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A study on the relationship between neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) in neurosurgery and the occurrence and prognosis of progressive hemorrhagic brain injury (PHI) in patients with traumatic brain injury

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Abstract

Objective To investigate the correlation between neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) in neurosurgery and their impact on the occurrence and prognosis of acute traumatic progressive hemorrhagic brain injury (PHI) among traumatic brain injury patients.

Method A retrospective analysis encompassed 220 traumatic brain injury patients treated between 2019 and 2022. Patients were categorized into two groups: those experiencing progressive hemorrhagic brain injury (PHI) and those without PHI. The levels of neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) were examined within each group. Within the PHI cohort, patients were further stratified based on their Glasgow Outcome Scale (GOS) scores into good and poor prognosis groups, with corresponding observations of NLR and PLR levels. Logistic regression was used to identify factors influencing both the occurrence and poor prognosis of PHI. Additionally, Pearson's linear analysis was utilized to investigate the correlation between serum NLR and PLR levels among PHI patients and the occurrence and prognosis of the disease.

Result We found no statistically significant differences were observed between the PHI group and the non-PHI group in terms of gender, age, history of hypertension, smoking history, types of intracranial lesions, heart rate (HR), Injury Severity Score (ISS), Abbreviated Injury Scale (AIS), pupillary reflex status, mean arterial pressure (MAP), intracranial pressure (ICP), and cerebral perfusion pressure (CPP) ($P > 0.05$). However, there were significant differences in GCS scores, PaO2, and Hb levels ($P < 0.05$). Furthermore, the non-PHI group had higher NLR and PLR than the PHI group

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($P < 0.05$). Multiple Logistic regression analysis showed that neutrophil to lymphocyte ratio (NLR) and platelet to lymphocyte ratio (PLR) were independent risk factors for progressive hemorrhagic brain injury (PHI) in TBI patients ($P < 0.05$). Kendall analysis showed that there was a significant negative correlation between GOS score PHI (r=-0.458, $P = 0.000$). Additionally, Pearson linear correlation analysis showed a notable positive correlation between serum NLR and PLR levels in PHI patients and the occurrence of the disease ($r = 0.377$, $P = 0.000$). Evaluation based on the Glasgow Outcome Scale (GOS) score demonstrated no significant differences in gender, age, history of hypertension, smoking, types of intracranial lesions, heart rate (HR), Injury Severity Score (ISS), Abbreviated Injury Scale (AIS), pupillary reflex status, mean arterial pressure (MAP), intracranial pressure (ICP), and cerebral perfusion pressure (CPP) between the good and poor prognosis groups but significant differences in GCS score, PaO2, and Hb levels ($P < 0.05$). In addition, the NLR and PLR of the poor prognosis group were higher than those of the good prognosis group ($P < 0.05$). Multiple Logistic regression analysis showed that NLR and PLR were independent risk factors for poor prognosis in PHI patients ($P < 0.05$). Pearson linear correlation analysis showed a statistically significant positive correlation between serum NLR and PLR levels in PHI patients and the likelihood of poor prognosis ($r = 0.307$, $P = 0.000$).

Conclusion Elevated NLR to PLR ratios in TBI patients significantly elevate the risk of PHI occurrence. Moreover, higher NLR to PLR ratios correlate with poorer prognostic outcomes among PHI patients.

Keywords Neutrophil-to-lymphocyte ratio (NLR), Platelet-to-lymphocyte ratio (PLR), Traumatic brain injury, Acute traumatic progressive hemorrhagic brain injury

