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Original Article

Application value of evidence-based nursing based on the Plan-Do-Check-Action cycle in the nursing of neonatal hypoxic ischemic encephalopathy

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Abstract: Objective: To explore the application value of evidence-based nursing (EBN) based on a Plan-Do-Check-Action (PDCA) cycle, in the nursing of neonatal hypoxic ischemic encephalopathy (HIE). Methods: A total of 80 neonates with HIE were enrolled in our study, which was a randomized controlled clinical trial; neonates were randomly divided into an observation group (n = 40) and a control group (n = 40) according to a random number table method. The neonates in the control group were treated with routine nursing, and the neonates in the observation group were treated with EBN based on the PDCA cycle. All the neonates were followed up for 18 months after discharge. The length of hospital stay, adverse outcomes during hospitalization, and adverse prognosis events of neonates as well as psychological condition at discharge, mastery of health knowledge, and nursing satisfaction of neonates' families were compared between the two groups. Neonatal behavioral neurological assessment was used to evaluate the recovery of neurological function of neonates in the two groups at discharge, two weeks after discharge, and 1 month after discharge. Mental development index, psychomotive development index and Gesell scale were used to evaluate the intellectual development of neonates in the two groups at 3, 6, 12 and 18 months after discharge. Results: Compared with the control group, there were lower length of hospital stay as well as scores of Self-Rating Anxiety Scale and Self-Rating Depression Scale, and higher scores of mastery of health knowledge as well as nursing satisfaction in the observation group ($P < 0.05$). The scores of neonatal behavioral neurological assessment, mental development index, psychomotive development index, and Gesell scale in the observation group were significantly higher than those in the control group after discharge ($P < 0.05$). There was no significant difference in the incidence of adverse events during hospitalization and adverse prognosis events between the two groups ($P > 0.05$). Conclusion: EBN based on the PDCA cycle can effectively shorten the length of hospital stay of neonates with HIE and improve the recovery of neurological function and intellectual development. It also can improve the confidence and psychological state of the neonates' families effectively.

Keywords: Hypoxic ischemic encephalopathy, neonate, Plan-Do-Check-Action cycle, evidence-based nursing, neurological recovery, intellectual development

Introduction

Neonatal hypoxic ischemic encephalopathy (HIE) is defined as ischemic and hypoxic injury of brain tissue resulting from hypoxia and decrease of cerebral blood flow in neonates after birth, which can result in a number of complications such as brain edema, necrosis of brain parenchyma and hydrocephalus [1, 2]. HIE is one of the most common causes of post-neonatal disabilities in neonates [3]. HIE can not only lead to subsequent intellectual development disorders, but also cause irreversible damage to brain tissue and death in neonates [2]. According to World Health Organization (WHO) data released in 2003, neonatal deaths accounted for 37% of all deaths among children under the age of 5 as well as in neonates [4]. With the progress of medical treatment technology, the mortality of HIE has been significantly reduced, but mental retardation caused by HIE is still a challenge in the clinic.

Neonates with HIE receive treatment and care mainly in the closed management of the neonatal ward, and nursing is an important guarantee

for the implementation of treatment plans and rehabilitation after treatment [5]. Neonatal HIE nursing has been identified as one of the difficulties in clinical care. On the one hand, the development of organs in neonates is immature due to the insufficient term after birth; on the other hand, the conditions of neonates are very poor because of HIE [6, 7]. There are many reports about the content of neonatal HIE nursing, but the following shortcomings still exist [8-10]. First, neonatal HIE nursing pays more attention to the conditions in neonates, neglecting the psychological state of their families, without attention to out-of-hospital rehabilitation nursing of neonates. Second, a fixed nursing protocol was applied for all neonates due to poor nursing work flexibility. The reports on HIE nursing models are mainly the Plan-Do-Check-Action (PDCA) cycle management and evidence-based nursing (EBN). However, the implementation of EBN is not flexible and the nursing content is fixed. The content of PDCA cycle management is flexible but its nursing content is limited, and it cannot effectively combine clinical evidence to develop more comprehensive care.

This study adopted the EBN model based on the PDCA cycle for neonates with HIE, which has not been reported previously. EBN can effectively increase the comprehensiveness of nursing content, and PDCA cycle management can effectively improve the flexibility of EBN content in implementation.

