC curves were constructed for CSF HBP, CD64, and their combination to assess their predictive value for CNS infections in patients with hypertensive cerebral hemorrhage. The analysis revealed area under the curve (AUC)

Table 7. Predictive values of CSF HBP, CD64, and their combined application for CNS infection in patients with hypertensive cerebral hemorrhage

Indicator	Critical value	Sensitivity (%)	Specificity (%)	Omission diagnosis rate (%)	Misdiagnosis rate (%)	AUC value (%)	AUC 95% CI
HBP (μg/L)	21.37	62.91	77.05	37.09	22.95	0.745	0.657-0.832
CD64	0.58	58.03	79.57	41.97	20.43	0.709	0.616-0.802
Combined use	-	80.48	73.18	19.52	26.82	0.846	0.778-0.913

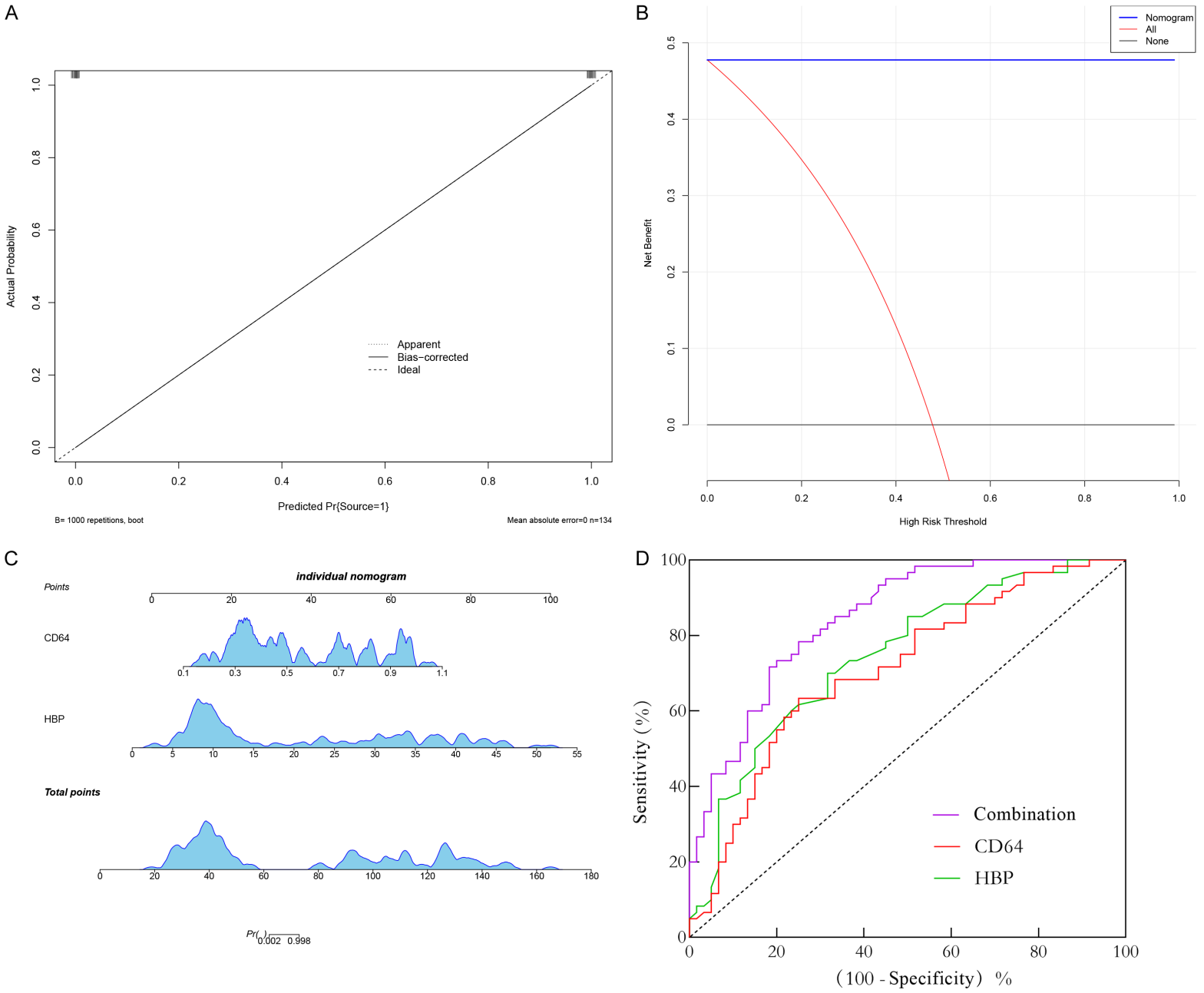
CSF: Cerebrospinal fluid; HBP: Heparin-binding protein; CD64: Cluster of differentiation 64; AUC: Area under the curve; CI: Confidence interval.

