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INTEGRATED PROGNOSTIC SIGNIFICANCE OF SERUM S100B, PROCALCITONIN, AND NEURON-SPECIFIC ENOLASE IN SEVERE TRAUMATIC BRAIN INJURY: A CLINICAL BIOCHEMISTRY STUDY

INTEGRISANI PROGNOSTIČKI ZNAČAJ SERUMSKOG S100B, PROKALCITONINA I NEURON-SPECIFIČNE ENOLAZE KOD TEŠKE TRAUMATSKE POVREDE MOZGA: STUDIJA KLINIČKE BIOHEMIJE

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Summary

Background: Severe traumatic brain injury (STBI) is associated with high mortality and long-term neurological disability. Reliable circulating biomarkers reflecting glial injury, neuronal damage, and systemic inflammatory activation may improve early prognostic stratification. This study evaluated the prognostic value of serum S100B protein, procalcitonin (PCT), and neuron-specific enolase (NSE) in patients with STBI.
Methods: A total of 103 patients with STBI admitted between June 2021 and April 2025 were enrolled, together with 100 age-matched healthy controls. Peripheral venous blood was collected within 24 h after injury. Serum S100B was determined by enzyme-linked immunosorbent assay, PCT by chemiluminescent immunoassay, and NSE by electrochemiluminescence immunoassay. Functional outcome at 6 months was assessed using the Glasgow Outcome Scale (GOS). Patients were categorized into favorable prognosis (GOS 4–5) and poor prognosis (GOS 1–3) groups. Receiver operating characteristic (ROC) analysis was used to determine predictive performance.
Results: Serum concentrations of S100B, PCT, and NSE were significantly elevated in patients with STBI compared with healthy controls ($P<0.001$). Patients with poor prognosis showed significantly higher levels of all three biomarkers than those with favorable prognosis ($P<0.001$). ROC analysis demonstrated good prognostic discrimination

Kratak sadržaj

Uvod: Teška traumatska povreda mozga (TPMM) povezana je sa visokom smrtnošću i dugoročnim neurološkim invaliditetom. Pouzdani cirkulišući biomarkeri koji odražavaju glijalno oštećenje, oštećenje neurona i sistemsku inflamatornu aktivaciju mogu poboljšati ranu prognostičku stratifikaciju. Ova studija je procenila prognostičku vrednost serumskog S100B proteina, prokalcitonina (PCT) i neuronski specifične enolaze (NSE) kod pacijenata sa TPMM.
Metode: Ukupno je uključeno 103 pacijenta sa STBI primljenih između juna 2021. i aprila 2025. godine, zajedno sa 100 zdravih kontrola usklađenih po starosti. Periferna venska krv je prikupljena u roku od 24 sata nakon povrede. Serum S100B je određen enzimski povezanim imunosorbentnim testom, PCT hemiluminescentnim imunotestom i NSE elektrohemiluminescentnim imunotestom. Funkcionalni ishod nakon 6 meseci procenjen je korišćenjem Glazgove skale ishoda (GOS). Pacijenti su kategorisani u grupe sa povoljnom prognozom (GOS 4–5) i lošom prognozom (GOS 1–3). Analiza ROC (Receiver Operating Characteristic) je korišćena za određivanje prediktivnih performansi.
Rezultati: Serumske koncentracije S100B, PCT i NSE bile su značajno povišene kod pacijenata sa STBI u poređenju sa zdravim kontrolama ($P<0,001$). Pacijenti sa lošom prognozom pokazali su značajno više nivoe sva tri biomarkera nego oni sa povoljnom prognozom

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for S100B (AUC=0.876), PCT (AUC=0.931), and NSE (AUC=0.981), while combined biomarker analysis yielded the highest predictive accuracy (AUC=0.996).
Conclusion: Serum S100B, PCT, and NSE represent complementary biomarkers reflecting blood-brain barrier disruption, systemic inflammatory burden, and neuronal injury in STBI. Their combined assessment provides excellent prognostic performance and may serve as a practical laboratory tool for early risk stratification and individualized clinical management.