Materials and methods

General information

A total of 80 neonates with HIE were enrolled in our study, which was a prospective randomized controlled clinical trial from December 2015 to July 2018.

Inclusion criteria: Neonates met the latest definition of newborn stipulated by WHO (≤ 28 days) [11]; neonates met the clinical diagnostic criteria for HIE [12]; neonates received conventional and hypothermia therapy within 6-12 h of birth; the family members of neonates have good literacy and communication and can cooperate with the corresponding scale assessment.

Exclusion criteria: Neonates born with congenital diseases such as malformation and limb insufficiency; neonates whose family members were expected to be less cooperative; neonates whose family members were unwilling to cooperate with the study for long-term follow-up.

This study was based on the requirements of the Declaration of Helsinki of the World Medical Association and was approved by the medical Ethics Committee of The First Affiliated Hospital, Sun Yat-sen University. All family members of the neonates participated in our study voluntarily and signed the informed consent.

Methods

The neonates were randomly divided into the observation group (n = 40) and the control group (n = 40) upon admission. The neonates in the control group received routine care and the neonates in the observation group received EBN based on the PDCA cycle. The family members of neonates in both groups were informed about the matters needing attention during hospitalization. All family members of neonates signed the informed consent after they were informed. Neonates who didn't meet the requirements of our study were excluded.

Clinical treatment of neonates: After diagnosis, all the neonates were treated with routine maintenance therapy for regular ventilation and gas exchange. Normal blood perfusion of organs and basic vital signs such as blood glucose and blood pressure were maintained. The symptomatic treatments for neonates including decreasing intracranial pressure, controlling convulsions, and eliminating brainstem symptoms were performed. Head hypothermia combined with mild systemic hypothermia was performed for all neonates within 6-12 h after diagnosis to keep the temperature of the nasopharynx at 33-34°C and anus at 34-35°C, and natural rewarming was conducted after 72 h. During treatment, all neonates received hospital nursing with corresponding nursing measures.

Nursing of neonates in the control group: The neonates in the control group were treated with routine basic nursing. Therapeutic procedures prescribed by the doctor's orders were performed. Nutrition support, reducing intracranial pressure, keeping neonates warm, feeding, skin and respiratory tract care, and other nurs-

ing measures were given. The monitoring of changes in symptoms, signs, and illness of neonates was enhanced. Targeted treatments were performed immediately if changes were found. Health education for family members of neonates was conducted at discharge, and their family members were reminded of timely follow-up.

Nursing of neonates in the observation group: The neonates in the observation group were treated with EBN based on the PDCA cycle. The method of EBN was adopted first to summarize the problems and solutions in the previous studies and clinical practice of neonatal HIE nursing, then the method of Plan, Do, Check, and Action, a four-stage cycle management was adopted for the management of multiple evidence-based results. The management of EBN based on the PDCA cycle can more efficiently ensure the effective application of the content of EBN for neonates. A nursing group for neonates with HIE was set up, and the group consisted of a group leader and key nursing staff mainly responsible for the program development and implementation.

Evidence-based nursing: A literature search on neonatal HIE nursing was performed through Pubmed, Google scholar and other platforms, and nursing measures available were screened according to the display conditions in The First Affiliated Hospital, Sun Yat-sen University. The evidence-based process showed the main problems in the current clinical nursing of neonatal HIE. First, lack of rehabilitation nursing content: There are insufficient rehabilitation nursing measures for neonates during hospitalization after treatment, which is not conducive to the early recovery of neurological function in neonates. Second, lack of systematic nursing for neonates: Systematic nursing should be provided in the direction of aspiration, limbs, signs, feeding and environmental problems. Third, lack of enough attention to neonates' families: The negative emotions of neonates' families were not valued and there is insufficient training in health education knowledge. Forth, lack of sufficient continuous nursing: Out-of-hospital nursing of neonates mainly relies on their family members, and the nursing staff don't provide continuous nursing for neonates. Fifth, lack of flexible nursing content: There is insufficient individualized nursing content, and the adjustments to nursing programs aren't made regularly [13-17].

