

ORIGINAL RESEARCH



Quality improvement for reducing nasal continuous positive airway pressure related nasal injury in neonatal intensive care unit

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Abstract

To reduce the incidence and severity of nasal injury in nasal continuous positive airway pressure ventilated neonates through a quality improvement project, a quality improvement project has been implemented in a neonatal intensive care unit (NICU) in a Level III hospital. Newborns requiring nasal continuous positive airway pressure (NCPAP) ventilation admitted to the NICU were included in this quality improvement project. A quality improvement team was established and developed guidance applicable to our unit on a standard method for nasal prong wear. Then, all the NICU nurses received a 15-minute uniform training session on nasal prong/mask-wearing standards. In addition, daily clinical inspections were made to give targeted 1-on-1 instruction to those who did not implement the method correctly. The primary outcome measures were the rate of correct nasal prong/mask wear and the incidence rate of neonatal NCPAP-related nasal injury. The secondary outcome measure was the prevalence rate of nasal injury. The quality improvement project was conducted in April 2020 and April 2021. The rate of correct nasal prong/mask wear (78.17% vs. 83.29%, $\chi^2 = 18.660$, $p < 0.001$), the incidence rate of neonatal NCPAP-related nasal injury (18.26% vs. 8.36%, $\chi^2 = 19.674$, $p < 0.001$), and the prevalence rate of nasal injury (27.52% vs. 13.85%, $\chi^2 = 166.299$, $p < 0.001$) all showed statistically significant differences before and after the quality improvement. Standardizing the way in which nasal prongs/masks are worn can reduce the incidence of nasal injury with low costs and relatively high benefits; thus, this approach is worth promoting.

Keywords

Quality improvement; Continuous positive airway pressure; Nasal injury; Newborn

1. Background

Nasal continuous positive airway pressure (NCPAP) has been the “gold standard” in noninvasive respiratory support used to treat preterm infants [1]. To effectively deliver NCPAP, binasal prongs must be fit tightly to maintain constant airway pressure. Therefore, nasal injuries are increasingly becoming a widespread complication among neonates receiving NCPAP ventilation due to a lack of nasal protection and prolonged, improper wearing [2–4]. NCPAP may damage the integrity of the skin surrounding the nasal areas and even cause full-thickness skin loss and columellar necrosis, seriously affecting the appearance. Infants may need surgery to restore the normal appearance of the nose, which increases costs, wastes resources and increases infant suffering.

It is known that the incidence rate of nasal injuries is relatively high. Fischer *et al.* [5] reported a 42.5% (420/989) incidence rate of nasal trauma. Of 420 neonates with nasal trauma, 371 (88.3%) presented with persistent erythema, 46 (11%) presented with superficial ulceration, and 3 (0.7%) pre-

sented with necrosis [5]. Although nasal injuries are difficult to prevent in neonates, especially those with very low or extremely low birth weights, studies have shown that preventive measures such as adopting wearing methods that do not add extra pressure to the skin, alternating the use of nasal prongs and masks, using hydrocolloid dressing on the nose, and using oil for nasal lubrication can reduce the incidence and severity of nasal injury [6–10].

We noticed that compared to past incidence rates, the incidence rate of NCPAP-related nasal injury in our department was increasing in April 2020. To reduce the incidence of nasal injury, our department initiated a quality improvement program in 2020. Our goal was to reduce the incidence and severity of nasal injury in NCPAP-ventilated neonates.

2. Methods

This manuscript was written based on the Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0) [11].

2.1 Context

In April 2020, we found that the prevalence of NCPAP-related nasal injury in our department, a neonatal intensive care unit (NICU) in a Level III hospital, was trending upward. A clinical quality improvement project was initiated to address this situation. This project was a quality improvement project in which baseline data were collected from April–June 2020, and these data were compared to data collected after the implementation of the quality improvement program. Multiple interventions may be required based on the effectiveness of the interventions.