Keywords: severe traumatic brain injury, S100B protein, procalcitonin, neuron-specific enolase, biomarkers, prognosis, clinical biochemistry, ROC analysis

(P<0,001). ROC analiza je pokazala dobru prognostičku diskriminaciju za S100B (AUC=0,876), PCT (AUC=0,931) i NSE (AUC=0,981), dok je kombinovana analiza biomarkera dala najveću prediktivnu tačnost (AUC=0,996).
Zaključak: Serumski S100B, PCT i NSE predstavljaju komplementarne biomarkere koji odražavaju poremećaj krvno-moždane barijere, sistemsko inflamatorno opterećenje i neuronske povrede kod STBI. Njihova kombinovana procena pruža odlične prognostičke performanse i može poslužiti kao praktičan laboratorijski alat za ranu stratifikaciju rizika i individualizovano kliničko lečenje.

Ključne reči: teška traumatska povreda mozga, S100B protein, prokalcitonin, neuronski specifična enolaza, biomarkeri, prognoza, klinička biohemija, ROC analiza

Introduction

Severe Traumatic Brain Injury (STBI) is a common and critical condition in neurosurgery, characterized by high incidence, high disability, and high mortality rates. The condition is often complex with rapid progression, leading to significant variability in patient outcomes. Timely and accurate assessment of patient prognosis is crucial for formulating personalized treatment plans and improving patient survival rates and quality of life (1, 2). Currently, numerous clinical methods are used to evaluate the prognosis of patients with severe traumatic brain injury, including imaging examinations such as computed tomography (CT) and magnetic resonance imaging (MRI), as well as neurological function scores like the Glasgow Coma Scale (GCS). However, these methods have certain limitations. Imaging examinations primarily focus on observing morphological and structural changes in the brain, making it difficult to reflect the functional status of brain tissue and the dynamic evolution of injury severity in real-time. Neurological function scores are subject to significant subjective influence and may exhibit a certain lag during disease progression (3). As objective and quantitative indicators, serum biomarkers have garnered widespread attention in recent research on severe traumatic brain injury (4). S100B protein is an acidic calcium-binding protein derived from glial cells, abundantly present in brain tissue. Following traumatic brain injury, disruption of the blood-brain barrier allows S100B protein to be released into the bloodstream, and changes in its serum levels can reflect the extent of brain tissue damage. Procalcitonin (PCT) is a protein that significantly increases in conditions such as systemic bacterial infections and sepsis. Patients with severe traumatic brain injury often have concurrent infections, and PCT levels can be used to assess the severity of infection and its impact on prognosis. Neuron-specific enolase (NSE) is an acidic protease specific to neurons and neuroendocrine cells; elevated serum NSE levels are closely associated with neuronal damage and death. Dynamic monitoring of serum S100B protein, PCT, and NSE levels is expected to comprehensively reflect the degree of brain tissue damage, infection status, and neuronal damage state in patients with severe traumatic brain injury from different perspectives, providing a more reliable basis for accurately predicting patient prognosis (5). This study aims to investigate the predictive value of serum S100B protein, PCT, and NSE for the prognosis of patients with severe traumatic brain injury, with the goal of informing clinical treatment decisions.

Materials and Methods

General Information

A total of 103 patients with severe traumatic brain injury (GCS score ≤ 8) admitted to our hospital from June 2021 to April 2025 were selected as the severe traumatic brain injury (STBI) group. All patients met the diagnostic criteria for traumatic brain injury (6). The exclusion criteria for patients were as follows: (1) history of previous traumatic brain injury or neurosurgery; (2) pre-existing neurological disorders (e.g., stroke, epilepsy, neurodegenerative diseases); (3) severe systemic diseases including hepatic failure, renal failure, or malignancy; (4) active infection or sepsis at admission; (5) use of immunosuppressive agents or corticosteroids within the past 3 months; (6) pregnancy or lactation; and (7) age < 18 years. This group included 56 males and 47 females, aged 58-75 years, with a mean age of (66.12 ± 5.08) years. Concurrently, 100 healthy individuals who underwent physical examinations at our hospital during the same period were selected as the healthy group. The exclusion criteria for healthy controls were: (1) history of any neurological or psychiatric disorder; (2) history of traumatic brain injury; (3) acute or chronic infection; (4) severe cardiac, hepatic, or renal diseases; (5) malignancy; and (6) pregnancy or lactation. This group included 55 males and 45 females, aged 55-70 years, with a mean age of (60.85 ± 5.36) years.