PDCA cycle management: (1) Plan: The nursing team discussed the evidence-based results and worked out the implementation programs of rehabilitation nursing, systematic nursing, psychological intervention in neonates' families, strengthening of health knowledge training for neonates' families, and continuous nursing. After discussion, it was made clear that rehabilitation care and psychological intervention in neonates' families were also considered as part of systematic nursing, and health knowledge training for neonates' families was regarded as the beginning of continuous nursing. PDCA cycle management could effectively guarantee the implementation and flexibility of EBN. Therefore, the nursing team decided to make the implementation plan from two aspects: systematic nursing and continuous nursing during hospitalization.

(2) Do: Systematic nursing: First, a good hospital environment should be guaranteed. Disinfection was performed more than twice a day. The temperature was controlled at 25±2°C and the humidity was controlled at 60±10%. The hearing and vision of neonates were stimulated through music and decorations in front of the bed. Second, the symptomatic nursing of neonates during treatment was enhanced. The mucus from the respiratory tract and oral cavity was removed in a timely manner. Artificial aspiration or positive pressure ventilation were performed if necessary. The feeding mode was nasal feeding. The changes of neonates' signs were monitored. Third, the rehabilitation nursing content during rehabilitation period after treatment was enhanced. Stroking-like massage of limbs and torso of neonates was performed with soft body parts such as palm, thenar muscle and hypothenar muscle. The massage was performed twice every day, once in the morning and once in the evening, and the time of each massage was not less than 15 min. Forth, psychological interventions in neonates' families were strengthened. The physicians communicated with the neonates' families about the disease-related knowledge. The neonates' families were told about the disease development of neonates, and treatment regimen and success cases of HIE were introduced. The family members of neonates were guided to reasonably release their negative emotions such as tension and anxiety. A good relationship was established between medical staff and neonates' families to relieve their negative

emotions and improve the compliance of neonates' families to cooperate with the treatment.

Continuous nursing after discharge: First, the content of nursing promotion materials for neonates with HIE was enriched. The nursing manuals and subject videos for HIE neonates developed by The First Affiliated Hospital, Sun Yat-sen University were handed out to neonates' families for learning autonomously, during hospitalization. Second, the training and assessment in health knowledge of neonate's families were strengthened. Thematic learning activities were organized at least once a week, and the neonates' family members were organized to study together. All neonates' family members received training from the mainstay of nursing staff and completed the assessment at discharge. The training content mainly included scientific feeding, bathing, touching, umbilical nursing, and early rehabilitation exercise. Third, responsibility system of specially-assigned person was instituted during continuous nursing. Each nursing staff was responsible for the continuous nursing of ten neonates. Nursing staff communicated with neonates' family members about the problems of out-of-hospital nursing and corresponding solutions through telephone follow-up weekly and taught the nursing experience to them. Prompt attention to neonates was paid, and the neonates' family members were guided to return to the hospital for medical visits with neonates when adverse events occurred. During the outpatient follow-up at 3, 6, 12, and 18 months after discharge, the health education knowledge of neonates' family members was reviewed by professional nursing staff to correct their wrong nursing methods. The clinical significance of out-of-hospital home rehabilitation to the neurological function and intellectual recovery of neonates was emphasized to improve the nursing consciousness of neonates' family members.

(3) Check: The centralized training of nursing staff and self-examination during nursing process were strengthened.

(4) Action: In the weekly meetings, the nursing staff was trained by the mainstay of nursing staff. The problems in the process of nursing and corresponding solutions were discussed and studied. The actual situations of each neonate and parturient were collected and sorted out. On this basis, the conditions of the neonates were accessed and the applicability of nursing content to neonates and was checked regularly by the nurse who was in charge of the specific work according to the actual situations of the neonates. Based on this, the PDCA cycle began and the nursing content was improved constantly.

Outcome measures

The main outcome measures included neurological recovery and intellectual development of neonates in both groups after discharge from hospital. The secondary outcome measures included the length of hospital stay, adverse events during hospitalization, and incidence of adverse events in neonates as well as the negative emotion score, the mastery of health knowledge and the nursing satisfaction of neonates' family members.

The length of hospital stay and adverse events during hospitalization of neonates in both groups: The adverse events mainly included pneumonia and death, and the total incidence = (pneumonia cases + death cases)/total number of cases * 100%.

