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ORIGINAL RESEARCH

Analysis of the Diagnostic Efficacy of Neonatal Neurobehavioral Assessment Scores Combined with Cranial MRI in Brain Injury Due to Severe Hyperbilirubinemia in Neonates

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Background and Objective: Current diagnostic methods for SHB-related brain injury (serum bilirubin, ABR testing) have limitations in sensitivity and specificity, often leading to delayed intervention. To investigate the application value of neonatal neurobehavioral assessment (NBNA) scores combined with cranial magnetic resonance imaging (MRI) in the diagnosis of brain injury in neonates with severe hyperbilirubinemia (SHB).

Methods: A retrospective analysis was conducted on 25 neonates with SHB who received treatment in our hospital from December 2022 to October 2024 as the experimental group of this study. Additionally, 25 neonates with general hyperbilirubinemia born in our hospital during the same period were included as the control group. The NBNA scores and MRI manifestations of the two groups were compared to evaluate the diagnostic efficacy of combined detection.

Results: There were no significant differences in the general data between the two groups ($P > 0.05$). The NBNA scores of the neonates in the experimental group were lower than those in the control group ($P < 0.05$). The total bilirubin levels of the neonates in the experimental group were higher than those in the control group ($P < 0.05$). The RSI values in the globus pallidus (GP) region of the neonates in the experimental group were higher than those in the control group ($P < 0.05$). The NBNA scores of neonates with abnormal cranial MRI were lower than those with normal cranial MRI, and the duration of severe hyperbilirubinemia was shorter in neonates with abnormal cranial MRI than in those with normal cranial MRI ($P < 0.05$). The accuracy of predicting brain injury using neonatal neurobehavioral assessment scores combined with cranial MRI was higher than that of single diagnosis ($P < 0.05$).

Conclusion: NBNA combined with cranial MRI has high clinical application value in the early diagnosis of brain injury associated with SHB, which can improve the accuracy of diagnosis and provide an important basis for early intervention.

Keywords: neonatal hyperbilirubinemia, neurobehavioral assessment score, cranial MRI, brain injury, diagnostic efficacy

Introduction

Neonatal hyperbilirubinemia is a common clinical problem during the neonatal period, particularly severe hyperbilirubinemia (SHB). If bilirubin levels are excessively high and timely intervention is not implemented, it can lead to kernicterus, causing severe damage to the neonatal nervous system and even triggering long-term neurological deficits such as cerebral palsy, intellectual disability, and hearing impairment.[1–4] Therefore, how to early identify SHB-related brain injury and take intervention measures is one of the key issues of concern in the field of neonatal medicine. Currently, the early diagnosis of SHB-related brain injury primarily relies on clinical manifestations and laboratory tests. Common diagnostic methods include serum bilirubin level detection, auditory brainstem response (ABR) testing, and transcranial Doppler ultrasound. However, these methods all have certain limitations. For example, although serum bilirubin level is the primary diagnostic indicator for SHB, its correlation with brain injury is not entirely consistent, and there are differences in bilirubin tolerance thresholds among different individuals.[5–7] Additionally, auditory brainstem

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response testing can be used to assess the impact of kernicterus on the auditory pathway, but it has low sensitivity for screening early brain injury and is prone to false-negative results. Therefore, finding more reliable early diagnostic methods to improve the recognition rate of SHB-related brain injury is currently a focus of clinical research.[8,9]

This study intends to retrospectively analyze the NBNA scores and cranial MRI manifestations of neonatal SHB patients and compare them with those of children with general hyperbilirubinemia to explore the application value of NBNA scores combined with MRI in the diagnosis of SHB-related brain injury. The main objectives of this study include: (1) comparing the NBNA scores, MRI imaging characteristics, and total bilirubin levels between neonates with SHB and children with general hyperbilirubinemia; (2) analyzing the correlation between NBNA scores, MRI, and SHB brain injury; (3) evaluating the diagnostic efficacy of NBNA combined with MRI in predicting SHB brain injury. Through this study, we hope to establish a more precise early screening strategy to improve the recognition rate of SHB-related brain injury, guide clinical early intervention, reduce the incidence of long-term neurological complications, and enhance the quality of life of affected children.