Research Methods

Serum levels of S100B protein, PCT, and NSE were measured and compared between the severe traumatic brain injury (STBI) group and the healthy group. Patients in the severe traumatic brain injury (STBI) group were assessed six months post-injury using the Glasgow Outcome Scale (GOS). Based on the GOS score, patients with severe traumatic brain injury were divided into a favorable prognosis group (scores 4–5) and a poor prognosis group (scores 1-3). The levels of S100B protein, PCT, and NSE were compared between the two groups. Grouping criteria: GOS score descriptions: 1 point - Death: Patient dies due to brain injury or its complications. 2 points - Persistent Vegetative State: Patient is unconscious but has sleep-wake cycles, may exhibit some reflex actions, but shows no cognitive function. 3 points - Severe Disability: Patient is conscious but has severe disability; requires assistance from others for daily activities (e.g., eating, dressing) and cannot live independently. 4 points - Moderate Disability: Patient can live independently but has disabilities in social activities, work, etc., requiring assistance or assistive devices. For example, they may need to adjust their work or cannot drive. 5 points - Good Recovery: Patient can return to normal life, although there may be minor neurological or psychological sequelae (e.g., mild memory problems, personality changes) that do not affect overall independence and quality of life.

Indicator Detection Methods

S100B Protein Detection

The ELISA method was used. The specific kit was the Human S100B ELISA Kit (Abcam, Cambridge, UK). The microplate reader used was the Multiskan FC (Thermo Fisher Scientific, Waltham, MA, USA). Venous blood from patients with severe traumatic brain injury was collected - at 1 day post-injury. The serum was separated by centrifugation and stored. The patient's serum sample was added to a microplate pre-coated with anti-S100B protein antibody. During this process, the S100B protein in the patient's serum sample reacted and bound with the anti-S100B antibody on the microplate surface. Subsequently, an enzyme-labeled primary antibody against S100B protein was added. After incubation and washing to remove unbound components, TMB chromogenic solution was added. The degree of TMB color reaction under the corresponding enzyme action was proportional to the amount of S100B protein in the sample. The OD value was read at a specific wavelength using an enzyme-linked immunosorbent assay reader, and the S100B protein content in the sample was calculated based on a standard curve.

PCT Detection

The immunoluminescence method was used. The specific kit was the Elecsys BRAHMS PCT electrochemiluminescence immunoassay kit (Roche Diagnostics, Mannheim, Germany), and the analyzer used was the Cobas e601 immunoassay analyzer (Roche Diagnostics). Venous blood was also collected from patients - at 1 day post-injury, and serum was separated. The serum specimen was placed in a reaction solution containing anti-PCT antibody, allowing the PCT in the specimen to bind and form complexes. A secondary antibody labeled with a chemiluminescent substance was then bound to these complexes. The PCT content in the specimen was determined based on the luminescence intensity measured in a corresponding instrument.

NSE Detection

The electrochemiluminescence immunoassay method was used. The specific kit was the Elecsys NSE electrochemiluminescence immunoassay kit (Roche Diagnostics, Mannheim, Germany), and the analyzer used was the Cobas e601 immunoassay analyzer (Roche Diagnostics). Serum samples collected at 1 day post-injury were incubated with magnetic beads coated with anti-NSE antibody and anti-NSE antibody labeled with a luminescent substance to form immune complexes. Under the influence of an electric field, the complexes were adsorbed onto the electrode surface. The concentration of NSE in the sample was quantitatively detected by measuring the intensity of the luminescent signal.

