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Article

Effects of Preoperative Nutritional Conditions on Postoperative Recovery in Neonates with Congenital Heart Disease

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Abstract

Objective: The effects of preoperative nutritional conditions on postoperative recovery in neonates with congenital heart disease (CHD) were evaluated in this study. **Methods**: A retrospective analysis of data from neonates with CHD who underwent surgery at our hospital from January 2020 to December 2022 was conducted. The relationships between preoperative nutritional conditions and neonatal postoperative recovery were analyzed. **Results**: Eighty neonates were included in this study. The average gestational age was 38.4 (37, 39.2) weeks, the average birth weight was 3.1 (2.7, 3.4) kg, the average age at surgery was 23 (21, 26) days, and the average preoperative weight was 3.5 (3.0, 3.9) kg. The postoperative mechanical ventilation duration, length of intensive care unit stay, and length of hospital stay of preterm neonates were much longer than those of full-term neonates ($p < 0.05$). In addition, these values were notably greater for neonates with birth weights $\leq$3 kg than for neonates with birth weights $>$3 kg ($p < 0.05$). The correlation analysis suggested that gestational age, birth weight, preoperative weight-for-age z-score (WAZ) and preoperative height-for-age z-score (HAZ) were negatively correlated with postoperative mechanical ventilation duration, length of intensive care unit stay, and length of hospital stay. **Conclusions**: Preterm birth and low birth weight significantly prolong the duration of mechanical ventilation and postoperative intensive care unit and hospital length of stay. More attention should be given to nutritional management during the perioperative period for premature or low-birth-weight neonates with CHD. For neonates with CHD requiring surgery, the time available for nutritional support before surgery is very limited; thus, more attention and guidance are needed for prenatal nutritional strategies.

Keywords

congenital heart disease; neonatal; nutrition; gestational age; weight; postoperative recovery

Introduction

Congenital heart disease (CHD) is a common congenital defect and is also the most common cause of death in children [1,2]. Neonates with critical CHD require surgical treatment in the first year of life [3]. Although the overall survival of patients with CHD after cardiac surgery has improved, the mortality rate among neonates with CHD after cardiac surgery is still high.

Adequate nutrition is essential for neonates. Neonates with CHD have increased energy requirements, but they are unable to consume enough calories due to their disease, which leads to a persistent catabolic state and decreased organ function [4,5]. Infants with CHD are confronted with numerous nutritional challenges, e.g., incremental metabolic demands, altered gastrointestinal perfusion, and delayed oral motor skills. In addition to severe caloric intake and expenditure imbalances, CHD is frequently complicated by heart failure and frequently leads to fluid restriction, further hindering the ability of clinicians to provide adequate calories [6]. Owing to poor feeding and intestinal absorption of nutrients and metabolic demand, children with CHD face a high risk of growth failure [7]. An association between abnormal anthropometric measures and poor surgical outcomes has been confirmed previously [8,9]. CHD data from the Academy of Thoracic Surgeons database revealed that a low height-for-age z-score (HAZ) and weight-for-age z-score (WAZ) are related to increased mortality and other adverse consequences [10]. Malnutrition is strongly related to an increased risk of postoperative infection, resulting in poor wound healing, long intensive care unit stays and hospital stays, as well as low postoperative survival rates [11–14]. Poor nutrition in neonates