Materials and Methods

Subjects

This study was designed as a retrospective study, collecting all cases of neonatal severe hyperbilirubinemia admitted to our hospital from December 2022 to October 2024 as the research subjects. Using a 1:1 case-control matching design, key variables such as age, gender, and birth weight were paired to control for confounding factors. The sample size was limited by the 24 month time span of the single center retrospective study. After strictly screening according to complete inclusion criteria, a total of 25 cases were included in the experimental group, and 25 cases of general hyperbilirubinemia children born in our hospital during the same period were included in the control group. This study was approved by the Ethics Committee of Pidu District People's Hospital of Chengdu City. This study adhered to the Declaration of Helsinki. Since this is a retrospective study, it has been approved by the Ethics Committee of our hospital to waive the requirement for guardian informed consent. All patient data undergoes rigorous privacy protection measures: Before data collection, personal identifiable information (eg, names and ID numbers) is anonymized to remove identifiable details. A hierarchical access control system ensures only authorized researchers can access the complete dataset. When research findings are published, all clinical data is presented in aggregated form to eliminate risks of individual information leakage.

Inclusion and Exclusion Criteria

Inclusion criteria: Children in the experimental group needed to meet the diagnostic criteria for SHB (According to the AAP guidelines, a total bilirubin level exceeding the 95th percentile of newborns of the same gestational age is defined as SHB) and have significantly elevated serum bilirubin levels;[10–12] gestational age must be 35 weeks or more, with no other complications after birth; all children must have completed NBNA score assessment; MRI should be performed as early as possible after admission (within 24–72 hours after admission), and cranial MRI should be conducted after sedation with 5% chloral hydrate enema.

Exclusion criteria: Children with congenital neurological diseases were excluded; those with a history of perinatal asphyxia or intracranial infection were not included in the study; those with incomplete follow-up data or missing key data were also excluded. Additionally, children with other diseases affecting nervous system development, such as cranial hematoma, hypoxic-ischemic encephalopathy, intracranial hemorrhage, and congenital cranial malformations, were excluded.

The inclusion criteria for the control group are newborns born at the same time, with gestational age $\geq$ 37 weeks, birth weight $\geq$ 2500g, and no history of perinatal asphyxia. Newborns without a history of SHB and with normal NBNA scores ($\geq$ 35 points) at birth, and no abnormal signals observed on cranial MRI" during the research design phase.

Research Methods

The NBNA score was completed by trained professional physicians within 24–72 hours after neonatal admission in a quiet and warm environment, with the testing process controlled within 10 minutes. The scoring will be based on the 20 evaluation scales developed by the Capital Institute of Pediatrics, with each item rated at three levels of 0–2 points.

A total score of ≥ 35 points is considered normal. The assessment covered five aspects: behavioral ability, passive and active muscle tone, primitive reflexes, and general condition, with each item scored from 0–2 points, totaling 40 points. The scoring criteria were as follows: >37 points were considered normal, 35–37 points were considered borderline, and <35 points suggested possible brain injury or neurological dysfunction.

Before cranial MRI examination, 5% chloral hydrate enema sedation was administered to the child to ensure the smooth progress of the examination. Using GE Discovery MR750 3.0T scanner, T1WI using FSE sequence (TR 450ms/TE 12ms), T2WI using FLAIR sequence (TR 8000ms/TE 120ms). After scanning, the image data were transmitted to the image analysis workstation, and two radiologists jointly reviewed and evaluated the images. The relative signal intensity (RSI) of the basal ganglia, globus pallidus, and thalamic regions was observed, and the presence of abnormal signal manifestations was judged. RSI values were independently measured by two senior radiologists and averaged, and consistency was verified using intra group correlation coefficient (ICC=0.85). The imaging features of SHB-related brain injury were mainly manifested as symmetric hyperintensity of the globus pallidus and thalamus on T1WI sequences during the acute phase. Additionally, the ratio of ASI (apparent signal intensity) within the ROI (region of interest) between the GP (globus pallidus) area and the CSF (cerebrospinal fluid) area was calculated, ie, the relative signal intensity (RSI) of the GP area.

