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Non-Invasive Cerebral Edema Monitoring and High-Risk Blood Biomarkers in Pediatric Sepsis-Associated Encephalopathy: A Clinical Application Study

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[Abstract]: Objective: To investigate the non-invasive cerebral edema monitoring and high-risk blood biomarkers in pediatric sepsis-associated encephalopathy.**Methods:** 62 children diagnosed with septic encephalopathy in the Intensive Care Medicine Department of Hebei Children's Hospital from February 2024 to May 2025 were selected as the injury group, and 62 children without septic encephalopathy who were admitted to the intensive care unit during the same period were selected as the control group. General information, including gender, weight, early warning score,routine blood tests, blood biochemistry, cranial imaging examination and other indicators was collected from the two groups of children.Two groups of children were monitored for cerebral edema using non-invasive brain edema monitoring, and the disturbance coefficients(DC) were recorded at 24 hours, 72 hours, and 7 days after admission. Logistic regression analysis was used to identify independent risk factors for sepsis complicated with encephalopathy, and using receiver operating characteristic (ROC) curve analysis to assess the predictive value of DC in sepsis complicated with encephalopathy. **Results:** There was a statistically significant difference (P<0.05) in the modified GCS score, early warning score, and lactate, blood glucose, platelet count, albumin, APTT, and D-dimer levels between the two groups of children. The 24-hour DC values of the injured group were lower than those of the control group, with 15 patients showing cerebral edema on cranial imaging and 38 patients showing abnormal EEGs. The differences were statistically significant (P<0.05). The early warning score, lactate level, platelet count, and albumin level(P<0.05) are independent risk factors for sepsis complicated with encephalopathy in children. The area under the ROC curve for predicting sepsis complicated with encephalopathy using the DC value was 0.713, with an optimal cutoff value of 82, a sensitivity of 54.8%, and a specificity of 76.2%. **Conclusion:** Septicemic encephalopathy is the result of the interaction of multiple factors, and early warning scores, lactate levels, platelet counts, and albumin levels should receive increased attention in clinical practice. DC monitoring upon admission can serve as a warning tool, early intervention, dynamic monitoring and evaluation of treatment outcomes, and improve the prognosis of pediatric

patients.

Keywords: Non-invasive cerebral edema monitoring; Sepsis-associated encephalopathy; Increased intracranial pressure; Risk factors

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1 Background

Sepsis refers to life-threatening organ dysfunction caused by host response dysregulation due to infection [1-2]. When immune function is impaired, multiple organs and systems can be affected, and sepsis associated encephalopathy (SAE) is a prominent manifestation of immune dysfunction after an inflammatory storm[3]. SAE is one of the most common brain diseases in pediatric intensive care units and is strongly associated with increased mortality, prolonged hospitalization, and increased medical expenses [4]. Compared to adults, the pathological mechanism of septic encephalopathy in children has significant specificity. Immature development of the blood-brain barrier, high brain metabolic rate, and limited compensatory capacity of the brain volume in children make them more susceptible to rapidly progressing cerebral edema[5]..Direct measurement of intracranial pressure exceeding normal values through intraventricular drainage or intracranial pressure monitoring within the brain parenchyma is a method for diagnosing intracranial hypertension [6-7]. But these procedures are highly traumatic and not suitable for pediatric patients [8]. However, conventional cranial imaging methods such as computed tomography (CT) and magnetic resonance imaging (MRI) cannot be used to dynamically evaluate cerebral edema [9]. Therefore, it is very important to effectively monitor in real-time whether children with SAE have cerebral edema and its degree effectively, providing a basis for timely treatment in the future. The non-invasive brain edema monitoring is a utilizes electrical impedance technology and electromagnetic principles to provide real-time, non-invasive monitoring of intracranial conditions. It employs the disturbance coefficient (DC) as its primary output parameter, enabling clinicians to assess brain function without the need for invasive procedures[10-11]. At present, non-invasive brain edema monitoring has achieved certain therapeutic effects in the clinical application of intracranial lesions in adults, but research on children's DC values is still blank. This article mainly explores the clinical value of non-invasive brain edema monitoring technology, and provides evidence-based support for real-time monitoring of pediatric severe brain edema by establishing a child specific risk model and operating procedures.