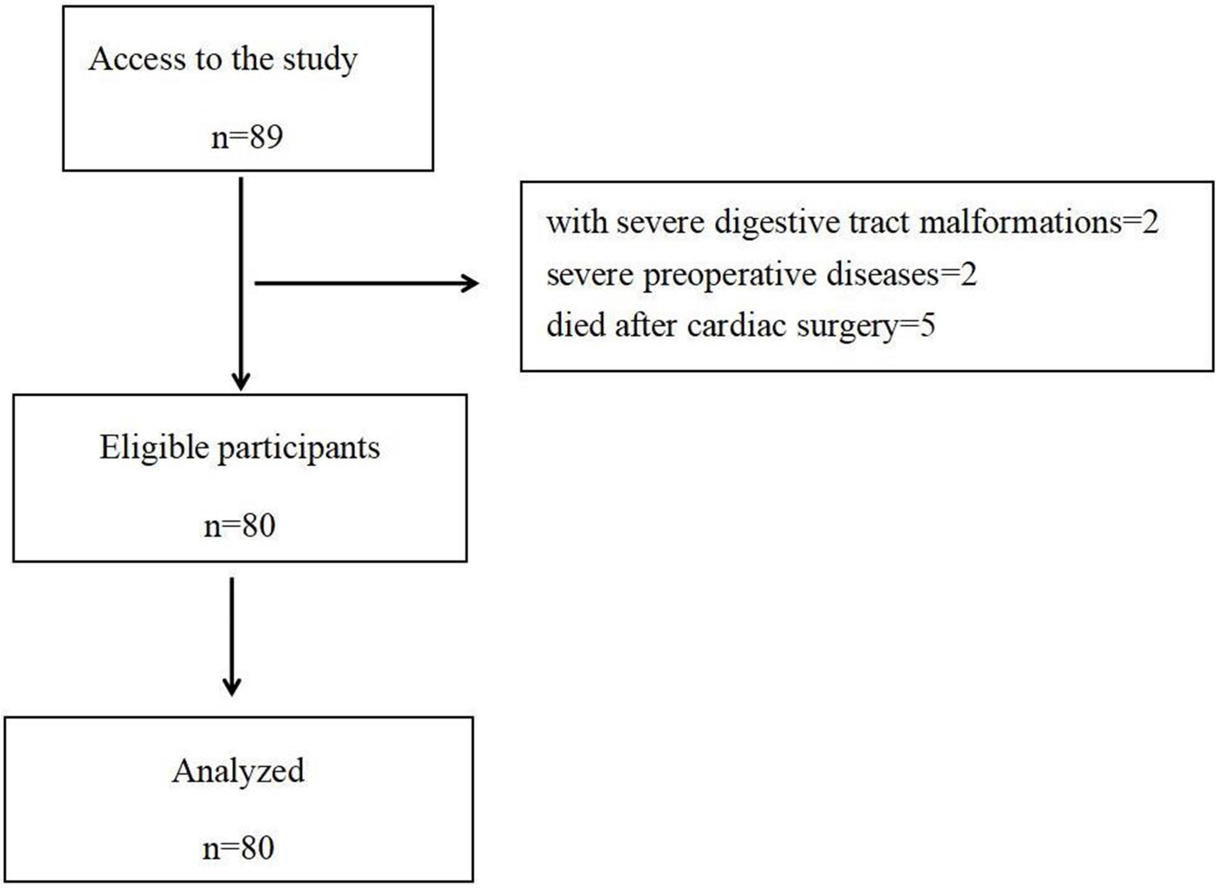

Fig. 1. The flowchart of patients.

can significantly impact their recovery after cardiac surgery [15]. This study retrospectively analyzed the preoperative nutritional conditions of neonates with CHD and further evaluated the impacts of preoperative nutritional conditions on the postoperative recovery of neonates.

Methods

A retrospective analysis of the data of neonates with CHD who underwent surgery at our hospital between January 2020 and December 2022 was performed. Preoperative nutritional conditions and postoperative recovery were analyzed. According to the inclusion and exclusion criteria, 80 neonates with CHD were included in this study.

Inclusion Criteria and Exclusion Criteria

The inclusion criterion was neonates who underwent cardiac surgery. The exclusion criteria were as follows: (1) Neonates with severe digestive tract malformations; (2) Neonates with severe diseases before surgery, such as severe liver and kidney dysfunction and necrotizing enterocolitis; (3) Neonates who died after cardiac surgery; and (4) Neonates with incomplete clinical data (Fig. 1).

Data Collection

We collected data from hospital admission records, including gestational age, maternal age, sex, birth weight, disease status, preoperative weight, preoperative WAZ, preoperative HAZ, cardiopulmonary bypass time, operation time, postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, postoperative length of hospital stay, and the incidence of postoperative complications. Among these indicators, birth weight, preoperative weight, preoperative WAZ, and preoperative HAZ were important indicators of nutritional conditions [16]. In neonates, gestational age is also an important status indicator [17].

Statistical Analysis

Statistical analysis was performed via SPSS 25 (IBM Corp., Armonk, NY, USA). Continuous and categorical variables are displayed as medians with interquartile ranges (IQRs) and frequencies with percentages, respectively. The Kruskal–Wallis test was used for the statistical analysis of continuous data, whereas the chi–square test was used for the analysis of categorical data. Correlation analysis was used to analyze the correlations among gestational age,

Table 1. Comparison of clinical data between neonates with birth weights ≤3 kg and neonates with birth weights >3 kg.