Brain injury assessment criteria: Based on the NBNA score, MRI results, and clinical manifestations, it was determined whether the child had brain injury.

Serum bilirubin detection: 1.5mL of venous blood was drawn from the research subjects, and the total bilirubin level was measured using an automated biochemical analyzer.

Statistical Analysis

SPSS 26.0 software was used for data analysis, and GraphPad Prism 8 was used for image processing. Measurement data were expressed as mean ± standard deviation ($\overline{x} \pm s$), and the *t*-test was used for intergroup comparisons. Count data were expressed as rates (%), and the χ^2-test was used. Using chi square test to compare categorical variables and positive/negative predictive values to evaluate diagnostic efficacy. A P-value <0.05 was considered statistically significant.

Results

General Information

The experimental group and the control group were comparable in baseline characteristics. The experimental group consisted of 25 neonates with severe hyperbilirubinemia (SHB), with an average gestational age of 38.25±1.17 weeks and an average birth weight of 3011.89±352.85 g. The control group included 25 neonates with general hyperbilirubinemia, with an average gestational age of 38.14±1.22 weeks and an average birth weight of 3052.14±325.25 g. There were no significant differences in gestational age (t=0.325, P=0.746) or birth weight (t=0.419, P=0.677) between the two groups. In terms of gender distribution, the experimental group had 17 males (68.00%) and 8 females (32.00%), while the control group had 18 males (72.00%) and 7 females (28.00%). There was no statistical difference in gender proportion (χ^2=0.081, P=0.776) (Table 1).

NBNA Scores

The neonatal behavioral neurological assessment (NBNA) scores of the experimental group were significantly lower than those of the control group. The average NBNA score in the experimental group was 34.2±3.8 points (range: 28–38 points), with 15 cases (60.00%) scoring below 35 points (indicating a risk of brain injury). In contrast, the control group had an average score of 38.9±1.1 points (range: 37–40 points), with all neonates scoring ≥37 points (within the normal range). The difference in scores between the two groups was statistically significant (t=6.74, P<0.001), indicating the presence of neurological abnormalities in neonates with SHB (Figure 1).

Table 1 Comparison of General Information Between the Two Groups of Study Subjects

		Control Group	Experimental Group	t	*P*
Number of cases	–	25	25	–	–
Gender	Male	18	17	–	–
–	Female	12	13	–	–
Gestational age (weeks)	Mean	38.14±1.22	38.25±1.17	0.325	0.746
Birth weight (g)	Mean	3052.14±325.25	3011.89±352.85	0.419	0.677

Total Bilirubin Levels

The total bilirubin levels in the experimental group were significantly higher than those in the control group. The average serum total bilirubin level in the experimental group was 390.68±22.61 μmol/L, compared to 280.65±23.23 μmol/L in the control group, with a significant difference (t=16.971, P<0.001) (Figure 2).

RSI Values

The relative signal intensity (RSI) of the globus pallidus (GP) on MRI was significantly increased in the experimental group. The average RSI in the GP region of the experimental group was 1.52±0.18, significantly higher than the 1.12 ±0.09 in the control group (t=10.65, P<0.001). Among the experimental group, 10 cases (40.00%) had an RSI>1.5 in the GP region, indicating brain injury caused by bilirubin deposition, while no such abnormalities were observed in the control group (Figure 3).

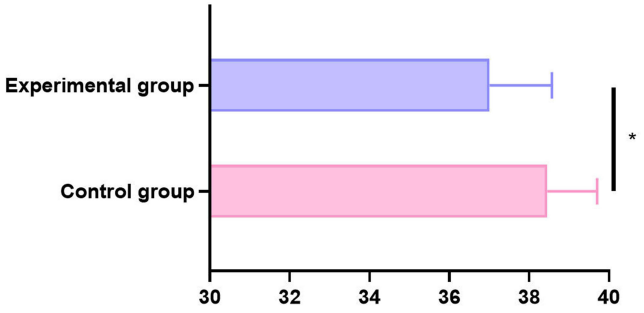

Figure 1 Comparison of NBNA scores between the two groups of study subjects.
Note: *Indicates a difference between the two groups, P<0.05.