Introduction

Traumatic brain injury (TBI) refers to the injury caused directly or indirectly by external violence on the head which is the main cause of death and disability in trauma patients. It is divided into primary brain injury and secondary brain injury, and primary brain injury is often irreversible. Therefore, management strategies for TBI mainly focus on preventing and treating secondary brain injury [1, 2]. Acute traumatic progressive hemorrhagic injury (PHI) is a type of secondary brain injury that is defined as the expansion or emergence of new hemorrhagic lesions, such as hematoma or brain contusion, as shown on the patient's first head computed tomography (CT) scan after injury, confirmed by another head CT scan or surgery. It is an extension of the concept of delayed hematoma in the past [3]. Post-traumatic cerebral ischemia, cerebral hemorrhage, and cerebral edema are important pathological and physiological foundations leading to progressive hemorrhagic injury [4]. Meanwhile, progressive hemorrhagic injury can increase the risk of death in patients with traumatic brain injury, leading to poor prognosis. With the rapid development of modern transportation technology, the incidence of traumatic brain injury has also increased, posing a great threat to the health of the general public [5]. Studies have shown that 35–65% of patients with traumatic brain injury suffer from secondary cerebral hemorrhage, ischemia, and edema due to progressive hemorrhagic injury, which worsens the condition and increases the mortality rate [6]. Therefore, early detection and prevention of PHI have become the key to reducing the mortality rate of traumatic brain injury. The platelet-to-lymphocyte Ratio (PLR), as a simple and easily obtainable inflammatory indicator in clinical practice, has been proven to have advantages in evaluating and predicting the occurrence, development, and prognosis of many diseases [7, 8]. In recent years, numerous studies both domestically and internationally have revealed that the neutrophil-to-lymphocyte ratio (NLR) has predictive value for the progression and prognosis of patients [9, 10]. However, upon reviewing relevant literature, it has been found that there is currently limited research on the correlation between NLR and PLR with the occurrence of progressive hemorrhagic injury and the prognosis of the disease after traumatic brain injury. Consequently, this study is based on the association between the platelet-to-lymphocyte ratio and neutrophil-to-lymphocyte ratio in neurosurgery practice and the implication for the occurrence and prognostication of progressive hemorrhagic injury in patients with traumatic brain injury. The primary aim is to promptly identify and manage high-risk patients with progressive hemorrhagic injury as early as possible.

Materials and methods

General information

Retrospective analysis was performed on 220 patients with craniocerebral injury who met the inclusion and exclusion criteria from 2019 to 2022, divide them into PHI group and non-PHI group based on whether PHI has occurred, Subsequently, based on the Glasgow Outcome Scale (GOS) score [11], the PHI group was divided into a good prognosis group and a poor prognosis group, the study has been approved by the hospital ethics committee.

Inclusion criteria: ① Confirmed by CT scan that there is a traumatic brain injury without any other serious injuries; ② Recently, no oral anticoagulant or other related drugs have been taken; ③ No cardiopulmonary

resuscitation and shock; ④ No coagulation dysfunction; ⑤ All underwent intracranial pressure (ICP) monitoring surgery.

Exclusion criteria: ① Incomplete clinical data loss; ② The first cranial CT scan indicated that the hematoma volume reached the indication for craniotomy surgery; ③ Individuals with unstable and life-threatening conditions; ④ Previous history of brain disease; ⑤ Tumor or other organ dysfunction; ⑥ Other infectious diseases; ⑦ The patient was transferred midway.

Method

Data collection

Record all patient general information including gender, age, history of hypertension, smoking history, heart rate (HR), injury severity score (ISS), injury score (AIS), pupillary reflex status, mean arterial pressure (MAP), intracranial pressure (ICP), cerebral perfusion pressure (CPP), Glasgow Coma Scale (GCS), partial pressure of carbon dioxide (PaO2), hemoglobin (Hb), NLR, and PLR levels.

Imaging examination

Evaluate the patient's intracranial condition through electronic computed tomography (CT) examination. The first CT scan was performed as soon as possible after admission. Patients with new neurological symptoms such as hemiplegia, aphasia, and dysplasia of the pupil, or coma or worsening of consciousness, need to undergo a second brain CT examination immediately. Compare the two scans. If a new bleeding lesion appears in the patient's skull, or if the original bleeding volume increases by more than 1/4, then there is PHI. On the contrary, it is non-PHI. Bleeding volume=A (longest diameter of the bleeding layer) x B (longest diameter perpendicular to the rider) x C (number of layers of hematoma)/2.

Laboratory inspection

NLR and PLR values were collected at the emergency room. By conducting blood routine tests, the levels of Hb, NLR, and PLR in the peripheral blood of patients within 24 h after admission were statistically analyzed.

Prognostic criteria

Evaluate the patient's traumatic brain injury status through GOS scoring. If the patient's GOS score reaches or exceeds 4 points, it indicates that the patient's neurological recovery is good, and their functional status has at least reached the standard of moderate disability and may even recover better. On the contrary, if the GOS score is below 4 points, it indicates that the patient's neurological prognosis is not optimistic and may face severe disability, vegetative survival status, and even a risk of death.

Statistical methods

SPSS 26.0 was used for data analysis and processing, Normally distributed econometric data are expressed as mean ± standard deviation ($\bar{x}\pm$ s), and t-tests are used for comparison between two groups. Count data is expressed as examples (n) or rates (%), and X2 test is used for data comparison. Logistic multivariate analysis was used to investigate the factors influencing the occurrence and poor prognosis of PHI. Pearson's linear analysis was used to examine the correlation between serum NLR and PLR in patients with PHI and the occurrence and prognosis of the disease, with $P<0.05$ as the test criterion.