The negative emotion score of family members of neonates in both groups: Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS) were used to evaluate anxiety and depression of neonates' family members separately at admission and discharge. SAS scores ≥ 50 were correlated with anxiety and SDS scores ≥ 53 were correlated with depression. Higher scores of SAS and SDS indicate a higher degree of anxiety and depression [18].

The mastery of health knowledge of family members of neonates in both groups: The mastery of health knowledge of family members was evaluated according to the Health Knowledge Questionnaire of HIE relevant to neonates' family members. The content of evaluation included disease knowledge, feeding knowledge, medication knowledge, treatment knowledge, and rehabilitation knowledge. Each evaluation had a score of 10 points, and a score of > 8 was regarded as mastering the knowledge of corresponding part [19].

Neurological recovery of neonates in both groups: Neonatal behavioral neurological assessment (NBNA) score was used to evaluate the neurological recovery of neonates at dis-

Table 1. Comparison of baseline data

Items	Observation group (n = 40)	Control group (n = 40)	χ^2/t	P
Gestational age (weeks)	38.1±1.4	38.5±1.5	1.233	0.221
Sex (n)				
Male	23 (57.50)	26 (65.00)	0.474	0.491
Female	17 (42.50)	14 (35.00)		
Birth weight (kg)	3.42±0.63	3.32±0.54	0.762	0.448
Apgar scale (score)	5.14±1.07	5.02±1.20	0.472	0.638
Severity of illness* (n)			0.325	0.627
Mild	10 (25.00)	9 (22.50)		
Moderate	20 (50.00)	18 (45.00)		
Severe	10 (25.00)	13 (32.50)		

Note: *The severity of HIE is judged according to the clinical manifestations. Mild: irritability and excitement; Moderate: suppressive symptoms; Severe: coma [12]. HIE: hypoxic ischemic encephalopathy.

Table 2. Length of hospital stay and incidence of adverse events during hospitalization

Items	Control group (n = 40)	Observation group (n = 40)	χ^2/t	P
Length of hospital stay (d)	20.43±5.68	15.22±4.51	4.543	< 0.001
Pneumonia	3	1	0.263	0.608
Death	0	0		
Incidence of adverse events	3 (7.50%)	1 (2.50%)	0.263	0.608

charge, 2 weeks after discharge and 1 month after discharge. The NBNA scale includes 20 items of evaluation, and the total score is 40 points. A higher score indicates a better recovery [20].

The intellectual development of neonates in both groups: Mental development index (MDI), psychomotive development index (PDI) and Gesell scale scores were used to evaluate the intellectual development of neonates in the two groups at 3, 6, 12, and 18 months after discharge [21].

The nursing satisfaction of family members of neonates in both groups: At the time of last follow-up, satisfaction with nursing was accessed by neonates' family members autonomously according to Nursing Satisfaction Survey Scale developed by The First Affiliated Hospital, Sun Yat-sen University. The scale was divided according to satisfaction into "very satisfied", "satisfied", "slightly satisfied", "dissatisfied" and "very dissatisfied". Satisfaction rate = (very satisfied cases + satisfied cases)/total number of cases * 100%.

The incidence of adverse events: The adverse events mainly included cerebral palsy and unresponsiveness. Total incidence rate = (number of neonates with cerebral palsy + number of neonates with unresponsiveness)/total number of neonates * 100%.

Statistical analysis

SPSS 24.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The enumeration data such as incidence of adverse events and nursing satisfaction of neonates' family members were expressed as number (n) and percentage (%) Data were analyzed using Pearson's χ^2 test ($n \geq 40$ but $T \geq 5$), χ^2 test with continuity correction ($n \geq 40$ but $1 \leq T < 5$) and Fisher's test ($n < 40$ or $T < 1$). The measurement data such as NBNA, MDI, PDI, and Gesell scale were expressed as mean ± standard deviation ($\bar{x}$ ± sd). Intergroup comparisons were conducted by independent-sample t-tests, while intragroup comparisons were analyzed by paired-sample t-tests. All statistical tests were two-sided with α set to 0.05. $P < 0.05$ was considered statistically significant.

