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Effect of Electrolyte Disturbance on Prognosis of Patients with Traumatic Brain Injury

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Abstract: *Objective:* To investigate the prognostic value of electrolyte disturbances in patients with traumatic brain injury (TBI). *Methods:* Cases of TBI patients admitted to the Department of Neurosurgery at Dezhou Second People's Hospital from September 2015 to September 2021 were analyzed to examine the impact of electrolyte disturbances on patient prognosis and to establish a risk prediction model. *Results:* Patients with electrolyte disturbances had poorer prognoses, with serum sodium and serum calcium levels significantly affecting the outcomes of patients with traumatic brain injury. *Conclusion:* Serum sodium and calcium levels may serve as potential prognostic markers in patients with traumatic brain injury.

Keywords: Electrolyte disturbance; Traumatic brain injury; Prognosis; Serum sodium; Serum calcium

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1. Introduction

Traumatic brain injury (TBI) is an acquired brain injury caused by external mechanical forces, which can lead to temporary or permanent damage and has a high morbidity and mortality rate [1]. China has the largest number of TBI patients in the world, making this condition a significant public health issue [2]. To develop personalized treatment plans and minimize the misuse of medical resources, accurate identification of patients with a poor prognosis is essential for guiding clinical decision-making [3]. Over the past few decades, research on TBI biomarkers has made rapid progress. These biomarkers play a crucial role in elucidating pathophysiological processes by examining concentration changes associated with cellular damage. Calcium and sodium are the most common electrolytes in human body fluids and participate in various physiological activities such as maintaining osmotic pressure, water balance, acid-base homeostasis, and coagulation function. Recent studies have found that electrolyte disturbances are closely related to the onset and prognosis of various diseases [4,5]. The aim of this study was to evaluate the role of electrolyte disturbances in the prognosis of patients with traumatic brain injury, with the goal of providing an effective prognostic marker for TBI.

2. Materials and methods

2.1. General information

From September 2015 to September 2021, 67 patients with TBI admitted to the neurosurgery department after emergency admission to Dezhou Second People's Hospital were selected for the study. The study was approved by the hospital's ethics committee, and informed consent was obtained from the patients and their families.

Inclusion criteria: Clear history of head trauma, emergency cranial CT showing signs of brain injury (contusion, bleeding), and the need for emergency hematoma removal plus decompressive craniectomy.

Exclusion criteria: Patients who died in the emergency department, patients with a history of severe cardiopulmonary or kidney disease, and patients who only underwent CT-guided intracranial hematoma localization or ventricular puncture drainage.

2.2. Clinical data

Upon admission, all patients were assessed using the Glasgow Coma Scale (GCS) [6] to determine the severity of brain trauma. Clinical data such as gender, age, and medical history were also recorded.

2.3. Treatment method

After admission, all patients underwent intracerebral hematoma removal and decompressive craniectomy under anesthesia. Dehydration therapy, hemostasis, energy mixtures, and general neurotrophic drugs were administered. Changes in consciousness, pupil reactions, and vital signs were closely monitored.

2.4. Observational indicators

(1) Degree of brain damage: Brain injury severity was categorized using the GCS score:
   (a) Severe brain injury: GCS ≤ 8;
   (b) Moderate brain injury: GCS 9–12;
   (c) Mild brain injury: GCS 13–15.

(2) Electrolyte index: Postoperative serum electrolyte levels were measured based on the following criteria:
   (a) Hyponatremia: Serum sodium < 135 mmol/L; hypernatremia: Serum sodium > 145 mmol/L;
   (b) Hypokalemia: Serum potassium < 3.5 mmol/L; hyperkalemia: Serum potassium >5.5 mmol/L;
   (c) Hypocalcemia: Serum calcium < 2.0 mmol/L; hypercalcemia: Serum calcium > 2.75 mmol/L
   (d) Hypomagnesemia: Serum magnesium < 0.75 mmol/L; hypermagnesemia: Serum magnesium > 1.02 mmol/L

(3) Prognosis evaluation: Patients were followed up for six months after surgery. Based on the Glasgow Outcome Scale (GOS) after six months, patients were divided into two groups:
   (a) Poor prognosis group (GOS ≤ 3 points);
   (b) Good prognosis group (GOS > 3 points).