Results

Univariate analysis of PHI occurrence in TBI patients

Through univariate analysis, it was found that there was no significant difference in general information such as gender, age, history of hypertension, smoking history, types of intracranial lesions, HR, ISS, AIS, pupil reflex status, MAP, ICP, and CPP between the two groups of patients ($P>0.05$). There were significant differences in GCS scores, PaO2, and Hb levels ($P<0.05$), as shown in Table 1.

Comparison of clinical indicators between non-PHI group and PHI group patients

After being admitted, the levels of NLR and PLR in non-PHI patients were significantly higher than those in the PHI group, and the differences were statistically significant ($P<0.05$). As shown in Fig. 1. There was no significant difference in NLR and PLR data between emergency and hospital admission ($P>0.05$). See Fig. 2.

Analysis of logistic multifactor analysis: factors influencing Phi in Tbi patients

Using the occurrence of PHI as the dependent variable Y (no occurrence of PHI=0, PHI=1), logistic multiple regression analysis showed that NLR and PLR are independent risk factors for PHI in TBI patients (both $P<0.05$), as shown in Table 2.

Correlation analysis between clinical indicators and disease occurrence in PHI patients

Kendall was used to analyze the correlation between GOS and PHI, and the results showed that there was a significant negative correlation between the two, as shown in Table 3. Pearson linear correlation analysis showed that the serum NLR and PLR of PHI patients were significantly positively correlated with disease occurrence ($r=0.377$, $P=0.000$), as shown in Fig. 3.

Univariate analysis of poor prognosis in PHI patients

Through univariate analysis, it was found that there was no significant difference in the prognosis of the two

Table 1 Univariate analysis of PHI occurrence in TBI patients

Clinical data		PHI group($n=100$)	Non PHI group($n=120$)	X^2/t	*P*
Gender (Example,%)	male	54(54.00)	66(55.00)	0.022	0.882
	female	46(46.00)	54(45.00)		
Age ($\bar{x}\pm$ s, years)		45.32 ± 3.54	45.14 ± 3.51	0.377	0.706
History of hypertension (cases,%)	yes	61(61.00)	76(63.33)	0.126	0.722
	no	39(39.00)	44(36.67)		
Smoking history (examples,%)	yes	58(58.00)	71(59.17)	0.031	0.861
	no	42(42.00)	49(40.83)		
types of intracranial lesions(examples,%)	epidural hematoma	37(37.00)	42(35.00)		
	subdural hematoma	33(33.00)	37(30.83)	0.435	0.805
	Subarachnoid hemorrhage	30(30.00)	41(34.17)		
HR($\bar{x}\pm$s, times/min)		87.65 ± 6.32	87.58 ± 6.17	0.083	0.934
ISS score($\bar{x}\pm$s, points)		32.32 ± 1.27	32.34 ± 1.21	0.119	0.905
AIS score($\bar{x}\pm$s, points)		3.14 ± 1.14	3.09 ± 1.12	0.327	0.744
Disappearance of pupil reflex (case,%)	yes	45(45.00)	58(48.33)	0.899	0.343
	no	55(55.00)	62(51.67)		
MAP($\bar{x}\pm$s)		92.21 ± 1.32	92.22 ± 1.30	0.056	0.955
ICP($\bar{x}\pm$s)		14.68 ± 4.21	14.59 ± 4.16	0.159	0.874
CPP($\bar{x}\pm$s)		82.35 ± 1.65	82.17 ± 1.62	0.814	0.417
GCS score ($\bar{x}\pm$s, points)		7.21 ± 1.78	9.64 ± 1.89	9.749	0.000
PaO_2($\bar{x}\pm$s, mmHg)		94.27 ± 2.04	82.07 ± 1.78	47.361	0.000
Hb($\bar{x}\pm$s, ×10 g/L)		8.32 ± 1.21	12.37 ± 1.32	23.529	0.000