Statistical Methods

Statistic Package for Social Science (SPSS) 26.0 (IBM, Armonk, NY, USA) was used for statistical analysis. Count data were expressed as n or % and analyzed using the χ^2 test. Measurement data were expressed as (mean ± standard deviation) and analyzed using the t-test. The receiver operating characteristic (ROC) curve was used to evaluate the predictive efficacy of S100B, PCT, and NSE for the prognosis of patients with traumatic brain injury. A P-value < 0.05 was considered statistically significant.

Results

Comparison of Serum S100B Protein, PCT, and NSE Levels Between the severe traumatic brain injury (STBI) group and the Healthy Group.

Serum levels of S100B protein, PCT, and NSE in the severe traumatic brain injury (STBI) group were significantly higher than those in the healthy group ($P < 0.05$). See *Table I*.

Table I Comparison of Serum S100B Protein, PCT, and NSE Levels Between the severe traumatic brain injury (STBI) group and the Healthy Group ($\bar{x}\pm s$).

Group	n	S100B (ng/mL)	PCT (μg/L)	NSE (ng/mL)
(STBI) group	103	0.86±0.22	1.26±0.13	26.27±3.37
Healthy Group	100	0.19±0.09	0.38±0.06	14.20±1.92
t		28.245	61.617	31.230
P		P<0.001	P<0.001	P<0.001

Table II Serum S100B Protein, PCT, and NSE Levels in Craniocerebral Injury Patients with Different Prognoses ($\bar{x}\pm s$).

Group	n	S100B (ng/mL)	PCT (μg/L)	NSE (ng/mL)
Good Prognosis Group	72	1.08±0.14	0.82±0.11	16.34±1.58
Poor Prognosis Group	31	1.34±0.18	1.26±0.28	22.32±2.93
t		7.912	11.487	13.417
P		P<0.001	P<0.001	P<0.001

Table III Predictive Efficacy of S100B, PCT, and NSE for Prognosis in Craniocerebral Injury Patients.

Test Result Variable(s)	Area	Std. Error	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
S100B (ng/mL)	0.876	0.040	P<0.001	0.798	0.955
PCT (μg/L)	0.931	0.030	P<0.001	0.872	0.989
NSE (ng/mL)	0.981	0.010	P<0.001	0.961	1.000
Combined (Three markers)	0.996	0.004	P<0.001	0.989	1.000