See **Table 1** for GOS criteria.

Table 1. Glasgow Outcome Scale (GOS)

Scores	Criterion
1	Dead
2	Vegetative state (minimal response, e.g., eyes open with sleep/wake cycle)
3	Severe disability (conscious, but disabled and needing care in daily life)
4	Moderate disability (disabled, but able to live independently and work)
5	Good recovery (return to normal life, albeit with mild impairments)

2.5. Statistical analysis

Statistical analysis was performed using SPSS 25.0. Quantitative data were expressed as mean ± standard deviation (SD), and group differences were analyzed using the *t*-test. Qualitative data were expressed as percentages, and group differences were analyzed using the chi-squared test. Univariate and multivariate logistic regression analyses were conducted to assess the impact of electrolyte disturbances on prognosis after injury. A P-value < 0.05 was considered statistically significant. The ROC curve was used to evaluate the predictive value of risk factors in TBI patients.

3. Results

3.1. General information

All 67 patients included in the study met the diagnostic criteria for traumatic brain injury, comprising 54 males and 13 females, aged 17–79 years, with an average age of 51.7 ± 14.6 years. Upon admission, 27 patients had a GCS score of 9–12, 16 patients had a GCS score of 6–8, and 24 patients had a GCS score of ≤ 5. There were significant differences in age and admission GCS scores between the poor prognosis and good prognosis groups ($P < 0.05$). However, there were no significant differences in gender or histories of hypertension and diabetes ($P > 0.05$).

3.2. Electrolyte characteristics of patients

As shown in **Table 2**, among the 67 patients, 45 (67.2%) experienced sodium disturbances postoperatively. Potassium ion disturbances occurred in 20 patients (29.8%), calcium ion disturbances in 19 patients (28.4%), and magnesium ion disturbances in 32 patients (47.8%).

Table 2. Electrolyte characteristics in patients with TBI

Symptoms	Number of cases [*n* (%)]	Mean value (mmol/L)
Hyponatremia	12 (17.9%)	133.4 ± 1.5
Hypernatremia	22 (32.8%)	152.4 ± 4.3
Hypokalemia	16 (23.9%)	3.2 ± 0.2
Hyperkalemia	4 (6.0%)	6.2 ± 0.9
Hypocalcemia	11 (16.4%)	1.9 ± 0.1
Hypercalcemia	8 (11.9%)	2.8 ± 0.1
Hypomagnesemia	17 (25.4%)	0.7 ± 0.1
Hypermagnesemia	15 (22.4%)	1.1 ± 0.1

3.3. Univariate logistic regression analysis of the effect of electrolyte disturbances on prognosis

Univariate logistic regression analysis revealed that abnormal serum sodium and serum calcium levels significantly impacted the prognosis of TBI patients ($P < 0.05$), with statistical significance. See **Table 3**.

Table 3. Univariate logistic regression analysis of the influence of electrolyte disturbances on prognosis

	Wald χ^2 value	*P*-value
Serum sodium	13.316	0.001
Serum potassium	1.420	0.492
Serum calcium	6.878	0.032
Serum magnesium	2.487	0.288

3.4. Multivariate logistic regression analysis of the influence of electrolyte disturbances on prognosis

Multivariate logistic regression analysis indicated that age, serum sodium levels, and serum calcium levels significantly influenced the prognosis of TBI patients ($P < 0.05$). See **Table 4**.