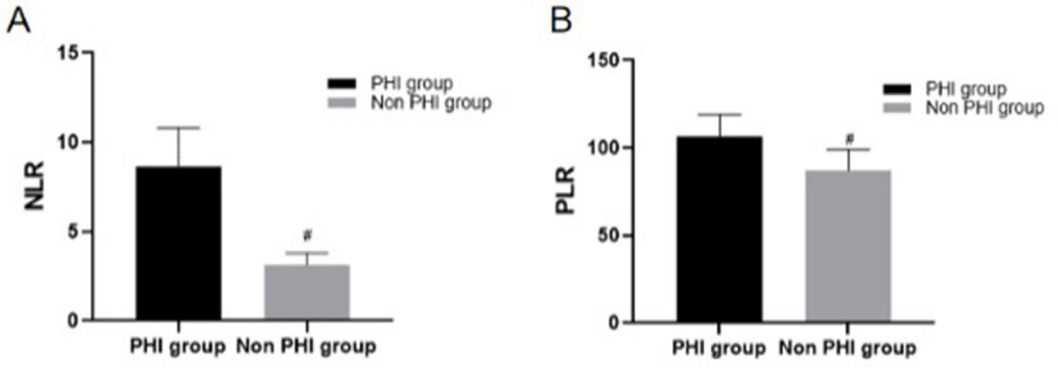

Fig. 1 Comparison of NLR and PLR levels after hospitalization between the two *groups (Note*: **A**: Comparison of NLR levels between two groups of subjects; **B**: Comparison of PLR levels between two groups of subjects. $^{\#}P<0.05$)

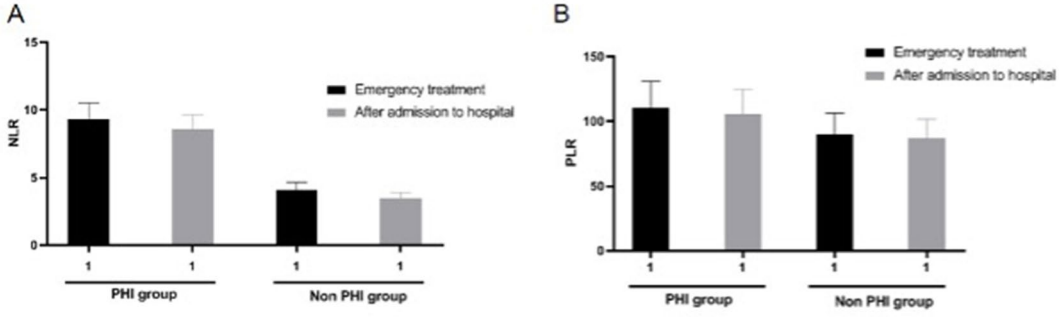

Fig. 2 Comparison of NLR and PLR levels in the emergency department and after admission (Note: **A**: Comparison of NLR in the emergency department and after admission between the two groups; **B**: Comparison of PLR in the emergency department and after admission between the two groups)

Table 2 Analysis of logistic multivariate analysis: factors influencing Phi in Tbi patients

argument	B	S.E	Wals	*P*	OR	OR95%CI
NLR	0.233	0.033	50.183	0.000	1.262	1.184 ~ 1.346
PLR	0.611	0.107	32.575	0.000	1.842	1.494 ~ 2.272
constant	-28.337	3.824	54.904	0.000		

Table 3 Correlation analysis between GOS and PHI

Index	Kendall correlation	*P*	*N*	Standard error	OR95%CI	
					floor	Upper limit
GOS	-0.458**	0.000	220	0.040	-0.529	-0.377

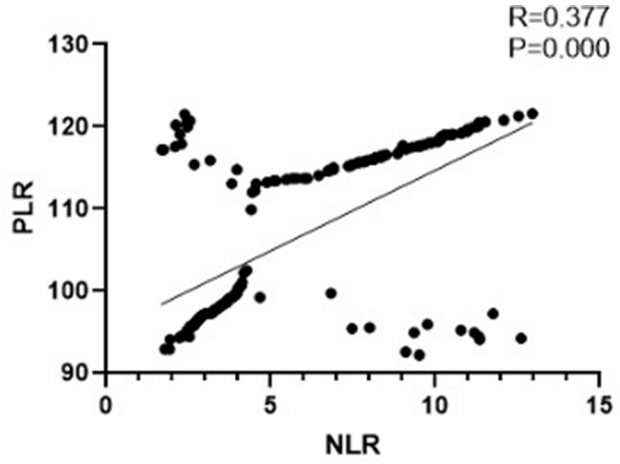

Fig. 3 Correlation analysis of serum NLR and PLR with disease occurrence in PHI patients

groups of patients compared to general data such as gender, age, history of hypertension, smoking history, types of intracranial lesions, HR, ISS, AIS, pupil reflex status, MAP, ICP, and CPP ($P>0.05$). There were significant differences in GCS scores, PaO2, and Hb levels ($P<0.05$), as shown in Table 4.

Comparison of clinical indicators between patients with good prognosis and those with poor prognosis

The NLR and PLR levels in patients with poor prognosis were significantly higher than those in those with good prognosis, and the difference was statistically significant ($P<0.05$). As shown in Fig. 4.