2 Subjects and methods

2.1 Study population

This study included a total of 62 children diagnosed with septic encephalopathy in the Intensive Care Medicine Department of Hebei Children's Hospital from February 2024 to May 2025 as the injury group, including 37 boys and 25 girls, aged 8 months to 13 years, with an average age of 4.00

(1.00, 7.25) years; 62 non brain disease children with sepsis treated in the same hospital's intensive care unit during the same period were selected as the control group, including 32 boys and30 girls, aged 3 months to 12 years, with an average age of 3.00 (1.00, 7.25) years.

2.2 Inclusion and exclusion criteria

The inclusion criteria for the study included the following: all the children met the diagnostic criteria for sepsis in the 2015 edition of the expert consensus on the diagnosis and treatment of septic shock (septic shock) in children [12], and the children with septic encephalopathy met the criteria of the third edition of the international consensus on the definition of sepsis and septic shock [13]: when sepsis patients experience brain dysfunction,the Glasgow Coma Scale (GCS) is abnormal, and central nervous system infections, ischemic hypoxic encephalopathy, water and electrolyte disorders, and patients who used sedatives that affect central nervous system function were excluded. The length of hospital stay and survival time were greater than 1 day.

The exclusion criteria for the study included patients aged>14 years ; those who were hospitalized for less than 24 hours or had given up treatment during hospitalization; those with previous underlying diseases such as leukemia, or kidney disease, and those who used hormones, immunosuppressants, etc.

The Ethics Committee of Hebei Children's Hospital has approved the conduct of this study (Approval Number: 202136). Guardians of all participants were informed and provided their consent, adhering to ethical guidelines for research.

2.3 Methods

All the children who participated in this study received the same routine treatment as those who did not participate in the study. All patients were in a calm state during cerebral edema monitoring, with a Comfort-B score between 11-22 points. Their body temperature, heart rate, blood pressure, and respiration were all within normal ranges. All enrolled children were monitored using BORN-BE-IVA non-invasive brain edema monitor (Chongqing Boenfuk Medical Equipment Co., Ltd.). The nurse removes the hair above the temporal area of the patient's ear screen to ensure a smooth scalp in the spare skin area at the wing point. Connect the electrode pads by a physician: Use alcohol or disinfectant wipes to degrease and disinfect the electrode bonding area 2-3 times. The lead wires were connected to the device,and the electrode pads were fastened in brown, green, white, and black order. The four electrode pads are symmetrical on both sides, and the center (button) of the rear electrode pad is aligned with the highest point of the auricle above the external auditory canal. The lower edge of the electrode pad overlaps with the extension line of the outer corner of the eye. The front electrode pad is closely attached to the rear electrode pad and placed side by side, using the "meter" method is used for bonding. The non-invasive brain edema DC values of the two groups of children were monitored at 24 hours, 72 hours, and 7 days after admission, with each monitoring time being 2 hours.When measuring the DC value, monitor for 2 hours, and the

instrument will capture data once per minute. The average of these values will be taken as the final result.

2.4 Outcome measures

The observation indicators used in this study include gender, weight, early warning score, modified GCS score, intracranial pressure, lactate, blood glucose, white blood cell count, hemoglobin, platelet count, albumin, etc. in all patients;ALT,AST,Troponin I, APTT, plasma D-dimer, blood sodium, blood potassium, disturbance coefficient, cranial imaging results (indicating cerebral edema), and whether clinical symptoms and signs disappeared within 7 days of treatment.