Results

Baseline data

There was no significant difference in baseline data between the two groups ($P > 0.05$). See **Table 1**.

EBN based on PDCA cycle can significantly reduce the length of hospital stay of neonates

As shown in **Table 2**, the length of hospital stay in the observation group was significantly shorter than that in the control group ($P < 0.001$). There was no significant difference in incidence of adverse events between the two groups ($P > 0.05$).

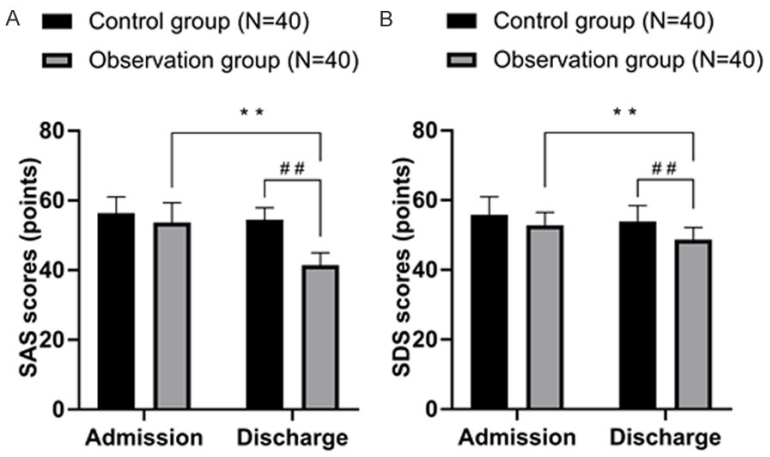

Figure 1. Comparison of SAS and SDS scores. A. Comparison of SAS score; B. Comparison of SDS score. Compared with at admission in the observation group, $^{**}P < 0.01$; compared with the control group at discharge, $^{\#\#}P < 0.01$. SAS: Self-Rating Anxiety Scale; SDS: Self-Rating Depression Scale.

Table 3. The mastery of health knowledge of family members of neonates

Items	Control group (n = 40)	Observation group (n = 40)	χ^2	P
Disease knowledge	29	37	4.501	0.034
Breastfeeding knowledge	31	38	5.165	0.023
Medication knowledge	30	38	6.275	0.012
Treatment knowledge	28	36	5.000	0.025
Rehabilitation Knowledge	30	39	8.538	0.003

EBN based on PDCA cycle can significantly improve the negative emotions of family members of neonates with HIE

As shown in **Figure 1**, there was no significant difference in SAS and SDS scores at admission between the two groups (P > 0.05). Compared with at admission, the scores of SAS and SDS in the control group were lower at discharge (P > 0.05), but the scores of SAS and SDS in the observation group were significantly lower at discharge (P < 0.01). Moreover, the scores of SAS and SDS in the observation group were significantly lower than those in the control group (P < 0.01).

EBN based on PDCA cycle can significantly improve the mastery of health knowledge of HIE neonates' family members

As shown in **Table 3**, the number of neonates' families who mastered all health knowledge in the control group was more than that in the control group (P < 0.05 or P < 0.01).

EBN based on PDCA cycle can significantly promote the recovery of neurological function of HIE neonates

No neonate was lost to follow-up within 1 month after discharge. As shown in **Table 4**, the NBNA scores of neonates in both groups after discharge were all increasing gradually, and there was no significant difference in NABA score at discharge between the two groups (P > 0.05). The NBNA scores after 2 weeks and 1 month of discharge in the observation group were significantly higher than those at discharge (P < 0.001). Compared with the control group, the NABA scores after 2 weeks and 1 month of discharge in the observation group were higher (P < 0.001).

EBN based on PDCA cycle can significantly improve the intellectual development of HIE neonates

During the 18-month follow-up, there were a total of 11 losses, with 4 losses in the observation group and 7 losses in the control group. As shown in **Tables 5**-**8**, the MDI, PDI and Gesell scores in both groups were increasing gradually after 3, 6, 12, and 18 months of discharge, and the scores of MDI, PDI and Gesell in the observation group were all significantly higher those in the control group (P < 0.05). In the observation group, there was no neonate with cerebral palsy and unresponsiveness, but in the control group, there was one with cerebral palsy and one with unresponsiveness. The difference in the incidence of adverse prognosis events between the two groups was not significant (P > 0.05).