Multivariate analysis of factors influencing poor prognosis in PHI patients

Using the prognostic effect of PHI patients as the dependent variable Y (good prognosis=0, poor prognosis=1),

Table 4 Univariate analysis of poor prognosis in PHI patients

Clinical data		Good prognosis group($n=70$)	Poor prognosis group($n=30$)	X^2/t	*P*
Gender (Example,%)	male	37(52.86)	17(56.67)	0.123	0.726
	female	33(47.14)	13(43.33)		
Age ($\bar{x}\pm$ s, years)		45.32 ± 3.54	45.28 ± 3.57	0.052	0.959
History of hypertension (cases,%)	yes	40(57.14)	21(70.00)	1.459	0.227
	no	30(42.86)	9(30.00)		
Smoking history (examples,%)	yes	39(55.71)	19(63.33)	0.500	0.479
	no	31(44.29)	11(36.67)		
types of intracranial lesions(examples,%)	epidural hematoma	26(37.14)	14(46.63)		
	subdural hematoma	30(42.86)	8(26.67)	2.349	0.309
	Subarachnoid hemorrhage	14(20.00)	8(26.67)		
HR($\bar{x}\pm$s, times/min)		87.65 ± 6.32	87.45 ± 6.18	0.146	0.884
ISS score($\bar{x}\pm$s, points)		32.32 ± 1.27	32.17 ± 1.23	0.546	0.586
AIS score($\bar{x}\pm$s, points)		3.14 ± 1.14	3.13 ± 1.12	0.040	0.968
Disappearance of pupil reflex (case,%)	yes	33(47.14)	12(40.00)	0.433	0.511
	no	37(52.86)	18(60.00)		
MAP($\bar{x}\pm$s)		92.21 ± 1.32	92.16 ± 1.30	0.174	0.862
ICP($\bar{x}\pm$s)		14.68 ± 4.21	14.59 ± 4.14	0.098	0.922
CPP($\bar{x}\pm$s)		82.35 ± 1.65	82.31 ± 1.58	0.113	0.911
GCS score ($\bar{x}\pm$s, points)		7.24 ± 1.65	7.07 ± 1.21	0.508	0.613
PaO_2($\bar{x}\pm$s, mmHg)		95.24 ± 1.98	90.35 ± 1.65	11.867	0.000
Hb($\bar{x}\pm$s, ×10 g/L)		8.33 ± 1.27	7.65 ± 1.26	2.459	0.016

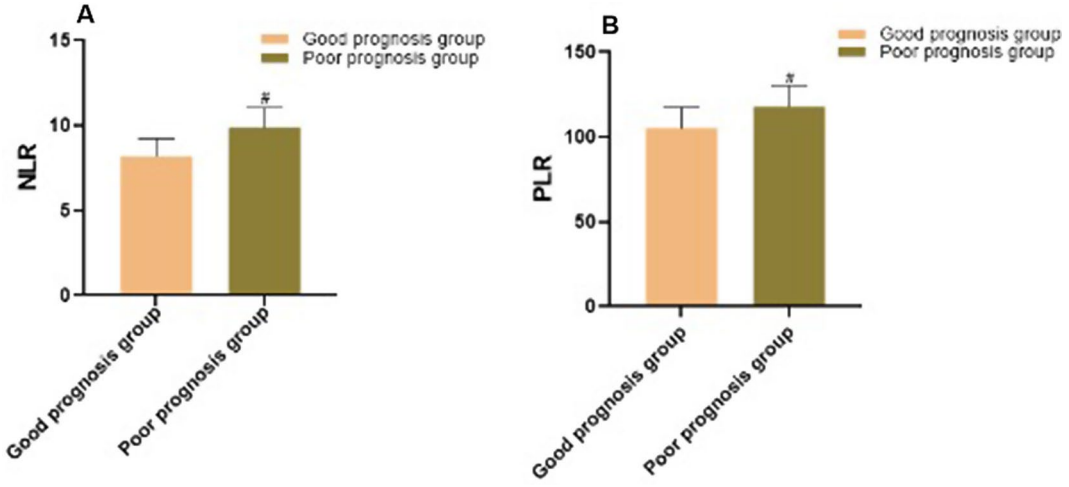

Fig. 4 Comparison of clinical indicators between patients with good prognosis and those with poor prognosis. (Note: **A**: Comparison of NLR levels between two groups of subjects; **B**: Comparison of PLR levels between two groups of subjects. $^{\#}P<0.05$)

Table 5 Multivariate analysis of factors influencing poor prognosis in PHI patients

argument	B	S.E	Wals	*P*	OR	OR95%CI
NLR	2.185	0.564	15.022	0.000	8.894	2.945 ~ 26.855
PLR	0.182	0.045	16.504	0.000	1.200	1.099 ~ 1.310
constant	-40.933	9.355	19.203	0.000	0.000	