Table 4. Multivariate logistic regression analysis of the influence of electrolyte disturbances on prognosis

	β	SE	Wald χ^2	*P*	OR	95% CI
Gender	-0.525	1.198	0.192	0.661	0.591	0.057–6.188
Age	-36.742	1.906	371.713	< 0.001	1.105E-16	2.637E-18–4.628E-15
Hypertension	0.923	1.586	0.339	0.560	2.517	0.113–56.332
Diabetes	1.063	1.845	0.332	0.564	2.896	0.078–107.645
GCS	-18.317	8613.962	0.000	0.993	1.109E-8	> 0.000
Serum sodium	-38.564	1.748	485.761	< 0.001	1.787E-17	5.810E-19–5.494E-16
Serum potassium	-20.726	4152.209	0.000	0.996	5.340E-34	> 0.000
Serum calcium	40.480	1.594	645.119	< 0.001	3.805E+17	1.674E+16–8.649E+18
Serum magnesium	0.833	1.884	0.196	0.658	2.301	0.057–92.367

3.5. Prognostic value of electrolyte disturbances in TBI

To evaluate the prognostic value of electrolyte disturbances in patients with traumatic brain injury, ROC curve analysis was performed for each factor. The results showed that the AUCs for sex, age, hypertension, diabetes, GCS, serum sodium, serum potassium, serum calcium, and serum magnesium were 0.504, 0.580, 0.544, 0.497, 0.698, 0.832, 0.436, 0.470, and 0.454, respectively (**Figure 1**). These findings indicate that GCS and serum sodium levels are highly accurate predictors, suggesting that both can be used as prognostic factors for traumatic brain injury.

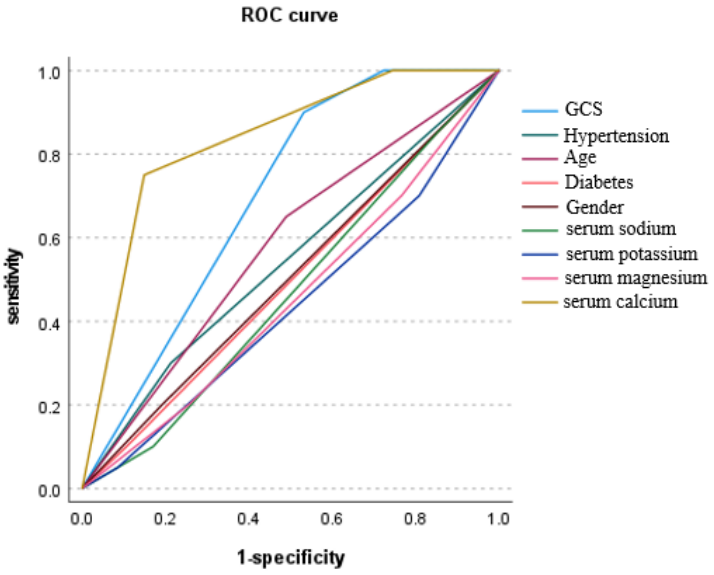

Figure 1. ROC curves

4. Discussion

Traumatic brain injury is a significant public health issue worldwide and a leading cause of death and disability among young adults and children, with high morbidity and mortality rates. Due to the specific nature of head injuries, along with factors such as patient age, pre-existing conditions, and post-admission treatment, electrolyte imbalances frequently occur and can affect postoperative mortality. Currently, both domestic and international studies provide a certain data basis on the incidence of electrolyte disorders in TBI patients, and there has been considerable analysis of the factors contributing to these disorders [7,8]. However, the underlying pathophysiological mechanisms of electrolyte imbalances, such as hypernatremia, hyponatremia, and hypokalemia, remain incompletely understood. Additionally, there is a relative scarcity of research reports and data on the incidence of electrolyte disturbances and postoperative mortality in TBI patients, highlighting the need for larger comparative studies and more case data to investigate clinical outcomes related to mortality factors.

In this study, electrolyte levels in TBI patients were measured, and univariate and multivariate logistic regression analyses were performed on clinical factors and electrolyte levels. The results showed that serum sodium and calcium levels were important prognostic factors in TBI patients, with serum sodium displaying a higher AUC value and better prognostic accuracy. Therefore, serum sodium may be considered a prognostic marker for TBI.

However, the clinical sample size in this study is relatively small. Future large-scale clinical studies are needed to further support the role of electrolytes in TBI prognosis. Additionally, the related mechanisms require further investigation to guide clinical treatment, optimize surgical diagnosis, and improve the management of patients with TBI.

Disclosure statement

The authors declare no conflict of interest.

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