2.5 Statistical analysis

SPSS 22.0 statistical software was used to perform statistical processing of the data. Measurement data that conforms to normal distribution are represented by mean ± standard deviation ($\bar{x}\pm s$), while measurement data that does not conform to normal distribution are represented by median (interquartile range). The t-test is used for comparing continuous variables that followed a normal distribution, while the Mann-Whitney U test was used for comparing continuous variables that do not follow a normal distribution; Count data is presented in terms of the number of cases (%), and comparison between groups is performed using the chi square test or Fisher's exact test. The analysis of influencing factors adopts a multiple factor logistic regression model, and the receiver operating characteristic (ROC) curve of the subjects was plotted. $P<0.05$ was considered statistically significant.Adopting stepwise regression with FDR correction, set the entry criterion $p<0.1$ and the retention criterion $p<0.05$. Exclude multicollinearity interference through VIF value verification (all<3.0).

3 Results

3.1 Comparison of Basic Information of Selected Children

This study included 62 cases of SAE and selected 62 cases of SAE from the same period as the control group. There was no statistically significant difference in gender, age, and weight between the two groups of patients ($P>0.05$), while there was a statistically significant difference in the warning score and GCS score between the two groups ($P<0.05$), as shown in Table 1.

3.2 Comparison of clinical indicators between the two groups of pediatric patients

The lactate and blood glucose levels in the injury group were higher than those in the control group upon admission, and the difference was statistically significant ($P<0.05$). There was no statistically significant difference in blood sodium and potassium levels ($P<0.05$). At admission, blood routine and organ indicators were monitored. The platelet count in the injury group was lower than that in the control group, albumin was lower than that in the control group, APTT and D-dimer were higher than those in the control group, and the differences were statistically significant ($P<0.05$). However,

there was no statistically significant difference between the two groups in terms of white blood cell count, hemoglobin, and troponin I (P>0.05), as shown in Tables 2 and 3.

3.3 Comparison of disturbance coefficients and cerebral edema indicators between the two groups of pediatric patients

The DC values monitored at 24 hours after admission in the injury group were lower than those in the control group, and the difference was statistically significant (P<0.05). However, there was no statistically significant difference in DC values between the two groups of children at 3 and 7 days after admission (P>0.05). There were 15 cases of cerebral edema and 38 cases of abnormal electroencephalogram in the injury group, which were significantly higher than those in the control group, and the difference was statistically significant(P<0.05). The symptoms of the two groups of children were basically relieved within 7 days, and the difference was not statistically significant (P>0.05), as shown in Table 4.

3.4 Multivariate logistic regression analysis results of sepsis complicated with encephalopathy in children

The logistic regression analysis of risk factors for sepsis complicated with brain disease in children with sepsis, with warning score, lactate, blood glucose, platelet count, albumin, APTT, and D-dimer as independent variables, showed that warning score, lactate, platelet count, and albumin (P<0.05) were independent risk factors for sepsis complicated with brain disease, as shown in Table 5.

3.5 The predictive efficacy of non-invasive brain edema monitor DC value for children with patients

The area under the ROC curve for predicting sepsis complicated with encephalopathy using DC value was 0.713(Figure 1), with an optimal cutoff value of 82, a sensitivity of 54.8%, and a specificity of 76.2%, as shown in Table 6.

Table1 Comparison of the general data between the two groups

Group	Number of cases (examples)	Gender	Age (years)	Weight (kg)	Early warning score (points)	Improved GCS score (points)

Injuries group	62	Male 37 Female25	4.00（1.00,7.25）	15.16±7.86	4.09±0.84	8.74±2.94
Control group	62	Male 32 Female 30	3.00（1.00,7.25）	14.94±7.53	3.42±0.88	15.00±0.00
$t/x^2/Z$		0.817[b]	1.112[c]	0.184[a]	3.516[a]	10.708[a]
P		0.366	0.266	0.478	0.001	0.000

Note: a = t-test; b= chi-square test; c = Mann-Whitney U test

Table 2 Comparison of internal environmental indices between the two groups

Group	Lactic acid (mmol/L)	Blood glucose (mmol/L)	Blood sodium (mmol/L)	Blood potassium (mmol/L)
Injuries group	2.27±1.13	7.86±4.98	134.03±5.23	4.02±0.73
Control group	1.54±0.58	5.62±1.28	132.89±3.15	3.92±0.46
t/x^2	3.709	2.578	1.207	0.761
P	0.003	0.012	0.231	0.449