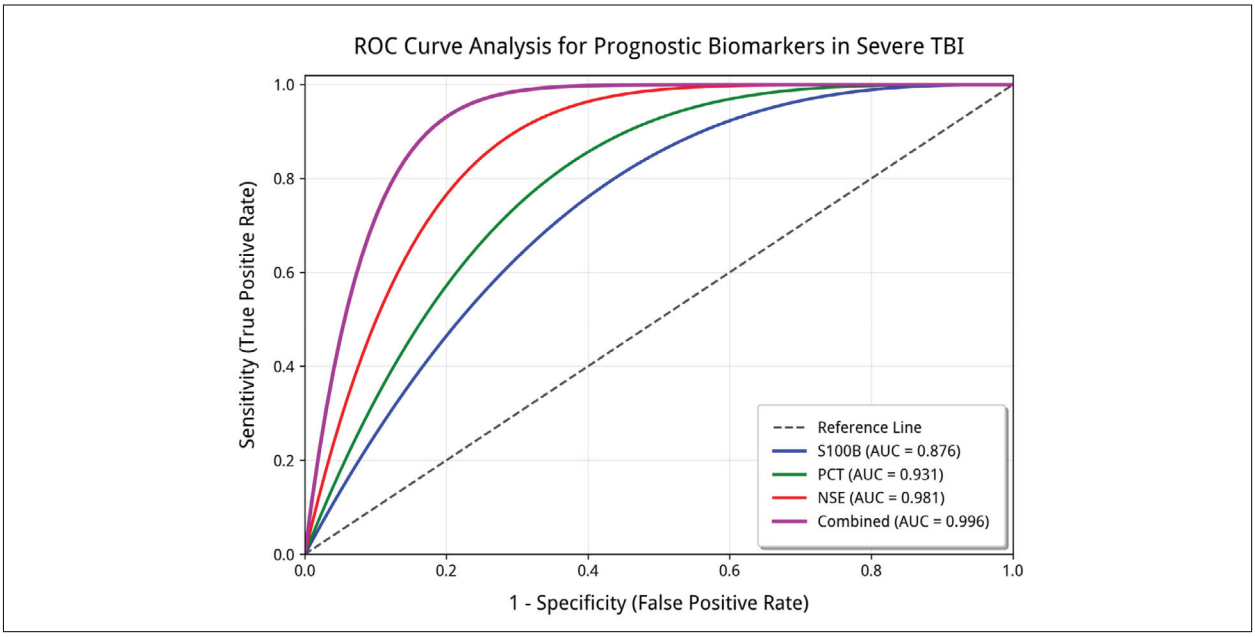

Figure 1 ROC Curve for predictive efficacy of S100B, PCT, and NSE for prognosis in caniocerebral injury patients.

Serum S100B Protein, PCT, and NSE Levels in Craniocerebral Injury Patients with Different Prognoses

Serum levels of S100B protein, PCT, and NSE in the poor prognosis group were significantly higher than those in the good prognosis group ($P < 0.05$). See *Table II*.

Prognostic Predictive Value of S100B, PCT, and NSE in Patients with Severe Traumatic Brain Injury

S100B, PCT, NSE, and their combined detection demonstrate high prognostic predictive value in patients severe with traumatic brain injury ($P< 0.05$). See *Table III* and *Figure 1*.

Discussion

Severe traumatic brain injury (STBI) is a major disease that severely endangers human health. Following STBI, the body undergoes a series of complex changes. In the acute phase of STBI, damage to the blood-brain barrier (BBB) occurs due to cerebral vascular rupture and cerebral contusion/laceration (7). The BBB normally prevents macromolecular substances in the blood from entering the brain tissue, maintaining homeostasis of the brain's internal environment. After BBB damage, biomarkers typically present in brain tissue, such as S100B protein and NSE, enter the bloodstream, increasing their serum concentrations. S100B is primarily produced and secreted by neuroglial cells; under normal conditions, serum S100B levels are very low. Following craniocerebral trauma, injured neuroglial cells can release large amounts of S100B into the blood. This not only reflects the degree of glial cell damage but also can influence intracellular signaling pathways by binding to intracellular target proteins, further exacerbating neuronal damage. Additionally, S100B protein can induce inflammatory responses, promoting the release of inflammatory cytokines and aggravating brain edema and tissue damage. NSE is present in neurons and neuroendocrine cells and plays an important role in glycolysis. After neuronal damage, cell membrane permeability increases, allowing NSE to be released into the extracellular fluid and enter the circulatory system through the damaged BBB. The increased serum NSE level reflects the extent and severity of neuronal damage (8). PCT is a prohormone of calcitonin with no hormonal activity. Under normal conditions, it is synthesized and secreted by thyroid C cells, present in extremely small amounts in serum. In patients with severe craniocerebral trauma, the immune system is activated due to the stress state, especially following concurrent infection. Various cells outside the thyroid (e.g., neuroendocrine cells in the lungs, liver, kidneys) can also synthesize and secrete large amounts of PCT. Elevated serum PCT not only indicates the presence of infection but also correlates with the severity of infection (9).

The results of this study showed that serum levels of S100B protein, PCT, and NSE in the severe traumatic brain injury (STBI) group were significantly higher than those in the healthy group. Furthermore, serum levels of S100B protein, PCT, and NSE in the poor prognosis group were significantly higher than those in the good prognosis group. This trend is generally consistent with previous research findings (10, 11). Dynamic changes in S100B protein levels can reflect the repair process of brain tissue damage. For patients with good prognosis, a rapid decrease in S100B protein indicates better recovery of brain tissue damage. In patients with poor prognosis, persistently elevated or slowly declining S100B protein levels may indicate ongoing brain tissue damage, secondary brain injury such as cerebral edema, or cerebral infarction. Dynamic changes in PCT are related to infection control (12). When infection is controlled, PCT levels decrease accordingly; if infection persists or worsens, PCT levels continue to rise. Serum NSE reflects the degree of neuronal damage. In patients with severe traumatic brain injury (STBI), NSE levels increase post-injury, and the degree of elevation is related to the severity of the patient's condition. This study found that serum NSE levels in the poor prognosis group were significantly higher than those in the good prognosis group. Continuously elevated NSE suggests ongoing neuronal damage, possibly involving extensive cerebral cortical damage. Dynamic monitoring of NSE levels can help assess the patient's neurological recovery. In recovering patients, NSE can gradually decrease. If NSE levels remain elevated or increase again, it may indicate poor neurological prognosis or new neurological injury (13). For example, during rehabilitation after traumatic brain injury, dynamic monitoring of NSE can assess the effectiveness of rehabilitation treatment and allow timely adjustments to the treatment plan (14).