	Neonates with birth weights ≤3 kg	Neonates with birth weights >3 kg	p
Number	35	45	
Age at surgery (d)	24 (21.0, 24.0)	23 (20.0, 26.5)	0.675
Preoperative WAZ	–2.3 (–3.2, –1.0)	–0.2 (–1.0, 0.2)	0.000
Preoperative HAZ	–2 (–2.80, –0.30)	0 (–0.55, 0.20)	0.000
The distribution of disease			
Simple congenital heart disease	25	30	0.808
Complex congenital heart disease	10	15	
Preoperative nutritional support method			
Breastfeeding	13	22	
Formula feeding	4	2	
Mixed feeding	9	15	0.356
Addition of energy formula or breast milk fortifier	6	5	
Supplementation with parenteral nutrition	3	1	
Operation time (min)	160 (145.0, 210.0)	180 (151.0, 227.5)	0.216
Cardiopulmonary bypass time (min)	65 (54.0, 81.0)	68 (55.5, 108.0)	0.393
Aortic cross-clamp time (min)	33 (26.0, 41.0)	37 (30.0, 67.5)	0.128
Postoperative complications			
Renal failure	3	2	0.449
Low cardiac output syndrome	4	5	0.964
Pulmonary infection	11	12	0.312
Arrhythmia	2	5	0.397
Liver failure	0	0	-
Postoperative mechanical ventilation duration (h)	132 (110, 165)	114 (96.5, 140)	0.073
Postoperative length of intensive care unit stay (d)	11 (8, 15)	9 (7, 11)	0.010
Postoperative length of hospital stay (d)	17 (14, 21)	16 (13,18)	0.030

WAZ, weight-for-age z-score; HAZ, height-for-age z-score.

birth weight, WAZ and HAZ, mechanical ventilation duration, length of intensive care unit stay and length of hospital stay in neonates after cardiac surgery.

Results

Patients' Basic Clinical Data

In this study, 80 neonates with CHD were included, including 8 patients with total anomalous pulmonary venous connection (TAPVC), 7 patients with coarctation of the aortic arch, 5 patients with an interrupted aortic arch, 4 patients with pulmonary stenosis, 3 patients with transposition of the great arteries, 2 patients with an aortopulmonary window, 19 patients with a ventricular septal defect combined with a patent ductus arteriosus, and 32 patients with a ventricular septal defect. The gestational age of the patients was 38.4 (37, 39.2) weeks, the birth weight was 3.1 (2.7, 3.4) kg, the age at surgery was 23 (21, 26) days, and the preoperative weight was 3.5 (3.0, 3.9) kg. The postoperative mechanical ventilation duration was 118.5 (97.3, 142.8) hours, the postoperative length of intensive care unit stay was 10 (7.3, 12) days, and the postoperative length of hospital stay was 16 (14, 19) days. The preoperative nutritional support methods used were as follows: 35 patients were breastfed, 6 patients were fed formula, 24 patients were fed with mixed methods, 11 patients were given an energy formula or a breast milk fortifier, and 4 patients were supplemented with parenteral nutrition.

Comparison of Clinical Data between Neonates with Birth Weights ≤3 kg and Neonates with Birth Weights >3 kg after Cardiac Surgery

The differences in age at surgery, disease distribution, preoperative nutritional support method, operation time, cardiopulmonary bypass time, aortic cross-clamp time and incidence of postoperative complications between the two groups were not significant ($p > 0.05$). However, the postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, and postoperative length of hospital stay of neonates with birth weights ≤3 kg were significantly longer than those of neonates with birth weights >3 kg ($p < 0.05$) (Table 1).

Comparison of Clinical Data between Neonates with a Preoperative WAZ ≤–2 and Neonates with a Preoperative WAZ >–2

The differences in age at surgery, disease distribution, preoperative nutritional support method, operation time,

Table 2. Comparison of clinical data between neonates with preoperative WAZ ≤–2 and neonates with preoperative WAZ >–2.