Table 3 Comparison of organ function indices between the two groups

Group	White blood cell count (×109/L)	Hemoglobin (g/L)	Platelet count (×109/L)	Albumin (g/L)	Troponin I (ug/L)	APTT	D-dimer (mg/L)

Injuries group	14.00 ± 7.51	108.78 ± 21.80	113.76 ± 35.19	30.25 ± 3.33	0.03(0.02 ,0.07)	39.45 ± 12.45	3.26(0.85, 6.05)
Control group	12.23 ± 4.92	110.26 ± 14.64	211.47 ± 87.28	37.12 ± 4.90	0.03(0.01 ,0.06)	30.50 ± 4.85	1.20(0.55, 2.04)
t/x^2	1.275	0.364	6.729	7.511	0.609	4.342	3.180
P	0.206	0.717	0.000	0.000	0.542	0.000	0.002

Table 4 Comparison of DC and brain edema indices between the two groups

Group	DC within 24 hours of admission	DC admitted for 3 days	DC admitted for 7 days	Abnormal electroence phalogram [case (%)]	Head imaging suggests cerebral edema [case (%)]	Symptoms relieved within 7 days [case (%)]
Injuries group	67.64±18.80	81.97±20.52	92.61±14.67	38（61.29）	15（24.19）	59（95.16）
Control group	85.54±24.41	87.35±24.63	91.28±24.64	5（8.06）	3（4.84）	62（100）
t/x^2	3.765	1.918	0.292	38.770	9.358	3.074
P	0.000	0.918	0.771	0.000	0.002	0.080

Table 5 Logistic regression analysis of risk factors for encephalopathy in children with sepsis

Factor	B	S.E,	Wals	*P value*	Exp（B）	95% CI of Exp (B)	
						upper limit	lower limit

Early warning score	1.301	0.637	4.166	0.041	3.673	1.053	12.821
Lactic acid	1.471	0.625	5.542	0.019	4.354	1.279	14.821
Blood sugar	0.578	0.466	1.540	0.215	1.783	0.715	4.444
Platelet count	-0.054*	0.021	7.011	0.008	0.947	0.910	0.986
Albumin	-0.540*	0.200	7.327	0.007	0.583	0.394	0.862
APTT	0.018	0.099	0.031	0.859	1.018	0.838	1.235
D-Dimer	0.003	0.324	0.000	0.991	1.003	0.532	1.891

*Note: A negative coefficient between platelet count and albumin (OR<1) indicates a higher risk with smaller values.

Table 6 Predictive efficacy of DC in children with sepsis and encephalopathy

Index	Best Truncation Value	AUC	95%CI	Sensitivity (%)	Specificity (%)	*P value*
DC	82	0.713	0.605~0.822	54.8	76.2	0.001