Through an evidence-based literature analysis, we found that measures that can reduce nasal injury include adopting wearing methods that do not add extra pressure, using barrier dressing, rotating nasal masks with nasal prongs, and applying oil lubrication. Standardized measures that have been adopted in our department include using hydrocolloid dressings on the nose, rotating nasal masks and prongs, and applying nasal lubrication. Through clinical observation, we found that improper nasal wearing occurs frequently and may cause additional pressure on the nose. Considering that we have not trained on the correct wearing method, we believe that improper nasal prong wearing is an important factor contributing to nasal injury in our unit. Therefore, we propose the implementation of the clinical quality improvement of standardized nasal prong wearing.

2.2 Criteria for patients

Neonates who need to be admitted to the NICU and require NCPAP ventilation are included. Neonates with pre-existing nasal injury prior to NCPAP ventilation and with developmental malformations of the nose are excluded.

All eligible cases with NCPAP ventilation over the quality improvement program period were included. Considering nasogastric may causing additional nasal injury, all neonates with NCPAP ventilation had orogastric tubes placement rather than nasogastric tubes. All newborns were treated with standardized nutritional strategies to ensure that the newborns were not impacted by differences in nutritional strategies for wound healing outcomes.

2.3 Interventions

First, a quality improvement team was established, including a team leader and 7 team members. The leader was a nursing administrator with extensive clinical and management experience. The team members were a nursing researcher, a nursing educator, and 5 quality control nurses. The quality improvement team worked together to formulate quality improvement plans. The team leader, quality control nurses and nursing educator were responsible for implementing the quality improvement project. The nursing researcher was in charge of data analysis.

Second, intervention measures were developed. In our department, Drager ventilators with prongs were the primary tool used to provide NCPAP ventilation, while a nasal mask was the secondary choice if a neonate's nose showed signs of erythema. Referring to the manufacturer's guidance and the resources currently available to us, we developed guidance applicable to

our unit on a standard method for nasal prong/mask wear. A picture (Fig. 1) and video of an example of this standard were taken.

Then, all the NICU nurses received a 15-minute uniform training session on nasal prong/mask-wearing standards. The quality improvement team conducted the training and demonstrated the prong/mask-wearing methods on a neonatal body model. Question and answer sessions were included to solve problems highlighted by staff members. The training was provided several times to ensure that each staff member attended at least 1 session, and a sign-in sheet was used to verify that every staff member had attended the training. After the training, all the nurses were required to take an operational exam regarding the wearing of nasal prongs/masks. The nurses were required to demonstrate the nasal prong/mask-wearing method on a neonate who was being ventilated by a Drager ventilator while the examiners, namely, a quality improvement team leader and quality control nurses, were watching. After that, the examiners scored the quality of the nasal prong/mask application of each individual. A scoring sheet was created based on the wearing standards, which consisted of 5 items; 20 points were assigned to each item for a total score of 100 points. To pass, each nurse had to receive a perfect score. Those who failed once needed to take a second or even third exam until they passed.

Finally, the quality control nurses made daily clinical inspections to determine if the wearing method being implemented was correct, and they gave targeted 1-on-1 instruction to those who did not implement the method correctly to enhance the training effect.

2.4 Study of the interventions

To ascertain the effectiveness of the quality improvement project, we conducted a before-and-after comparison. Prior to the implementation of the project, we completed a 3-month baseline data collection to determine the status of nasal prong/mask wearing and to record the occurrence of nasal injuries through clinical observation. This information was also recorded during and after the quality improvement project.

In addition, the routine measures used to prevent nasal injury were consistently implemented before and after the quality improvement project. These measures included the following: double-layer hydrocolloid barrier dressing to protect the skin of the nose area, cod liver oil to lubricate the nostrils, and alternating between the use of nasal prongs and masks depending on the skin condition of the neonates.