values of 0.745 (95% CI: 0.657-0.832) for HBP alone, 0.709 (95% CI: 0.616-0.802) for CD64 alone, and 0.846 (95% CI: 0.778-0.913) for the combined indicators (**Table 7**). A comprehensive evaluation of these predictive models is further illustrated in **Figure 2**. The calibration curve (**Figure 2A**) shows good agreement between the predicted and actual probability, indicating reliable predictive performance. Decision curve analysis (**Figure 2B**) demonstrates the net benefit across different high-risk thresholds, suggesting that the combined use of HBP and CD64 provides significant clinical utility over other strategies. The nomogram (**Figure 2C**) offers a visual tool for individual risk assessment, integrating the contributions of both HBP and CD64 levels to predict the likelihood of CNS infections. Finally, the ROC curve (**Figure 2D**) visually confirms the superior discriminatory ability of the combined indicators compared to HBP or CD64 alone, with an AUC of 0.846.

Discussion

Postoperative CNS infection is a severe complication following surgical management of hypertensive intracerebral hemorrhage. The underlying pathophysiology involves neutrophil activation, cytokine cascade initiation, blood-brain barrier (BBB) disruption, and subsequent pathogen invasion. Additional risk factors include postoperative immunosuppression, CSF external drainage, and iatrogenic factors. While CRP and PCT remain widely used diagnostic markers for CNS infections, their limited sensitivity and specificity impede early detection of postoperative cases [9]. Our findings indicate that patients in the infection group were significantly older than those in the control group, consistent with prior reports by Jiang et al. [10]. Advanced age correlates with immunosenescence and the presence of frequent comorbidities (e.g., hypertension, diabetes), which collectively reduce resistance to infection [11].

The levels of CSF HBP and CD64 were elevated in the infection group compared to the control group. As a protein derived from neutrophils, HBP exhibits a strong binding affinity for the lipid A component of lipopolysaccharides. When activated, neutrophils release HBP, resulting in rapid increases in its concentration in both the blood and CSF during acute bacterial infections. Studies confirm that CSF HBP levels rise significantly during bacterial CNS infections, aiding in the differentiation from non-infectious or viral causes [12]. Research by Namiduru et al. [13] also found variations in HBP levels across different types of meningitis. Patients with bacterial meningitis showed significantly higher HBP levels in both CSF and serum compared to other types, suggesting HBP's potential as a diagnostic biomarker for CNS infections. In hospital-acquired meningitis, HBP achieved an AUC of 0.99, demonstrating high sensitivity (97%) and specificity (95%). This performance surpasses traditional markers such as PCT, which had an AUC of only 0.69 [14]. These findings suggest that CSF HBP is a sensitive and early indicator of CNS infections, particularly effective for identifying bacterial origins. CD64, also known as Fc gamma receptor I, is a high-affinity receptor located on the surface of neutrophils. Under normal conditions, CD64 expression remains low; however, bacterial infections can trigger a rapid increase in CD64 levels within 4 to 6 hours. This increase enhances neutrophil phagocytic and bactericidal activity, making CD64 another promising early marker for bacterial infection detection [15]. Clinical studies by Gao et al. [16] support this, showing that the neutrophil CD64 index is significantly higher in infected patients compared to non-infected individuals, offering rapid insight into infection progression. Similarly, Liu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D
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Combination
CD64
HBP

Figure 2. Comprehensive evaluation of CSF HBP, CD64, and their combined use for CNS infections in patients with hypertensive cerebral hemorrhage. A: Calibration curve; B: Decision curve analysis; C: Nomogram; D: ROC curve. CNS: Central nervous system; HBP: Heparin-binding protein; CD64: Cluster of differentiation 64; ROC: receiver operator characteristic.

et al [17] observed significantly elevated CSF neutrophil CD64 expression by flow cytometry in severe neonatal meningitis cases, consistent with current findings.