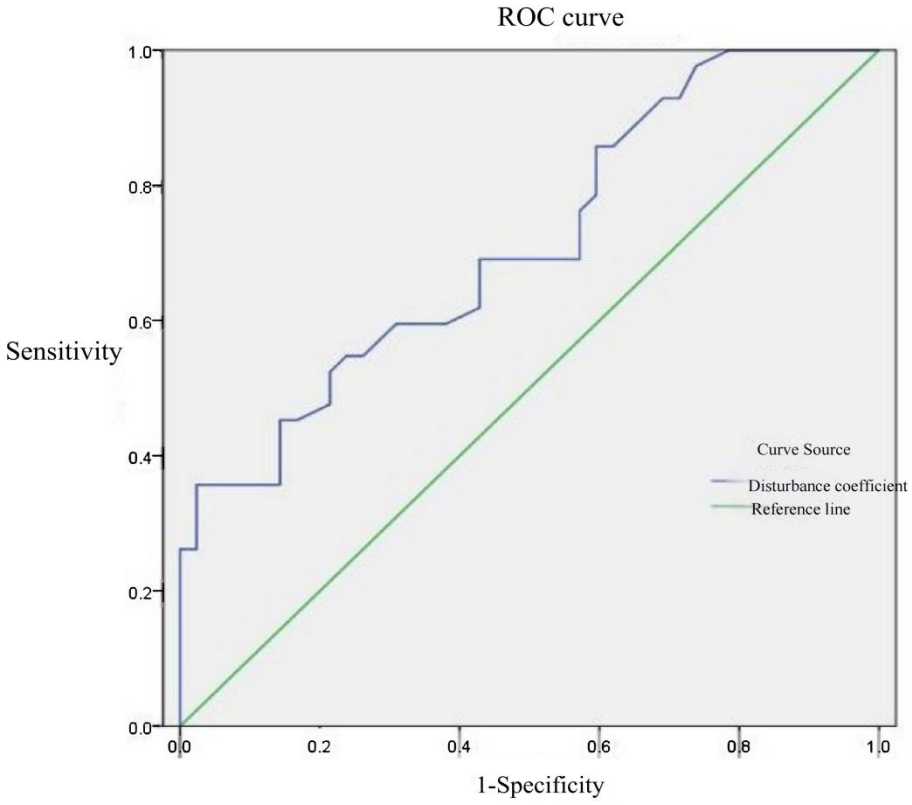


Figure1 ROC curve of the DC value for predicting sepsis in patients with encephalopathy

4 Discussion

Sepsis is still a common critical illness in pediatric intensive care units. Immune dysfunction caused by infection leads to multiple organ dysfunction, especially in the central nervous system, which is susceptible to stress, oxidation, inflammation, and other factors that can cause SAE [14-15]. SAE, as one of the main manifestations of multiple organ dysfunction in sepsis, has a mortality rate of up to 70.0%. Some children may experience long-term mental state abnormalities, stress disorders, and poor quality of life, which seriously affect their growth, development, and physical and mental health. Therefore, early identification and treatment of SAE are highly important for improving the prognosis of children.

Children with patients often exhibit changes in their mental state, such as irritability, crying, irritability, difficulty in calming, and even drowsiness, convulsions, delirium, and coma. During infancy, children may experience personality changes, decreased attention, and impaired orientation [16]. These clinical characteristics reflect the possibility of increased intracranial pressure in children with sepsis. Early identification of increased intracranial pressure and timely effective treatment measures can reduce the risk of neurological sequelae and death in children with sepsis, thereby improving their quality of life. There are two monitoring methods for cerebral edema: invasive and

non-invasive. In clinical practice, invasive intracranial pressure monitoring methods, including lumbar puncture pressure measurement and ventricular tube pressure measurement, are technical and invasive, with potential risks of infection and cerebral herniation. The low acceptance of these methods by parents limits their clinical application [17-18]. However, non-invasive monitoring methods such as transcranial Doppler ultrasound and fundus examination have low sensitivity, strict operation, and difficulty in exploration, which limits their clinical application [19]. Head imaging examinations, such as CT and MRI, cannot always identify increased intracranial pressure, and children are at risk of high radiation, difficulty in sedation, and cannot be monitored in real-time or continuously. In addition, these technologies are costly for critically ill children and there is a risk of unexpected events during patient transportation. New monitoring technologies based on principles of optics, audiology, ophthalmology, and acoustics have been explored, but their clinical value needs to be fully evaluated [20]. In recent years, non-invasive brain edema monitoring devices have been widely used in clinical practice, and their bedside, non-invasive, and dynamic real-time capabilities have been recognized by clinical physicians. Its working principle is based on biological electromagnetic fields and electrical impedance imaging technology. Normal brain tissue, as a stable state, is disturbed by conditions such as edema or bleeding. When electromagnetic waves pass through the brain, different signals can be detected and converted into disturbance coefficients. By monitoring DC values, quantitative data on brain edema can be provided to clinical physicians [21-22]. Early and timely intervention can be carried out to control the development of brain edema, help physicians evaluate the condition of children, and improve their prognosis. The non-invasive brain edema monitor can monitor in real-time at the bedside [23], with convenient and simple operation, and is not affected by whether the child has a tracheal intubation, a ventilator, or a fixed position. The impact of movement and other factors can timely detect children with cerebral edema, and guide the clinical application of dehydrating agents based on the changes in DC values in different age groups.