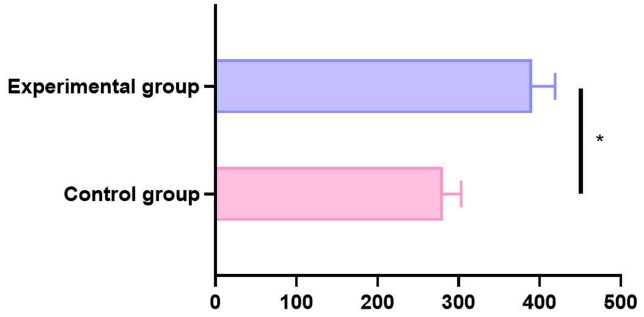

Figure 2 Comparison of total bilirubin levels between the two groups of study subjects.
Note: *Indicates a difference between the two groups, P<0.05.

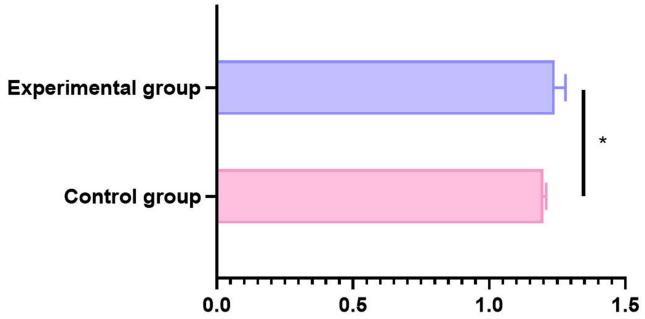

Figure 3 Comparison of RSI values in the GP region between the two groups of study.
Note: *Indicates a difference between the two groups, P<0.05.

Relationship Analysis

Neurological impairment was more pronounced in neonates with abnormal MRI findings. In the experimental group, the average NBNA score of the 10 neonates with abnormal GP regions on MRI was lower than that of the 15 neonates with normal MRI findings (P<0.05). Additionally, the onset time of SHB was shorter in the MRI-abnormal group (4.01±1.54 days vs 5.73±1.23 days, P<0.001), suggesting a close association between early hyperbilirubinemia and the risk of brain injury (Table 2).

Predictive Value

The predictive accuracy of neonatal behavioral neurological assessment scores combined with cranial MRI for brain injury was higher than that of a single diagnostic method, P<0.05. See Table 3.

Discussion

Neurological damage caused by severe hyperbilirubinemia (SHB) mainly stems from the toxic effects of unconjugated bilirubin (UCB) on the central nervous system.[13,14] Due to the immaturity of the blood-brain barrier in neonates, UCB can easily penetrate the barrier and deposit in high-metabolic brain regions such as the basal ganglia, globus pallidus, and thalamus, damaging neurons and affecting neural development. Accumulation of bilirubin can trigger abnormalities in

Table 2 Correlation Between MRI Findings, NBNA Scores, and the Onset Time of Severe Hyperbilirubinemia

	MRI Normal	MRI Abnormal	*t*	*P*
Number of cases	15	10	–	–
NBNA score	37.91±0.85	37.08±0.69	2.569	0.017
Onset of severe hyperbilirubinemia (d)	4.01±1.54	5.73±1.23	4.364	<0.001

Table 3 Predictive Value of NBNA Scores and Cranial MRI

	NBNA Score	MRI	Joint	*P*
Sensitivity	35.14	61.25	82.14	–
Specificity	92.14	70.56	95.22	–
Accuracy	84.32	70.56	94.12	<0.05

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glial and mitochondrial function, ultimately leading to cell injury or even apoptosis.[15–17] Therefore, early identification and assessment of brain injury in children with SHB are crucial for improving prognosis.