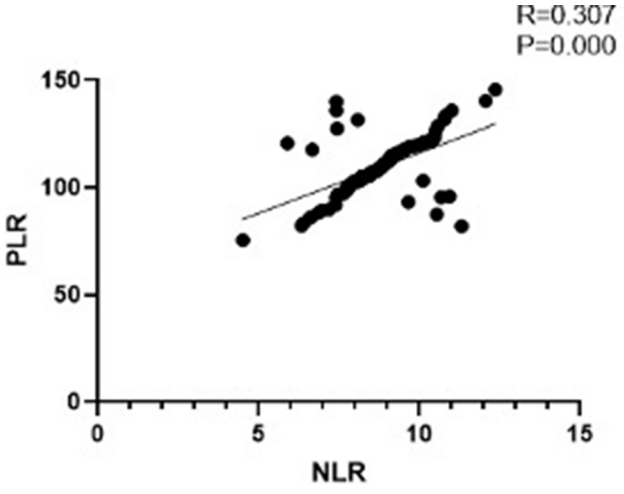

Fig. 5 Correlation analysis between serum NLR and PLR and poor prognosis in PHI patients

logistic multiple regression analysis showed that NLR and PLR are independent risk factors for poor prognosis in PHI patients (both $P<0.05$), as shown in Table 5.

Correlation analysis of serum NLR and PLR with poor prognosis in PHI patients

Pearson linear correlation analysis showed that the serum NLR and PLR of PHI patients were significantly positively correlated with poor prognosis ($r=0.307$, $P=0.000$), as shown in Fig. 5.

Discussion

Traumatic brain injury is a brain injury caused by external forces and is the disease with the highest mortality and disability rates among all systemic injuries [12, 13]. Acute traumatic progressive hemorrhagic brain injury is one of its serious complications, usually caused by severe trauma to the head, the characteristic of this disease is the continuous increase of intracerebral hemorrhage, which rapidly worsens the condition and can to some extent lead to severe neurological damage, even endangering life. It is one of the main causes of death in patients with traumatic brain injury [14, 15]. When a patient's brain is traumatized and shows obvious cerebral hemorrhage, a large amount of blood accumulates in the blood vessels, leading to impaired cerebral vascular circulation and an increase in intracranial pressure, which can compress the patient's brain tissue and further exacerbate brain damage [16]. At the same time, in patients with traumatic brain injury, extensive trauma can facilitate the ingress of airborne pathogenic bacteria into the cranial cavity through wounds, potentially resulting in intracranial infections [17]. These infections can easily lead to complications such as meningitis and encephalitis, which can pose significant threats to patient health, impede disease progression, and may even jeopardize patient survival [17].

Therefore, observation of traumatic brain injury is essential. Analysis to determine whether a patient is at high risk for acute traumatic progressive hemorrhagic

brain injury and take active and effective treatment can reduce the harm caused by complications. Clinical findings have shown that the neutrophil-to-lymphocyte ratio is a low-cost and easily obtainable novel inflammatory marker for evaluating disease activity and efficacy monitoring [18]. Some researchers have pointed out that the NLR is closely related to poor prognosis in cancer patients [19]. However, in recent years, domestic and foreign studies have found that platelet-lymphocyte-ratio has predictive value for the progression and prognosis of patients [20]. Abdelwahab HM et al. [21] pointed out in their study that the ratio of NLR to PLR can be used for risk stratification management in patients with acute methanol poisoning, meanwhile, he predicted results have high predictive value. Therefore, this study is based on the association between the NLR and PLR in neurosurgery practice and the implication occurrence and prognostication of acute traumatic progressive hemorrhagic brain injury in patients with traumatic brain injury and has also received good feedback.