In this study, ROC curve analysis showed that serum levels of S100B, PCT, NSE, and their combined detection have high predictive efficacy for the prognosis of patients with craniocerebral injury. Although monitoring serum S100B protein, PCT, or NSE individually can reflect the condition and prognosis of patients with severe traumatic brain injury (STBI) to some extent, each has limitations (15). S100B protein primarily reflects glial cell damage and blood-brain barrier disruption, but its assessment of the degree of neuronal damage is less accurate. PCT is mainly used to determine the presence of infection and has limited value in assessing brain tissue damage itself (16). NSE primarily reflects neuronal damage but cannot reflect glial cell damage or in-

fection status. Combined monitoring of serum S100B protein, PCT, and NSE allows for a comprehensive assessment of the condition of patients with severe traumatic brain injury (STBI) from multiple perspectives (17). Integrating these three indicators can more accurately reflect the extent of brain tissue damage, the presence of concurrent infection, and the recovery of neurological function (18). For instance, if S100B protein and NSE levels are elevated but PCT is normal, it suggests predominant brain tissue damage without infection. If S100B protein and NSE levels are elevated along with significantly increased PCT levels (19), it indicates both brain tissue damage and concurrent infection. Combined monitoring can provide clinicians with more comprehensive and accurate information, aiding in the development of more individualized treatment plans and thus improving patient outcomes (20).

Conclusion

In conclusion, serum S100B, procalcitonin, and neuron-specific enolase are significantly associated with adverse neurological outcomes in severe traumatic brain injury. These biomarkers reflect distinct yet interconnected biochemical processes, including astroglial damage, neuronal cytolysis, and trauma-related inflammatory activation. Combined measurement markedly improves prognostic accuracy compared with single-marker assessment. Integration of these laboratory indicators into routine clinical evaluation may facilitate early risk stratification, therapeutic decision-making, and outcome monitoring in patients with STBI. Further multicenter studies with serial sampling are warranted to validate their dynamic prognostic utility.

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Conflict of interest statement

All the authors declare that they have no conflict of interest in this work.