In terms of clinical evaluation, the Neonatal Behavioral Neurological Assessment (NBNA) score is a commonly used tool that reflects the functional state of the nervous system in terms of behavioral ability, muscle tone, and primitive reflexes. Studies have shown that this score has certain value in the assessment of hypoxic-ischemic encephalopathy (HIE) and brain injury in premature infants. However, NBNA can only reflect abnormal neural function and cannot directly display structural changes in brain tissue injury, making imaging examinations a necessary complement.[18–20] MRI, with its high-resolution imaging capabilities, can visually display lesions in areas such as the basal ganglia, globus pallidus, and brainstem, and is particularly important in the assessment of bilirubin encephalopathy. Its typical imaging manifestations include T1WI hyperintensity and T2WI hypointensity, while quantitative analysis techniques such as relative signal intensity (RSI) measurement can further assess the degree of brain tissue injury.[21,22] However, due to the accessibility and cost limitations of MRI equipment, it is difficult to promote its use in all neonates. Therefore, combining NBNA scoring with comprehensive assessment can improve the accuracy of early screening while optimizing the allocation of medical resources.

The results of this study showed that the NBNA scores of children with SHB were significantly lower than those of the control group of children with general hyperbilirubinemia ($P<0.05$), indicating that high bilirubin levels may affect neural function. The NBNA score can sensitively detect mild impairment of the nervous system and reflect a decline in neural regulatory capacity even in children without obvious clinical symptoms. This study further found that the serum total bilirubin levels of children in the experimental group were higher than those in the control group and were negatively correlated with NBNA scores, suggesting potential damage to the nervous system by bilirubin. The results of this study are consistent with previous literature and support the importance of early intervention in reducing the risk of long-term neurodevelopmental impairment.

MRI findings indicated that the relative signal intensity (RSI) values of the basal ganglia and globus pallidus in children with SHB were significantly higher than those in the control group ($P<0.05$), suggesting that bilirubin deposition may lead to structural damage in these brain regions. Imaging features include symmetric hyperintensity in the basal ganglia and thalamus on T1WI sequences and possible hypointensity on T2WI sequences, reflecting the specific effects of bilirubin on brain tissue. Follow-up studies have found that if T2WI remains hyperintense after 2–3 months, it suggests a poorer prognosis. MRI not only provides a visual assessment of SHB-related brain injury but can also be used for disease monitoring and prognosis prediction.

This study further confirmed that the NBNA scores of children with abnormal MRI findings in the SHB group were significantly lower than those in the normal MRI group, and serum total bilirubin levels were higher, with a negative correlation between the two. Additionally, the earlier the onset of SHB, the higher the risk of abnormal MRI findings. Therefore, children with early SHB should routinely undergo NBNA scoring and MRI examinations, combined with follow-up assessments of brain injury, to facilitate timely intervention and optimize prognosis.

Both NBNA scoring and MRI examinations can be used to assess SHB-related brain injury, but each has certain limitations. NBNA can reflect abnormal neural function but lacks direct imaging evidence; MRI, while capable of detecting structural damage to brain tissue, may be relatively delayed in identifying early functional abnormalities. This study found that the diagnostic accuracy of combined NBNA and MRI applications was significantly better than that of a single method ($P<0.05$), suggesting that combined assessment can improve the early identification rate of SHB brain injury and provide a more reliable basis for screening and intervention in high-risk children.[23–25]

Although this study confirmed the importance of NBNA scoring combined with MRI in the diagnosis of SHB brain injury, there are still certain limitations. Firstly, this study was a single-center retrospective study with a relatively small sample size, which may affect the generalizability of the results. Secondly, this study did not conduct long-term follow-up of children with SHB and lacked systematic observation of long-term neurodevelopmental outcomes. Additionally, this study did not deeply explore the quantitative relationship between bilirubin levels and abnormal MRI signals.

Future studies should expand the sample size and conduct multi-center, large-scale prospective studies to further verify the reliability of NBNA scoring combined with MRI in the diagnosis of SHB brain injury.[26,27] Additionally, combining neurobiomarkers (such as S100B protein, neurofilament light chain protein, etc.) with advanced MRI

techniques (such as diffusion tensor imaging, magnetic resonance spectroscopy analysis, etc.) can deeply explore the specific damage mechanisms and long-term effects of bilirubin on the central nervous system.[28–30] Furthermore, long-term follow-up of children with SHB should be strengthened to assess their motor, cognitive, language, and social abilities, in order to comprehensively understand the long-term prognosis of SHB-related brain injury and provide a basis for clinical formulation of individualized intervention measures.