EBN based on PDCA cycle can significantly improve the nursing satisfaction of family members of neonates with HIE

According to the nursing satisfaction evaluation at the last follow-up, the total nursing satisfaction rate of family members of neonates in the

Table 4. Comparison of NBNA score

NBNA score	Control group (n = 40)	Observation group (n = 40)	t	P
At discharge	33.21±1.63	33.02±1.54	0.536	0.594
Two weeks after discharge	34.78±1.41$^{\#\#\#}$	36.82±1.30$^{\#\#\#}$	6.727	< 0.001
One month after discharge	37.25±1.17$^{\#\#\#,\&\&\&}$	39.05±0.88$^{\#\#\#,\&\&\&}$	7.777	< 0.001

Note: Compared with at discharge, $^{\#\#\#}$P < 0.001; compared with two weeks after discharge, $^{\&\&\&}$P < 0.001. NBNA: Neonatal behavioral neurological assessment.

Table 5. Comparison of MDI, PDI and Gesell scores after 3 months of discharge

Follow-up time	Control Group (n = 39)			Observation Group (n = 39)		
	MDI	PDI	Gesell	MDI	PDI	Gesell
Three months after discharge	70.25±8.58	61.23±8.72	70.33±4.68	74.62±8.95*	66.84±8.68**	73.65±4.75**

Note: Compared with the control group, *P < 0.05, **P < 0.01. MDI: mental development index; PDI: psychomotive development index.

Table 6. Comparison of MDI, PDI and Gesell scores after 6 months of discharge

Follow-up time	Control Group (n = 38)			Observation Group (n = 39)		
	MDI	PDI	Gesell	MDI	PDI	Gesell
Six months after discharge	76.59±8.69	68.42±8.80$^{\#}$	79.85±4.47$^{\#\#\#}$	81.59±9.52$^{\#\#,*}$	76.73±9.83$^{***,\#\#\#}$	82.42±4.57$^{\#\#\#,*}$

Note: Compared with after 3 months of discharge, $^{\#}$P < 0.05, $^{\#\#}$P < 0.01, $^{\#\#\#}$P < 0.001; compared with the control group, *P < 0.05, ***P < 0.001. MDI: mental development index; PDI: psychomotive development index.

Table 7. Comparison of MDI, PDI and Gesell scores after 12 months of discharge

Follow-up time	Control Group (n = 35)			Observation Group (n = 37)		
	MDI	PDI	Gesell	MDI	PDI	Gesell
Twelve months after discharge	80.77±9.12$^{\#\#}$	71.63±8.85$^{\#\#\#}$	85.56±4.83$^{\#\#\#}$	95.47±10.17$^{***,\#\#\#}$	87.38±10.44$^{***,\#\#\#}$	90.77±3.98$^{***,\#\#\#}$

Note: Compared with after 3 months of discharge, $^{\#\#}$P < 0.01, $^{\#\#\#}$P < 0.001; compared with the control group, ***P < 0.001. MDI: mental development index; PDI: psychomotive development index.

Table 8. Comparison of MDI, PDI and Gesell scores after 18 months of discharge

Follow-up time	Control group (n = 33)			Observation group (n = 36)		
	MDI	PDI	Gesell	MDI	PDI	Gesell
Eighteen months after discharge	90.58±9.55$^{\#\#}$	80.32±9.23$^{\#\#\#}$	89.54±4.39$^{\#\#\#}$	99.08±10.55$^{***,\#\#\#}$	95.53±10.83$^{***,\#\#\#}$	97.03±2.52$^{***,\#\#\#}$

Note: Compared with after 3 months of discharge, $^{\#\#}$P < 0.01, $^{\#\#\#}$P < 0.001; compared with the control group, ***P < 0.001. MDI: mental development index; PDI: psychomotive development index.

Table 9. Nursing satisfaction evaluation of family members of neonates in the two groups

Items	Control group (n = 33)	Observation group (n = 36)	χ^2	P
Very satisfied	20	30	1.852	0.013
Satisfied	7	5		
Slightly satisfied	3	1		
Dissatisfied	2	0		
Very dissatisfied	1	0		
Total satisfaction rate	81.82%	97.22%	4.482	0.034

observation group was significantly higher than that in the control group (P < 0.05). See **Table 9**.