As a single center exploratory study, this study is limited by the incidence of SAE in children, which is about 6.8% per year. It is clinically feasible to obtain 144 samples that meet the CONSORT criteria during the enrollment period of more than one year.This study found that early warning scores, lactate, platelet count, and albumin are risk factors for brain disease in children with sepsis upon admission. The Pediatric Early Warning System score (PEWS) is used to assess the severity of a child's condition upon admission. The higher the score, the faster the progression of the disease and the greater the impact on prognosis. Its main evaluation indicators include consciousness response, breathing, and circulation. The overall body function of children with sepsis decreases, organ function is damaged, tissue hypoxia, metabolic disorders, and other factors lead to high early warning scores, which also indicate that the child's condition is critical when admitted and the risk of developing SAE is high. Lactic acid is a product of anaerobic metabolism in the body and an indicator of inadequate perfusion in tissues and organs. Children with sepsis have high lactate levels, indicating insufficient effective circulating blood volume, inadequate cerebral perfusion, and brain

tissue hypoxia, which also increases the incidence of SAE. In children with severe sepsis infection, monitoring blood routine often shows a progressive decrease in platelets, which warns pediatricians that the child's condition is severe, disrupts the balance of the body, disrupts coagulation function, and the whole body is in a hypercoagulable state. This suggests that children with sepsis are at high risk of developing brain disease. Low albumin is also a risk factor for children with septic encephalopathy, which may be related to low tissue permeability caused by low albumin, leading to brain edema and severe inflammatory reactions. The non-invasive brain edema monitor monitors the dynamic changes in brain tissue water content based on the theory of biological electromagnetic fields, foreign body disturbance principles, and impedance imaging technology. By analyzing different signals, disturbance coefficients are obtained to evaluate intracranial conditions. This monitor can continuously, real-time, and quantify cerebral edema, and the measurement and analysis of disturbance coefficients are fast and portable, without causing interference or discomfort to the patient. This study found that the DC values of children with patients were significantly lower than those of the control group at 24 hours of admission.The observed statistical significance of DC values exclusively at the 24-hour mark carries profound clinical implications. This temporal pattern strongly suggests that non-invasive DC monitoring serves as a critical early-warning tool rather than a longitudinal tracking metric for cerebral edema in pediatric SAE.The exclusive significance of DC values at 24h aligns with the pathophysiological progression of pediatric systemic inflammatory response.Elevated cytokines potentiate vasogenic edema within hours post-infection, which the DC technology detects via electromagnetic impedance changes in real-time.So early intervention is needed to avoid aggravating brain edema. After 3 days of clinical treatment, the DC values were higher than before, and the difference was not statistically significant compared to the control group. This suggests that active and early treatment can improve prognosis, reduce neurological complications, and benefit children. The significant difference in 24-hour DC values and the disappearance of differences after 72 hours suggest that DC values can reflect short-term treatment efficacy.By observing DC value trends, clinicians can adjust medication dosages in real-time.DC value changes after treatment reflect the dynamic process of cerebral edema resolution, and non-invasive brain edema monitoring shows promise for real-time treatment evaluation. At the same time, the area under the ROC curve of DC prediction for sepsis complicated with encephalopathy is 0.713,it is within the acceptable discriminatory ability range (Hosmer Lemeshow grading), which is comparable to similar biomarker studies[24].The optimal cutoff value is 82. This data tells us that when monitoring non-invasive brain edema in clinical practice, if the DC value is close to 82, the risk of brain edema is the highest. Therefore, quantified DC values can provide more treatment basis for pediatric clinical practice and guide clinical treatment.However, the sensitivity of the optimal critical value (DC=82) is 54.8%, which is relatively low. There are several factors that may lead to this limitation: DC is derived from electromagnetic signal transmission through heterogeneous brain tissue. In pediatric patients with skull structure development (such as open fontanelle in infants, different skull thicknesses), signal attenuation may