	Preoperative WAZ ≤–2	Preoperative WAZ >–2	*p*
Number	24	56	
Age of surgery (d)	24 (20, 27)	23 (21, 26)	0.788
Preoperative HAZ	–2.55 (–2.95, –2.00)	0.00 (–0.48, 0.20)	0.000
The distribution of disease			
Simple congenital heart disease	14	41	0.191
Complex congenital heart disease	10	15	
Preoperative nutritional support method			
Breastfeeding	11	24	0.985
Formula feeding	3	3	
Mixed feeding	5	19	
Add energy formula or breast milk fortifier	2	9	
Supplement with parenteral nutrition	3	1	
Operation time (min)	162.5 (145, 235)	175.0 (150, 225)	0.585
Cardiopulmonary bypass time (min)	66.5 (53.3, 113.3)	62.0 (55.0, 94.3)	0.721
Aortic cross-clamp time (min)	34 (26.3, 57.8)	36 (29.3, 50.5)	0.793
Postoperative complications			
Renal failure	3	2	0.133
Low cardiac output syndrome	4	5	0.319
Pulmonary infection	7	16	0.957
Arrhythmia	2	5	0.932
Liver failure	0	0	-
Postoperative mechanical ventilation duration (h)	136.0 (110.8, 209.0)	115.5 (94.5, 140.8)	0.011
Postoperative length of intensive care unit stay (d)	12.5 (8.5, 18.0)	9.0 (7.0, 11.0)	0.001
Postoperative length of hospital stay (d)	18.5 (14.3, 24.8)	15.5 (13.3, 17.8)	0.008

cardiopulmonary bypass time, aortic cross-clamp time and incidence of postoperative complications between the two groups were not significant ($p > 0.05$). The preoperative HAZ of neonates with a preoperative WAZ ≤–2 was much lower than that of neonates with a preoperative WAZ >–2 ($p < 0.05$). The postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, and postoperative length of hospital stay of neonates with a preoperative WAZ ≤–2 were obviously longer than those of neonates with a preoperative WAZ >–2 ($p < 0.05$) (Table 2).

Comparison of Clinical Data between Preterm and Full-Term Neonates after Cardiac Surgery

The differences in age at surgery, disease distribution, preoperative nutritional support method, operation time, cardiopulmonary bypass time, aortic cross-clamp time and incidence of postoperative complications between preterm neonates and full-term neonates were not significant ($p > 0.05$). The preoperative weight of preterm neonates was much lower than that of full-term neonates ($p < 0.05$). The postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, and postoperative length of hospital stay of preterm neonates were obviously longer than those of full-term neonates ($p < 0.05$) (Table 3).

Correlation Analysis among Gestational Age, Birth Weight, Preoperative WAZ, Preoperative HAZ and Postoperative Recovery

Gestational age was negatively correlated with the duration of mechanical ventilation, length of intensive care unit stay, and length of hospital stay of neonates after cardiac surgery ($p < 0.05$). Birth weight was negatively correlated with the mechanical ventilation duration, length of intensive care unit stay, and length of hospital stay of neonates after cardiac surgery ($p < 0.05$). The preoperative WAZ was negatively correlated with the mechanical ventilation duration, length of intensive care unit stay, and length of hospital stay of neonates after cardiac surgery ($p < 0.05$). Preoperative HAZ was negatively correlated with the mechanical ventilation duration, length of intensive care unit stay, and length of hospital stay of neonates after cardiac surgery ($p < 0.05$) (Table 4).

Discussion

According to the correlation analysis, birth weight was negatively correlated with the duration of mechanical ventilation, length of intensive care unit stay, and length of hospital stay of neonates after cardiac surgery. The preoperative WAZ and preoperative HAZ were negatively correlated with the mechanical ventilation duration, length of inten-

Table 3. Comparison of clinical data between preterm and full-term neonates.