Clinically, the size of an intracerebral hemorrhage critically influences patient recovery and the risk of postoperative complications. In this study, the infection group had significantly larger cerebral hematoma volumes compared to the non-infection group. Larger bleeds often indicate more extensive surgical trauma, which can compromise the BBB, a critical defense against CNS pathogens. BBB impairment facilitates the entry of bacteria, viruses, and other infectious agents into the CSF, increasing the risk of CNS infections. Substantial bleeding also induces focal cerebral ischemia and hypoxia, triggering inflammatory cascades and the release of mediators. These mediators further degrade the BBB, allowing normally excluded pathogens to invade neural tissue and establish infections [18].

Regarding inflammatory markers, our study found that the peripheral blood levels of PCT, LDH, and CRP in the infection group were significantly higher than those in the control group, while ALB levels were lower. These results suggest a significant correlation between these markers and CNS infections following surgery for cerebral hemorrhage. Specifically, PCT serves as a specific indicator of bacterial infection. Its increase is primarily due to the activation of the NF-κB signaling pathway in monocytes by pathogen-associated molecular patterns, leading to abnormal PCT synthesis outside the thyroid gland. In cases of CNS infection, damage to the BBB allows bacterial components to enter the bloodstream, triggering a systemic inflammatory response. Moorthy et al. [19] noted that the median CSF PCT level in healthy individuals was 0.03 ng/mL, whereas in patients with postoperative bacterial meningitis, this level was significantly elevated compared to both healthy controls and patients with bacterial meningitis. The AUC for CSF PCT was reported at 0.767, indicating that measuring CSF PCT within 30 days after non-traumatic neurosurgery in patients with fever may aid in the early detection of bacterial meningitis. This observation aligns with the findings of our current study. LDH, an enzyme typically found inside cells, is released into the bloodstream when tissues are damaged or cells break down. During infections, bacterial toxins and inflammatory mediators can cause cell injury, resulting in increased LDH levels in the blood. Feng et al. [20] showed that the combined assessment of LDH, β2-transferrin, and interleukin-10 had high sensitivity for diagnosing both pyogenic and viral meningitis, further reinforcing the association between LDH and CNS infections.

CRP, an acute-phase protein produced by the liver in response to inflammation, begins to increase within 6 to 8 hours after infection onset and peaks between 24 to 48 hours, reaching levels hundreds of times higher than normal. A study involving 738 patients suspected of having neurological infections demonstrated that CRP in CSF has substantial diagnostic accuracy for CNS infections, particularly bacterial meningitis [21]. ALB, primarily synthesized by the liver, is crucial for maintaining colloid osmotic pressure and transporting various substances. During infections, systemic inflammatory responses increase capillary permeability, causing albumin to leak into the interstitial space and decreasing its concentration in plasma. This observation aligns with findings from Lu et al. [21].

Multivariate analysis identified several risk factors for postoperative CNS infection in patients with hypertensive intracerebral hemorrhage: elevated CSF HBP and CD64 levels, larger hematoma volume, increased peripheral blood PCT and CRP levels, and lower ALB levels. ROC curves were used to assess the predictive value of CSF HBP and CD64 for these infections. The AUC for CSF HBP was 0.745, for CD64 was 0.709, and for their combination was 0.846. This demonstrates that combining both biomarkers offered better predictive value than either alone. While HBP or CD64 individually had limited predictive value for postoperative CNS infections, their combined use enhanced diagnostic capability.

Our study explored the use of CSF HBP and CD64 as novel biomarkers for the early detection of CNS infection following hypertensive intracerebral hemorrhage surgery. Traditional markers, such as CRP and PCT, often lack sufficient sensitivity and specificity in the early stages of infection. Investigating HBP and CD64 provides a promising approach to enhance diagnostic accuracy and facilitate earlier treatment. Moreover, our results underscore the value of combining multiple biomarkers to improve predictive power, offering clinicians a more comprehensive diagnostic tool.

This study has several limitations. The sample size was relatively small, and patients were recruited solely from the Department of Neurosurgery, Shangyu People's Hospital of Shaoxing, during a specific time frame. These factors may have limited the generalizability of our findings. Future research should involve larger, multicenter studies with diverse patient populations from different regions and ethnic backgrounds, to enhance the representativeness and clinical relevance of the results.

In summary, CSF HBP and CD64 levels are associated with CNS infections following surgery for hypertensive intracerebral hemorrhage. Although each marker alone offered limited predictive value, their combined use enhanced diagnostic efficacy.

Disclosure of conflict of interest

None.

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