occur, reducing the accuracy of detecting local edema. This is particularly important considering that our cohort includes children aged 3 months to 13 years, which is a period of rapid neuroanatomical changes. The encephalopathy caused by sepsis involves complex mechanisms, including microvascular dysfunction, blood-brain barrier disruption, and metabolic acidosis. These processes generate fluctuating tissue impedance patterns that may temporarily mask the development of edema, especially in the early stages where cytotoxic edema dominates. Simultaneous clinical interventions such as fluid resuscitation, vasoactive drugs, and mechanical ventilation can alter cerebral hemodynamics. In future research, it is necessary to consider the age stratified DC threshold for skull maturation and implement multimodal monitoring combining DC and transcranial Doppler ultrasound (TCD) to improve sensitivity.Of course, this study has many limitations, such as small sample size, single center design, low sensitivity to DC values, and lack of age stratification research. In the future, it is necessary to expand the sample size, conduct further research on multiple centers, and conduct stratified analysis on different age groups to obtain accurate data and provide assistance for clinical work.

In summary, when children with sepsis are admitted to the hospital with high early warning scores, high lactate levels, and low platelet and albumin levels, they should be alert to the possibility of concomitant encephalopathy. Once diagnosed with sepsis encephalopathy, non-invasive brain edema should be monitored as early as possible, and timely and effective intervention should be carried out to minimize the damage caused by the disease to the child.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The studies involving humans were approved by the Ethics Committee of Hebei Children's Hospital(Approval Number: 202136). Informed consent was obtained before the study from parents, guardians, and children who could provide it(written), ensuring they were fully informed about the study's purpose, procedures, and potential risks or benefits.

Author contributions

SL performed the experiments and wrote the article. YL and XZ performed the experiments. MX revised the article. ZW designed the study and reviewed the article. All the authors have read and approved the final manuscript as submitted.

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Consent for publication

Not applicable.

Competing interests

All authors declare that there is no conflict of interest in this study.

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References

1.FU X,LIU Z,WANG Y. Advances in the study of immu nosuppressive mechanisms in sepsis[J].Inflamm Res,2023,16:39673981.

2. Wang Xianqi, Zhang Bin, Zhang Qi, Dai Zheng, Zhang Jinxin, Liang Xiaoli, Li Lin, Wu Lin, Liu Shanshou Analysis of platelet count and functional changes in early sepsis based on single-cell sequencing [J]. Journal of Practical Medicine, 2024, 40 (9): 1218-1224

3.PAN S,LV Z,WANG R,et al.Sepsis-induced brain dysfunction:pathogenesis,diagnosis,and treatment[J].Oxid Med Cell Longev,2022,2022:1328729.

4.EVANS L,RHODESA,ALHAZZANlW,et a1.Surviving sepsis campaign:international guidelines

for management of sepsis and septic shock 2021 [J].Intensive Care Medicine,2021,47(11)：1181-1247.

5.Sheibani, Abdolreza, Hashemi, et al. A narrative review of magnetic resonance imaging findings in pediatric idiopathic intracranial hypertension. Health Sci Rep. 2024; 7 (10): e70111. doi: 10.1002/hsr2.70111.

6.FAN JL,NOGUEIRA RC,BRASSARD P,et al. Integrative physiological assessment of cerebral hemodynamics and metabolism in acute ischemic stroke[J], Cereb Blood Flow Metab,2022,42(3)：454-470.

7. Wu Mengmeng, Hu Hongjian, Mei Qiyong. Research progress on non-invasive intracranial pressure monitoring technology [J]. Journal of the Second Military Medical University, 2021, 42 (8): 897-902

8.CANAC N，JAlAlEDDINI K，SAMUEl G,et al,Review:pathophysiology of intracranial hypertension and noninvasive in-tracranial pressure monitoring[J]. Fluids Barriers CNS,2020,17(1):40.