Based on the preliminary findings of this study, we have initiated a multicenter prospective cohort study that plans to include 500 SHB newborns. The study will use standardized NBNA assessment procedures and 3.0T MRI quantitative analysis techniques (DWI/DTI sequences), with four follow-up time points at 1 week, 1 month, 3 months, and 6 months after birth, focusing on monitoring neurodevelopmental outcome indicators.

Conclusion

In summary, NBNA scoring combined with cranial MRI can effectively improve the early diagnosis rate of SHB-related brain injury and provide important references for clinical early identification of high-risk children. NBNA scoring can reflect abnormal neural function, while MRI can provide imaging evidence of brain injury, and the combination of the two can improve the sensitivity and specificity of diagnosis. Future research should further optimize assessment methods and combine long-term follow-up data to explore more precise early screening strategies for SHB brain injury, in order to improve the neurodevelopmental prognosis of affected children.

Disclosure

The authors declare that they have no competing interests.

References

1. Par EJ, Hughes CA, DeRico P. Neonatal hyperbilirubinemia: evaluation and treatment. *Am Fam Physician*. 2023;107(5):525–534.
2. Muchowski KE. Evaluation and treatment of neonatal hyperbilirubinemia. *Am Fam Physician*. 2014;89(11):873–878.
3. Lee B, Piersante T, Calkins KL. Neonatal hyperbilirubinemia. *Pediatr Ann*. 2022;51(6):e219–e227.
4. Lauer BJ, Spector ND. Hyperbilirubinemia in the newborn. *Pediatr Rev*. 2011;32(8):341–349. doi:10.1542/pir.32.8.341
5. Alkén J, Håkansson S, Ekéus C, et al. Rates of extreme neonatal hyperbilirubinemia and kernicterus in children and adherence to national guidelines for screening, diagnosis, and treatment in sweden. *JAMA Network Open*. 2019;2(3):e190858. doi:10.1001/jamanetworkopen.2019.0858
6. Farouk ZL, Usman F, Musa BM, et al. Societal awareness on neonatal hyperbilirubinemia: a systematic review and meta-analysis. *Semin Perinatol*. 2021;45(1):151361. doi:10.1016/j.semperi.2020.151361
7. Hulzebos CV, Vitek L, Coda Zabetta CD, et al. Screening methods for neonatal hyperbilirubinemia: benefits, limitations, requirements, and novel developments. *Pediatr Res*. 2021;90(2):272–276. doi:10.1038/s41390-021-01543-1
8. Rivero A, Ollaquindia P, Acha B. Waiting for severe hyperbilirubinemia. *Clin Chem*. 2018;64(6):981. doi:10.1373/clinchem.2017.281022
9. Bhardwaj K, Locke T, Biringer A, et al. Newborn bilirubin screening for preventing severe hyperbilirubinemia and bilirubin encephalopathy: a rapid review. *Curr Pediatr Rev*. 2017;13(1):67–90. doi:10.2174/1573396313666170110144345
10. Kemper AR, Newman TB, Slaughter JL, et al. Clinical practice guideline revision: management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. *Pediatrics*. 2022;150(3). doi:10.1542/peds.2022-058859
11. Schwoebel A, Gennaro S. Neonatal hyperbilirubinemia. *J Perinat Neonatal Nurs*. 2006;20(1):103–107. doi:10.1097/00005237-200601000-00030
12. Pace EJ, Brown CM, DeGeorge KC. Neonatal hyperbilirubinemia: an evidence-based approach. *J Fam Pract*. 2019;68(1):E4–e11.
13. Christensen RD, Yaish HM. Hemolytic disorders causing severe neonatal hyperbilirubinemia. *Clin Perinatol*. 2015;42(3):515–527. doi:10.1016/j.clp.2015.04.007
14. Kaplan M, Bromiker R, Hammerman C. Severe neonatal hyperbilirubinemia and kernicterus: are these still problems in the third millennium? *Neonatology*. 2011;100(4):354–362. doi:10.1159/000330055
15. Hegyi T, Kleinfeld A. Neonatal hyperbilirubinemia and the role of unbound bilirubin. *J Matern Fetal Neonatal Med*. 2022;35(25):9201–9207. doi:10.1080/14767058.2021.2021177
16. Huang J, Zhao Q, Li J, et al. Correlation between neonatal hyperbilirubinemia and vitamin D levels: a meta-analysis. *PLoS One*. 2021;16(5):e0251584. doi:10.1371/journal.pone.0251584
17. Du L, Ma X, Shen X, et al. Neonatal hyperbilirubinemia management: clinical assessment of bilirubin production. *Semin Perinatol*. 2021;45(1):151351. doi:10.1016/j.semperi.2020.151351
18. Wu H, Li Z, Liu J, et al. Clinical study on amplitude integrated electroencephalogram in cerebral injury caused by severe neonatal hyperbilirubinemia. *Minerva Pediatr*. 2018;70(6):539–544. doi:10.23736/S0026-4946.17.04792-2
19. Davis-Lewis B. The NBNA: working through barriers to help our own and others survive a crisis. *J Natl Black Nurses Assoc*. 2005;16(2):vi.
20. Zhang XL, Liu Y-C, Xia L, et al. Role of neonatal behavioral neurological assessment combined with magnetic resonance diffusion tensor imaging in evaluating white matter development in preterm infants. *Zhongguo Dang Dai Er Ke Za Zhi*. 2021;23(9):916–921. doi:10.7499/j.issn.1008-8830.2106005
21. Abbey P, Kandasamy D, Naranje P. Neonatal jaundice. *Indian J Pediatr*. 2019;86(9):830–841. doi:10.1007/s12098-019-02856-0