	Preterm neonates	Full-term neonates	*p*
Number	19	61	
Preoperative weight (kg)	2.7 (2.3, 3.2)	3.7 (3.3, 4.1)	0.000
Age at surgery (d)	24 (21.0, 27.0)	23 (20.5, 26.0)	0.960
Preoperative WAZ	–3.0 (–3.50, –2.00)	–0.6 (–1.25, 0.20)	0.000
Preoperative HAZ	–2.5 (–3.00, –1.40)	–0.2 (–0.85, 0.20)	0.000
The distribution of disease			
Simple congenital heart disease	12	43	0.579
Complex congenital heart disease	7	18	
Preoperative nutritional support method			
Breastfeeding	8	27	
Formula feeding	2	4	
Mixed feeding	6	18	0.970
Addition of energy formula or breast milk fortifier	2	9	
Supplementation with parenteral nutrition	1	3	
Operation time (min)	170 (140.0, 210.0)	175 (150.0, 227.5)	0.315
Cardiopulmonary bypass time (min)	64 (54.0, 75.0)	68 (55.0, 100.5)	0.332
Aortic cross-clamp time (min)	32 (26.0, 46.0)	36 (29.5, 54.5)	0.384
Postoperative complications			
Renal failure	2	3	0.378
Low cardiac output syndrome	3	6	0.473
Pulmonary infection	6	17	0.755
Arrhythmia	2	5	0.335
Liver failure	0	0	-
Postoperative mechanical ventilation duration (h)	158 (110.0, 240.0)	117 (96.5, 140.0)	0.022
Postoperative length of intensive care unit stay (d)	12 (8.0, 20.0)	9 (7.0, 11.5)	0.009
Postoperative length of hospital stay (d)	18 (14.0, 29.0)	16 (13.5, 18.0)	0.037

Table 4. Correlation analysis among gestational age, birth weight, preoperative WAZ, preoperative HAZ and postoperative recovery.

	Gestational age	Birth weight	Preoperative WAZ	Preoperative HAZ
Postoperative mechanical ventilation duration	r: –0.609 *p*: 0.000	r: –0.537 *p*: 0.000	r: –0.441 *p*: 0.000	r: –0.449 *p*: 0.000
Postoperative length of intensive care unit stay	r: –0.704 *p*: 0.000	r: –0.577 *p*: 0.000	r: –0.470 *p*: 0.000	r: –0.484 *p*: 0.000
Postoperative length of hospital stay	r: –0.678 *p*: 0.000	r: –0.564 *p*: 0.000	r: –0.456 *p*: 0.000	r: –0.468 *p*: 0.000

sive care unit stay, and length of hospital stay of neonates after cardiac surgery. The postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, and postoperative length of hospital stay of neonates with birth weights $\leq$3 kg were significantly longer than those of neonates with birth weights >3 kg. The postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, and postoperative length of hospital stay of neonates with a preoperative WAZ $\leq$–2 were obviously longer than those of neonates with a preoperative WAZ >–2. These findings indicate that preoperative nutrition significantly affects the rate of postoperative recovery. The lower the preoperative nutritional indexes were, the slower postoperative recovery was. Several previous pediatric studies have described associations between preoperative nutritional conditions and clinical outcomes [18–20]. According to a single-center retrospective study in the United Kingdom, a low WAZ predicts an increase in the risk of mortality for neonates after CHD surgery [8]. A large single-center retrospective study in the United States reported that a WAZ or HAZ $\leq$–2 had a significant effect on mortality. Further reductions in the WAZ or HAZ are related to an increase in mortality risk [9]. Mehta and Duggan [4] reported that postoperative length of intensive care unit stay, postoperative hospital length of stay and the frequency of readmission were significantly associated with malnutrition. Wong *et al*. [21] reported that the WAZ and HAZ can predict postoperative mechanical ventilation duration, postoperative length of intensive care unit stay, and postoperative length of hospital stay. Studies have shown that surgical trauma after cardiac surgery with cardiopulmonary bypass, the occurrence of a systemic inflammatory response and the application of inotropic drugs can lead to postoperative hypermetabolism and increased energy expenditure, which further aggravates the problem of preoperative malnutrition [22,23]. After cardiac surgery, patients usually need to limit fluid intake and maintain a negative fluid balance, which results in insufficient nutritional intake and continuous energy expenditure after surgery [24]. It is well known that the repair of tissue and organ trauma requires energy, and insufficient energy affects the repair of tissue trauma [25]. The recovery of respiratory muscle function is closely related to ventilator weaning, and the strength of respiratory muscle function is closely related to nutritional status [10]. At the same time, malnutrition impairs immune function, increasing the risk of infection, the risk of poor incision healing, and the length of hospital stay [26]. The physiological reserve of neonates is often poor, and malnutrition has a greater impact on neonates undergoing CHD surgery [27].