This study implies that using univariate analysis, significant differences were found in GCS scores, PaO_2, and Hb levels between the non-PHI group and the PHI group. Additionally, the NLR and PLR levels in the non-PHI group were significantly higher than those in the PHI group, indicating that acute traumatic progressive hemorrhagic brain injury in patients with traumatic brain injury can be caused by many factors. The rationale behind its analysis lies in the widespread utilization of the Glasgow Coma Scale (GCS) as an assessment tool to evaluate the level of consciousness in patients, judging their level of coma by evaluating their eye-opening response, language response, and motor response. Low scoring individuals often indicate a more severe condition, indicating a higher risk of acute traumatic progressive hemorrhagic brain injury. If the patient's GCS score continues to decrease during the treatment process, it may indicate that the patient has developed acute traumatic progressive hemorrhagic brain injury. PaO_2 refers to the pressure generated by physically dissolved oxygen molecules in the blood, which is an important indicator for determining whether the body is experiencing hypoxia and the degree of hypoxia. A decrease in this level can exacerbate the hypoxic state of brain tissue, leading to impaired automatic regulation of cerebral blood vessels, thereby increasing the risk of cerebral hemorrhage. This study showed that PaO2 levels were lower in the non-PHI group, which may be related to the oxygen therapy used by the patients. The oxygen flow of nasal catheter and mask oxygen is limited, which can maintain the PaO2 level in the normal state. However, high-flow nasal catheter oxygen inhalation, non-invasive positive pressure ventilation and mechanical ventilation can effectively improve the FiO2 of patients, effectively control the ventilation and oxygenation of patients, and thus significantly increase the level of PaO2. Moreover, if a patient experiences hypoxemia due to a decrease in PaO_2, it can further exacerbate brain injury, leading to the occurrence of acute traumatic progressive hemorrhagic brain injury. The core feature of acute traumatic progressive hemorrhagic brain injury is intracerebral hemorrhage. When intracerebral hemorrhage occurs, red blood cells rupture and release hemoglobin, leading to a decrease in hemoglobin concentration in the blood and the formation of anemia. Therefore, a significant decline in hemoglobin not only indicates the severity of bleeding but may also have an impact on tissue oxygen supply and oxygen transport, aggravating brain injuries and resulting in acute traumatic progressive hemorrhagic brain injury. The NLR and PLR are both inflammatory markers. The NLR can reflect the state of inflammatory response in the body, an increase in this ratio indicates excessive inflammatory response in the patient's body. The PLR can reflect the activation of coagulation mechanisms in the body, an increase in this ratio further exacerbates brain tissue damage and bleeding, thereby affecting disease progression [22, 23].

This study used logistic multivariate analysis and found that both NLR and PLR are independent risk factors for developing PHI in TBI patients. Subsequently, using Pearson's linear correlation analysis, it was further found that the serum NLR and PLR of PHI patients were significantly positively correlated with disease occurrence. This indicates a significant association between the occurrence of PHI and the ratio of NLR to PLR. The rationale behind its analysis lies in both NLR and PLR are biomarkers that can reflect the inflammatory status in the body. However, relevant studies have found that the inflammatory response and hemostatic mechanism are interrelated. Platelets, as a key component of hemostasis and thrombosis, also play an essential role in the inflammatory response. At the same time, lymphocytes, an important component of the immune system, also participate in regulating the inflammatory response [24]. In acute traumatic progressive hemorrhagic brain injury, due to brain tissue damage and bleeding, a large number of neutrophils are activated and recruited to the site of injury. Neutrophils enhance oxidative capacity by releasing a large amount of ROS, further damaging cell membranes and proteins. Additionally, neutrophils participate in the amplification and maintenance of inflammatory responses. When the NLR increases, it can lead to TNF in the body- α. The increase in protein levels triggers an acute phase of the inflammatory response, which in turn increases IL-6 protein levels. This affects neuronal survival and function, further damages brain tissue, and causes massive bleeding, which results in patients with acute traumatic progressive hemorrhagic

brain injury. In acute traumatic progressive hemorrhagic brain injury, due to damage and bleeding of brain tissue, platelets are activated and aggregate at the site of injury, forming thrombi to stop bleeding. However, excessive platelet activation and thrombus formation may exacerbate ischemia and damage of brain tissue. Related studies have found that platelets, upon activation, release a large number of PDGF genes, promoting cell proliferation and differentiation, and aiding in wound healing and angiogenesis. However, after platelet activation, the expression level of TXA2 gene will also increase, promoting thrombosis, further exacerbating brain tissue damage and inflammatory response, leading to the occurrence of acute traumatic progressive hemorrhagic brain injury [25].