References

1. Maas AIR, Menon DK, Manley GT, Abrams M, Åkerlund C, Andelic N, et al. Traumatic brain injury: progress and challenges in prevention, clinical care, and research. The Lancet. Neurology 2022; 21(11): 1004–60.
2. Steyerberg EW, Mushkudiani N, Perel P, Butcher I, Lu J, McHugh GS, et al. Predicting outcome after traumatic brain injury: development and international validation of prognostic scores based on admission characteristics. Plos Med 2008; 5(8): e165.
3. Richter S, Czeiter E, Amrein K, Mikolic A, Verheyden J, Wang K, et al. Prognostic Value of Serum Biomarkers in Patients With Moderate-Severe Traumatic Brain Injury, Differentiated by Marshall Computer Tomography Classification. J Neurotraum 2023; 40(21–22): 2297–310.
4. Santing JAL, Hopman JH, Verheul RJ, van der Naalt J, van den Brand CL, Jellema K. Clinical value of S100B in detecting intracranial injury in elderly patients with mild traumatic brain injury. Injury 2024; 55(3): 111313.
5. Jeon S, Kang C, You Y, Park JS, Min JH, Jeong W, et al. Beyond blood-brain barrier disruption and molecular weight: compartmental kinetics of S100B and NSE for neurological prognostication after cardiac arrest. Critical Care (London, England) 2025; 29(1): 342.
6. Griswold DP, Fernandez L, Rubiano AM. Traumatic Subarachnoid Hemorrhage: A Scoping Review. J Neurotraum 2022; 39(1–2): 35–48.
7. Ji C, Cheng D, Yang S, Wang Z. Validation of the Mechanism of Action of TYROBP Related to Blood-Brain Barrier Function in Intracerebral Hemorrhage by Bioinformatics Analysis. Iran J Biotechnol 2025; 23(1): e4019.
8. Huang L, Kang J, Zhong Y, Zhang J, Qiang M, Feng Z. A predictive model for awakening in patients with prolonged disorders of consciousness after craniocerebral injury. Medicine 2024; 103(2): e36701.
9. Sun Y, Liu Y, Liu P, Zhang M, Liu M, Wang Y. Anesthesia strategies for elderly patients with craniocerebral injury due to foreign-body penetration in the plateau region: a case report. Front Med-Lausanne 2024; 11: 1385603.
10. Chaudhuri JR, Mridula KR, Rathnakishore C, Anamika A, Samala NR, Balaraju B, et al. Association Serum S100B Protein in Alzheimer's Disease: A Case Control Study from South India. Curr Alzheimer Res 2020; 17(12): 1095–101.
11. Bossola M, Picca A, Marzetti E, Pepe G, Antocicco M, Di Stasio E. Post-dialysis fatigue and serum S100B protein in patients on chronic hemodialysis. A pilot study. Therapeutic Apheresis and Dialysis: Official Peer-Reviewed Journal of the International Society for Apheresis, the Japanese Society for Apheresis, the Japanese Society for Dialysis Therapy 2023; 27(3): 471–9.
12. Kukacka J, Vajtr D, Huska D, Průsa R, Houstava L, Samal F, et al. Blood metallothionein, neuron specific

enolase, and protein S100B in patients with traumatic brain injury. Neuroendocrinol Lett 2006; 27 Suppl 2: 116–20.

13. Hernández-Ortega K, Canul-Euan AA, Solis-Paredes JM, Borboa-Olivares H, Reyes-Muñoz E, Estrada-Gutierrez G, et al. S100B actions on glial and neuronal cells in the developing brain: an overview. Front Neurosci-Switz 2024; 18: 1425525.
14. Sveen U, Guldager R, Soberg HL, Andreassen TA, Egerod I, Poulsen I. Rehabilitation interventions after traumatic brain injury: a scoping review. Disabil Rehabil 2022; 44(4): 653–60.
15. Egea-Guerrero JJ, Murillo-Cabezas F, Gordillo-Escobar E, Rodríguez-Rodríguez A, Enamorado-Enamorado J, Revuelto-Rey J, et al. S100B protein may detect brain death development after severe traumatic brain injury. J Neurotraum 2013; 30(20): 1762–9.
16. Khalil M, Teunissen CE, Lehmann S, Otto M, Piehl F, Ziemssen T, et al. Neurofilaments as biomarkers in neurological disorders - towards clinical application. Nature Reviews. Neurology 2024; 20(5): 269–87.
17. Czupryna P, Grygorczuk S, Pancewicz S, Świerzbińska R, Zajkowska J, Krawczuk K, et al. Evaluation of NSE and S100B in patients with tick-borne encephalitis. Brain Behav 2018; 8(12): e01160.
18. Gbyl K, Jørgensen NR, Videbech P. Serum S100B protein after electroconvulsive therapy in patients with depression. Acta Neuropsychiatr 2022; 34(5): 269–75.
19. Rogatzki MJ, Morgan JE, Baker JS, Knox A, Serrador JM. Protein S100B and Brain Lipid-Binding Protein Concentrations in the Serum of Recently Concussed Rugby Players. J Neurotraum 2021; 38(16): 2247–54.
20. Chen J, Yan C, Zhang X, Wang F, Chuai X. Clinical Value of Serum Neuron-Specific Enolase Combined with Serum S100B Protein in the Diagnosis of Systemic Lupus Erythematosus. Contrast Media Mol I 2022; 2022: 9390991.

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