Our study revealed that the mechanical ventilation duration, length of intensive care unit stay, and length of hospital stay of preterm neonates after cardiac surgery were much longer than those of full-term neonates. Gestational age was negatively correlated with the duration of mechanical ventilation, length of intensive care unit stay, and length of hospital stay in neonates after cardiac surgery. These findings suggest that gestational age significantly affects the rate of postoperative recovery. The younger the gestational age was, the slower the postoperative recovery. Advances in surgical techniques and improvements in intensive care have made it possible to perform CHD surgery on smaller, premature neonates with increasing survival rates. Numerous studies have shown that gestational age at birth is closely related to in-hospital mortality, postoperative hospital length of stay and complications in infants with CHD and that preterm birth is a risk factor for mortality after CHD surgery [28,29]. Premature infants are prone to organ dysfunction after cardiac surgery with cardiopulmonary bypass due to immature organ systems, light weight, low immunity, respiratory distress syndrome, bronchopulmonary dysplasia, intestinal absorption dysfunction and many other problems; thus, the recovery of organ function is slow after the operation, and patients require long-term postoperative respiratory support and long intensive care unit and hospital stays [30].

Although our findings are not very novel, they highlight the importance of preoperative assessments of nutritional conditions, including weight and gestational age, in neonates with CHD. Many full-term neonates are born at a normal weight, but due to severe CHD, they develop heart failure and respiratory failure in the early stage and need surgical treatment. The time available for nutritional support before surgery is very short, and the metabolic consumption increases due to the disease itself, so there is very little weight gain before surgery. In this study, 59 full-term neonates with a normal birth weight of 3.3 (3.1, 3.5) kg were operated on 23 (20, 26) days after birth, and the average preoperative weight was 3.7 (3.4, 4.0) kg. Neonates who need to undergo cardiac surgery in the neonatal period are in severe condition and face severe catabolism. Moreover, the duration of preoperative nutritional support is short, and it is difficult to achieve nutritional goals before surgery [31]. Therefore, more attention should be given to prenatal nutritional strategies. Active prenatal screening and assessment should be conducted for fetuses with CHD to promote nutritional optimization during the perinatal period, promote fetal weight gain and development, and avoid premature birth and events related to low birth weight as much as possible. A birth weight $\leq$3 kg and preterm birth can be used as thresholds for timely risk stratification for neonates with CHD.

Limitations

This study had several limitations. (1) This was a retrospective single-center study. (2) The sample size of this study was small. (3) The severity of different CHDs differed. Owing to the small sample size, it cannot be ruled out that the severity of different CHDs may have interfered with the research results.

Conclusions

The preoperative nutritional conditions of neonates with CHD have a significant effect on postoperative recovery after cardiac surgery. Preterm birth and low birth weight significantly prolong the duration of mechanical ventilation and the postoperative length of intensive care unit stay and hospital stay. More attention should be given to nutritional management during the preoperative period for premature or low-birth-weight neonates with CHD. For neonates with CHD requiring surgery during the neonatal period, the time available for nutritional support before surgery is very limited, and it is important to focus more on prenatal nutritional strategies.

Abbreviations

CHD, congenital heart disease; IQR, interquartile range; HAZ, height-for-age z-score; WAZ, weight-for-age z-score.

Availability of Data and Materials

The data for this study are available from the authors upon reasonable request with permission from the corresponding author.

Author Contributions

LCW made the substantial contributions to the conception and writing of the study. YNL and YTZ made the substantial contributions to the acquisition, analysis, and interpretation of data for the study. QLZ made the substantial contributions to the design and revision of the paper. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was approved by the ethics committee of Fujian Children's Hospital (ethical approval number: 2022ETKLR12048) and strictly adhered to the tenets of the Declaration of Helsinki. The research methodology of the study is a retrospective analysis of data, the risk of disclosure of personal privacy is controlled by means of anonymization and other means, and the subjects will not receive any additional medical interventions/examinations, which will not increase the risk of routine medical treatment and will not interfere with their access to normal medical treatment, which is less than minimal risk. Therefore, we submitted an application for exemption of subjects' informed consent to the ethics committee of Fujian Children's Hospital, which was approved.

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Conflict of Interest

The authors declare no conflict of interest.

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