This study also uncovered through logistic multivariate analysis that the NLR and PLR are also factors affecting the poor prognosis of patients with acute traumatic progressive hemorrhagic brain injury. Simultaneous Pearson linear correlation analysis revealed a significant positive correlation between serum NLR and PLR ratios and poor prognosis in PHI patients. This indicates a high correlation between serum NLR and PLR and poor prognosis in patients with acute traumatic progressive hemorrhagic brain injury. The rationale behind its analysis lies in inflammatory response is the main cause of acute traumatic progressive hemorrhagic brain injury. After acute traumatic progressive hemorrhagic brain injury, damage to the blood-brain barrier results in prostaglandins, NO, and IL-1 levels β Inflammatory factors such as IL-6 aggregate and activate surrounding astrocytes and microglia in local tissues. IL-1 β Activating microglia and astrocytes through the PI3K/Akt and ERK pathways respectively, and promoting their release of inflammatory cytokines and matrix metalloproteinase-9, which exacerbates the inflammatory response by eroding the extracellular matrix [26]. s. Furthermore, TNF-α released by locally damaged microglia and astrocytes can affect the brain's adhesion granule production, enhance neutrophil extravasation into the brain parenchyma, and release reactive oxygen species, aggravating damage to the blood-brain barrier, encouraging neuronal cell death, and consequently aggravating brain tissue damage, all of which have a grave negative impact on the prognosis of patients. Lymphocytes are important regulatory factors in the immune system. Among them, T lymphocytes can repair damaged brain tissue by releasing growth factors and regulating the proliferation of microglia, enabling peripheral macrophages to transform into MI type macrophages and migrate to the central nervous system, inducing continuous proliferation of T lymphocytes, and gradually differentiating into Th1 and Th17 types. However, the NLR reflects the balance between neutrophils and lymphocytes in the body. Due to the imbalance between neutrophil activation and lymphocyte immune regulation, the NLR may change. Meanwhile, platelets activate and aggregate around endothelial cells, promoting fibrinogen precipitation and more platelet aggregation around damaged brain tissue, resulting in blood hypercoagulability. A large amount of microthrombus forms and further consumes platelets, causing the aggregated platelets to release a large number of inflammatory factors, further exacerbating the inflammatory response, which is not conducive to the prognosis of patients. Some researchers have pointed out that both NLR and PLR are important indicators reflecting the inflammatory status of the body, and they are related to the prognosis of various diseases [27]. In the study by Jia W et al. [28], it was found that both NLR and PLR were elevated in lung cancer patients, and there was a positive correlation between the two, indicating that changes in the number of neutrophils, lymphocytes, and platelets may be interrelated to some extent. Additionally, it has been confirmed in the study by Noor A et al. [29]. In the study by Kumarasamy et al. [30], it was also found that the PLR, NLR, and MLR can become strong prognostic markers for head and neck cancer and can also guide treatment. Therefore, the NLR and PLR are significantly associated with the prognosis of acute traumatic progressive hemorrhagic brain injury. However, it is important to note that the date of sample collection and the original trauma intensity can affect the NLR and PLR values in the patient. In the emergency department, the number of neutrophils may increase rapidly due to acute inflammation, while the number of lymphocytes may decrease or remain unchanged, which may lead to the rapid increase of NLR and PLR in patients. After admission, the inflammatory response may be relieved to a certain extent, and the levels of NLR and PLR can be reduced. At the same time, the department of moderate and severe trauma causes acute inflammatory response in patients, which significantly increases the level of NLR and PLR in the body, while the NLR in mild trauma patients is usually not significantly increased, or the increase is small.

In summary, based on the relationship between the NLR and PLR in neurosurgery and the occurrence and prognosis of PHI in patients with traumatic brain injury, it was found that the NLR and PLR are independent risk factors for the occurrence of PHI in TBI patients. Moreover, the serum NLR and PLR of PHI patients are significantly positively correlated with the occurrence of the disease. It was also found that the ratio of NLR to PLR is a factor affecting the poor prognosis of PHI patients. The serum NLR and PLR of PHI patients are significantly positively correlated with the poor prognosis of the disease. However, this study also has certain limitations, as it did not conduct multiple factor analysis on single factor indicators of patients, and whether other indicators such

as hemoglobin are also influencing factors for the occurrence and poor prognosis of PHI. Although the sample size of this study is large, increasing the sample size can improve the applicability of the results. At the same time, as a retrospective trial, the selection of clinical indicator data is relatively limited, and prospective studies can be used for subsequent analysis to verify the scientific nature of this conclusion. Secondly, factors such as blood collection time, initial trauma severity and comorbidities were not analyzed in the study, which may lead to bias in the conclusion data. Therefore, the above limitations can be further studied in order to improve the applicability of the conclusions of this study.

Author contributions

Yanbin Ke (Corresponding Author) was responsible for conceptualization, methodology, investigation, project administration, formal analysis, and writing the review. Wei Li (First Author) contributed resources, conducted investigation, and wrote the original draft. Zhaotao Wang (Second Author) provided resources, conducted investigation, and handled data curation. Mengqi Gao (Third Author) participated in writing the review and editing, and data curation. Yezhong Wang (Fourth Author, Co-Corresponding) was involved in conceptualization, methodology, and supervision. All authors have read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

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