22. Li Q, Deng X, Yan J, et al. Neonatal severe hyperbilirubinemia online registry in Jiangsu province: protocol for a multicentre, prospective, open, observational cohort study. *BMJ Open*. 2021;11(2):e040797. doi:10.1136/bmjopen-2020-040797
23. Dai C, Chen C, Jiang L, et al. Severe neonatal hyperbilirubinemia secondary to combined RhC hemolytic disease, congenital hypothyroidism and large adrenal hematoma: a case report. *BMC Pediatr*. 2022;22(1):539. doi:10.1186/s12887-022-03594-7
24. Groenendaal F, Grond JVD, Vries LSD. Cerebral metabolism in severe neonatal hyperbilirubinemia. *Pediatrics*. 2004;114(1):291–294. doi:10.1542/peds.114.1.291
25. Shapiro SM. *Chronic bilirubin encephalopathy: diagnosis and outcome*. *Semin Fetal Neonatal Med*. 2010;15(3):157–163.
26. Yuan X, Song J, Gao L, et al. Early Amplitude-Integrated electroencephalography predicts Long-Term outcomes in term and Near-Term newborns with severe hyperbilirubinemia. *Pediatr Neurol*. 2019;98:68–73. doi:10.1016/j.pediatrneurol.2019.04.015
27. Kalinke L, Rashid M. A cholestatic diagnostic dilemma. *BMJ Case Rep*. 2013;2013.
28. Chang PW, Newman TB, Maisels MJ. Update on predicting severe hyperbilirubinemia and bilirubin neurotoxicity risks in neonates. *Curr Pediatr Rev*. 2017;13(3):181–187. doi:10.2174/1573396313666170123151408
29. Olusanya BO, Kaplan M, Hansen TWR. Neonatal hyperbilirubinaemia: a global perspective. *Lancet Child Adolesc Health*. 2018;2(8):610–620. doi:10.1016/S2352-4642(18)30139-1
30. Olusanya BO, Osibanjo FB, Slusher TM. Risk factors for severe neonatal hyperbilirubinemia in low and middle-income countries: a systematic review and meta-analysis. *PLoS One*. 2015;10(2):e0117229. doi:10.1371/journal.pone.0117229