2.5 Measures

The quality control nurses conducted inspections and recorded the following information: the number of neonates on NCPAP ventilation per day, the number of neonates correctly wearing nasal prongs/mask per day, the number of neonates with new nasal injuries caused by NCPAP per day, the number of neonates with nasal injuries caused by NCPAP per day, the duration of the nasal injuries (days) of the neonates, and the severity of their nasal injuries.

The primary outcome measures used and their calculation

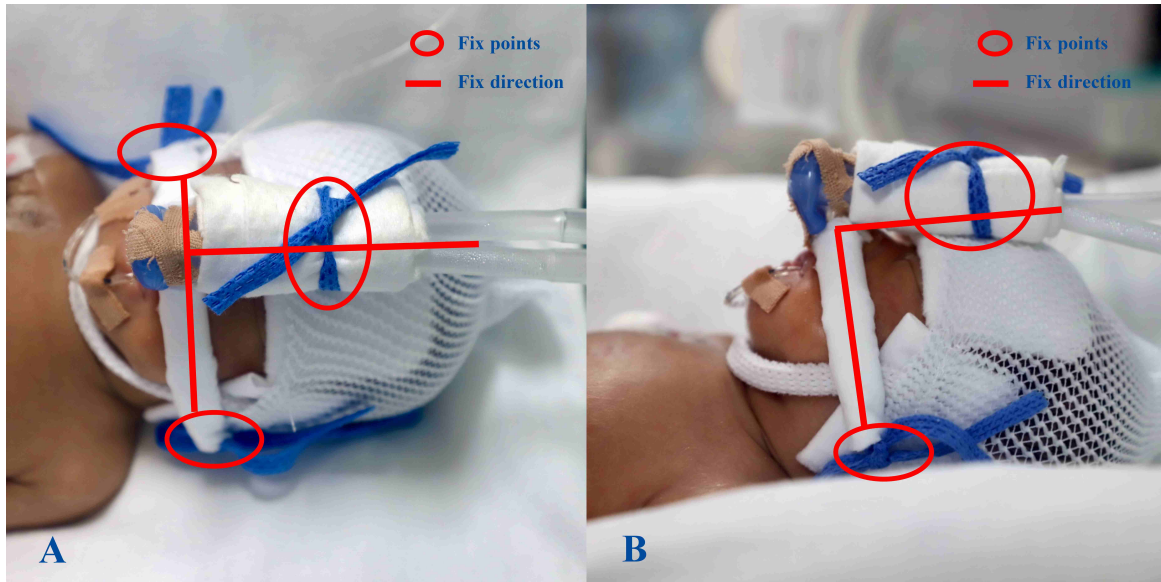


FIGURE 1. Standardized method for nasal prong/mask wearing. The standardized method for nasal prong/mask wearing is as follows: (a) The ventilator tube is fixed at a point on the forehead of the newborn. In addition, the tube is positioned along the midline of the body. (b) The nasal prong/mask fixation cord is fixed behind both ears so that the three points, namely, the fixation points on the left and right and the nasal prongs/mask position, align parallel with the horizontal planes of the human body. (c) The ventilator circuit line is perpendicular to the line formed by these three points, namely, the fixation points on the left and right and the position of the nasal prongs/mask, in the human coronal plane (A). (d) The ventilator circuit line is perpendicular to the line of the aforementioned three points in the human sagittal plane (B). (e) The elastic hat edges in contact with the skin are padded with cotton wool to disperse the pressure.

formulas are as follows:

(1) *Rate of correct nasal prong/mask wear = (sum of the number of neonates correctly wearing nasal prongs/masks per day during a period/sum of the number of neonates on NCPAP ventilation per day during the same period) × 100%*;

(2) *Incidence rate of neonatal NCPAP-related nasal injury = (sum of the number of neonates with new nasal injuries caused by NCPAP per day during a period/total number of neonates on NCPAP ventilation during the same period) × 100%*.

The secondary outcome measure and its calculation formula are as follows:

Prevalence rate of nasal injury = (number of days nasal injury existed in all neonates during a period/sum of the total number of days during which daily NCPAP ventilation was performed over the same period) × 100%.