Discussion

The therapy of hyperbaric oxygen combined with treatment for hypothermia is the primary treatment means for HIE at present. The nursing work is of great significance to the rehabilitation of HIE neonates since neonates with HIE need close management. At present, the reports on neonates with HIE are mainly about clinical treatment, but there are limited reports about reports on HIE nursing. However, neonatal HIE nursing is one of the most intractable problems in clinical nursing. EBN is one of the

mainstream nursing models used in clinic, which has been applied in such fields as nursing of pediatric tumors, senile dementia and urological diseases [22-24]. PDCA cycle management mode was first put forward by Dr. Shewhart, an American quality management expert. It is mainly used to improve the quality of work in management at present and has been gradually applied to all kinds of hospital management in recent years [25]. In China, some researchers have tried to apply PDCA cycle management model to the teaching of nursing teams [26]. However, based on the current research status of nursing model, there is still no mature model in HIE nursing. Our research team first proposed the EBN model based on PDCA cycle, the essence of which is a kind of nursing model using PDCA to manage the nursing work team, make up for the defects in nursing work and seek to achieve the best-quality nursing by constantly seeking ways to improve.

In our study, the feasibility of EBN based on PDCA cycle was confirmed. We set up a nursing team composed of mainstay nursing staff and head nurses, and the "evidence-based" process was conducted by the nursing team first. Through the investigation and discussion of the nursing team, the problems of clinical nursing for HIE were summarized for the first time, which included the lack of systematic nursing work, the neglect of psychological status and nursing knowledge of neonates' family members, the insufficient rehabilitation nursing content, the poor nursing continuity and the inflexible implementation of nursing plan [13-17]. According to the "evidence-based" results, the nursing team got involved in the PDCA cycle management and formulated a targeted nursing plan for the "evidence-based" results. Then the nursing plan was implemented, checked and processed by following PDCA cycle, and the nursing content was updated constantly. After practice, we improved and supplemented a number of nursing contents in systematic and continuous nursing.

The results of our study showed the EBN based on thr PDCA cycle was more beneficial to improving the rehabilitation of neonates with HIE and the satisfaction of their families. EBN based on the PDCA cycle can effectively shorten the length of hospital stay for neonates, which may be due to the fact that rehabilitation nursing for neonates by nursing staff during the rehabilitation period was performed after treatment [27]. EBN based on the PDCA cycle improved the negative emotions and mastery of health knowledge of the neonates' family members, which laid a foundation for the out-of-hospital rehabilitation. Our research team observed the neurological recovery of neonates with HIE after 1 month of discharge, and the NBNA score suggested the neurological function of all neonates with HIE after treatment were all recovering constantly, but EBN based on the PDCA cycle accelerated the neurological recovery of neonates with HIE. During the long-term follow-up, it was observed that the intellectual development of neonates in both groups increased gradually after 3, 6, 12, and 18 months of discharge, and the scores of MDI, PDI and Gesell showed a significant increasing trend, but EBN based on the PDCA cycle improved the intellectual development of neonates more effectively. There were two reasons for the above results: on the one hand, the neurological recovery of neonates in the observation group was better after 1 month of discharge; on the other hand, nursing intervention by neonates' families and continuous nursing also played a role in the neurological recovery [28]. In our study, EBN based on the PDCA cycle gained higher satisfaction of neonates' families due to three aspects: the care for the psychological state of neonates' families, training of health knowledge and guidance on out-of-hospital rehabilitation measures.

There are also some limitations in our study: Based on the fact that the nursing model of our study is proposed for the first time, although the PDCA cycle management and EBN model are widely applied in clinical practice, there are few reports on neonates with HIE. Therefore, there is limited evidence available at the EBN stage.

In conclusion, our study found that compared with the routine symptomatic nursing, EBN based on the PDCA cycle could not only effectively promote the neurological recovery and intellectual development of neonates but also shorten the length of hospital stay, which contributes to reducing the family's economic burden, alleviating the negative emotions of neonates' family members and improving the overall satisfaction.

Disclosure of conflict of interest

None.

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