9.OBENAUS A,BADAUT J.Role of the non-invasive imaging techniques in monitoring and understanding the evolution of brain edema[J].Neurosci Res,2022,100(5):1192-1200.

10.SCHWIMMBECK F,VOELLGER B,CHAPPELL D,et al.Hypertonic saline versus mannitol for traumatic brain injury: a systematic review and meta-analysis with trial sequential analysis[J]. J Neurosurg Anesthesiol,2021,33(1):10-20.

11.SCHIZODIMOS T,SOULOUNTSI V,IASONIDOU C,et al. An overview of management of intracranial hypertension in the intensive care unit [J]. J Anesth,2020,34(5):741-757.

12. Emergency Medicine Group of the Chinese Medical Association Science Branch, Pediatrics Group of the Chinese Medical Association Emergency Medicine Branch, and Pediatric Intensive Care Physicians Branch of the Chinese Medical Association Expert Consensus on Diagnosis and Treatment of Septic Shock (Infectious Shock) in Children (2015 Edition) [J]. Chinese Journal of Pediatric Emergency Medicine, 2015, 22 (11): 739-743. DOI: 10.3760/cma.jissn.1673-4912.2015.11.001

13.SINGER M,DEUTSCHMAN C S,SEYMOUR C W,et al. The Third International Consensus Definitions for Sepsis and Septic Shock(Sepsis3)[J]. JAMA,2016,315(8):801-810.

14. Wang Junling, Zhan Mengmeng, Zhang Zhaolong, He Shaoheng, Qin Bingyu Research progress on the role of mast cells in sepsis [J]. Journal of Practical Medicine, 2024, 40 (5): 596-600

15.FONT M D，THYAGARAJAN B，KHANNA A K. Sepsis and septic shock-basics of diagnosis, pathophysiology and clinical decision making[J]. Med Clin North Am，2020，104(4):573-585.

16.LIU D,HUANG S Y,SUN J H,et al. Sepsis-induced immunosuppression: mechanisms, diagnosis and current treatment options[J]. Mil Med Res,2022,9(1):56.

17.DAVIES L, DELCOURT C. Current approach to acute stroke management[J]. Intern Med J,2021,51(4):481-487.

18.FAN JL,NOGUEIRA RC,BRASSARD P,et al. Integrative physiological assessment of cerebral hemodynamics and metabolism in acute ischemic stroke[J]. Cereb Blood Flow Metab,2022,42(3): 454-470.

19.IRONSIDE N,CHEN CJ,DlNG D,et a1.Perihematomal edema after spontaneous intracerebral hemorrhage[J].Stroke,201 9,50 (6):1 626—1 633.

20. Liu Chengyin, Shi Xiang'en, Wang Youquan, etc Application of ultrasound monitoring of optic nerve sheath diameter in the diagnosis and treatment of adult patients with intracranial hypertension [J]. Chinese Journal of Physician Continuing Education, 2022, 45 (5): 403-406

21.YANG B,LI B,XU CH,et al.Comparison of electrical impedance tomography and intracranial pressure during deyhdration treatment of cerebral edema[J].Neuroimage Clin,2019,23:101909.

22. Lei Qingmei, Wang Shanshan, Cheng Jinmei, etc The application value of disturbance coefficient in monitoring cerebral edema in patients with traumatic brain injury [J]. Chongqing Medical Journal, 2018, 47 (13): 1737-1739

23.THOMPSON K, VENKATESH B, FINFER S. Sepsis and septic shock: current approaches to management [J]. Intern Med J, 2019, 49(2): 160 - 170.

24.Chen, L, Zhang, Z, Wang, E.. The Diagnostic and Prognostic Value of Serum Procalcitonin in Children with Sepsis[J]. Journal of Healthcare Engineering, 2021(1):1-7, DOI:10.1155/2021/4691406.