Finally, the quality control team collected information on any questions they had about nasal prong/mask wear from the charge nurses and solved these doubts through communication.

Nasal injuries were defined and classified according to the pressure ulcer classification system by European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel and Pan Pacific Pressure Injury Alliance [12].

2.6 Analysis

SPSS (Version 26.0, IBM Corp., Armonk, NY, USA) was used for data analysis. The rate of correct nasal prong/mask wearing, the incidence rate of neonatal NCPAP-related nasal injury and the prevalence rate of nasal injury were calculated on a monthly basis. A chi-square test was used to compare the data before and after improvement. Line graphs were drawn to

reflect changes in the rate of correct nasal prong/mask wearing and the incidence rate of neonatal NCPAP-related nasal injury over time as the improvement process progressed.

2.7 Ethical considerations

Nasal prong/mask use is a routine clinical practice, and improvements in the corresponding wearing methods do not involve ethical issues.

3. Results

3.1 Intervention process

An intervention timeline diagram is shown in Fig. 2. The baseline data collection on nasal injuries began in April 2020, immediately after we noticed an increasing trend in the rate of nasal injury in neonates, and the design of a quality improvement program began simultaneously. Nasal injury data were collected between April 2020 and April 2021. In July, the training session and operational exam were completed. Thereafter, clinical visits and 1-on-1 mentorship trainings were conducted until April 2021.

3.2 Characteristics of patients and nurses

Basic characteristics of patients were comparable before and after the quality improvement program (Table 1).

A total of 97 nurses participated in this quality improvement project. At the beginning of this project, 93 nurses from our unit participated in the initial training, whereas 1 nurse resigned and 3 nurses joined. The new nurses were required

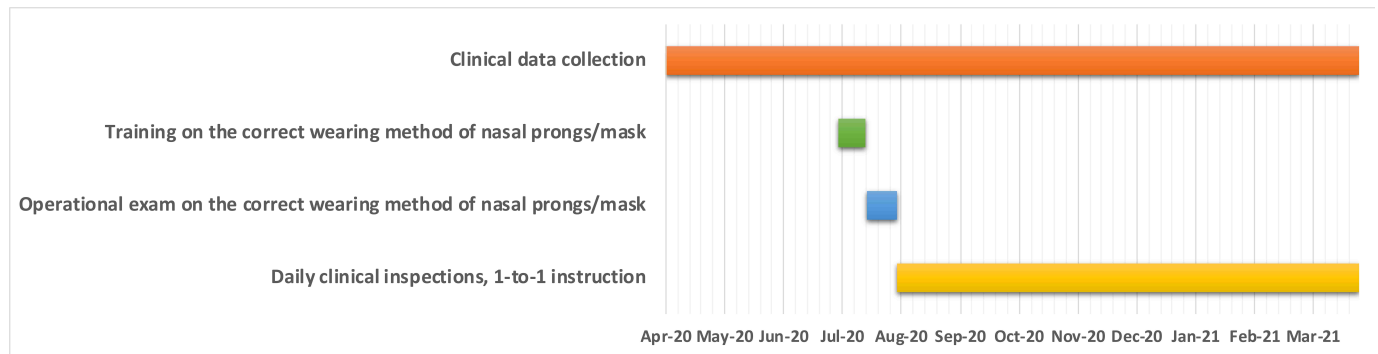


FIGURE 2. Timeline diagram of the interventions to reduce NCPAP-related nasal injury.

TABLE 1. Basic characteristics of the patients.

Items	Baseline*	After the quality improvement**	t/χ^2	p
Gestational Age, mean (SD***), wk	32.41 (2.72)	32.79 (3.02)	-1.753	0.080
Birth Weight, mean (SD), g	1714.81 (458.37)	1761.29 (556.27)	-1.189	0.235
Female sex, No. (%)	113 (46.89)	411 (47.74)	0.054	0.816
Male sex, No. (%)	128 (53.11)	450 (52.26)		
Neonatal respiratory distress syndrome, No. (%)	173 (71.78)	609 (70.73)	0.101	0.750
Sepsis, No. (%)	23 (9.54)	64 (7.43)	1.153	0.283
Pneumonia of newborn, No. (%)	61 (25.31)	176 (20.44)	2.645	0.104
Meconium aspiration syndrome, No. (%)	7 (2.90)	21 (2.44)	0.165	0.685

*Baseline: Baseline data regarding the occurrence and prevalence of nasal injury were collected from April to June 2020; those regarding correct wearing conditions were collected from May to June 2020 (correct wearing condition data collection began in May after the quality improvement project program was developed in April).

**After the quality improvement: August 2020 to April 2021 for post-quality-improvement data.

***SD: standard deviation.

to pass a training and examination before being qualified to wear nasal prongs/masks as was done with the old nurses. As for the educational training staff, there was no change in personnel. The original 8 members worked on the entire quality improvement project.

3.3 Rate of correct wearing and nasal injury

Before the quality improvement project (from April to Jun 2020), the incidence rate of nasal injury was 18.26%, the correct wearing rate was 78.17%, and the prevalence rate of nasal injury was 27.52%. After the quality improvement project (from August 2020 to April 2021), the incidence of nasal injury decreased to 8.36%, the correct wearing rate increased to 83.29%, and the prevalence rate of nasal injury decreased to 13.85%, with statistically significant differences (Table 2).

After the quality improvement project began in July 2020, there was an upward trend in the monthly rate of correct nasal prong/mask wearing and a downward trend in the monthly rate of nasal injury (Fig. 3).

3.4 Problem and solution related to the quality improvement process

During the training sessions in July 2020, the charge nurse raised a question. Every charge nurse understood the literal

meaning of the correct nasal prong/mask-wearing method, but their execution varied. To solve this problem, we observed the difference between the charge nurses' understanding and implementation of the correct wearing method and provided 1-on-1 instruction to help them implement the correct wearing method. A standard operating procedure video regarding nasal prong/mask wearing was filmed for all the nurses to learn from.

3.5 Relationship between the rate of correct nasal prongs/mask wear and the incidence rate of nasal injury

We noticed an interesting situation; that is, the increase in the rate of correct nasal prongs/masks wearing was accompanied by a decrease in the incidence rate of nasal injury, which may represent a correlation. However, we collected data on the ward as a whole and did not track data corresponding to each neonate's incorrect nasal prong/mask wearing in relation to the occurrence of nasal injury, which prevented us from performing a statistical analysis of the relationship between the rate of correct nasal prong/mask wearing and the incidence rate of nasal injury. Thus, this relationship can only be roughly described from the trend of the line graph and a comparison of the situation before and after the improvement.

TABLE 2. Comparison of before and after the quality improvement project.

Items	Baseline*	After the quality improvement**	χ^2	<i>p</i>
Correct wearing condition				
Number of days of correct wearing, days (%)	1010 (78.17)	4445 (83.29)	18.660	<0.001
Number of days of incorrect wearing, days (%)	282 (21.83)	892 (16.71)		
Incidence of nasal injury				
Number of neonates with nasal injury, No. (%)	44 (18.26)	72 (8.36)	19.674	<0.001
Number of neonates without nasal injury, No. (%)	197 (81.74)	789 (91.64)		
Prevalence of nasal injury				
Number of days during which injuries were present, days (%)	454 (27.52)	739 (13.85)	166.299	<0.001
Number of days without injury, days (%)	1196 (72.48)	4598 (86.15)		

*Baseline: Baseline data regarding the occurrence and prevalence of nasal injury were collected from April to June 2020; those regarding correct wearing conditions were collected from May to June 2020 (correct wearing condition data collection began in May after the quality improvement project program was developed in April).

**After the quality improvement: August 2020 to April 2021 for post-quality-improvement data.

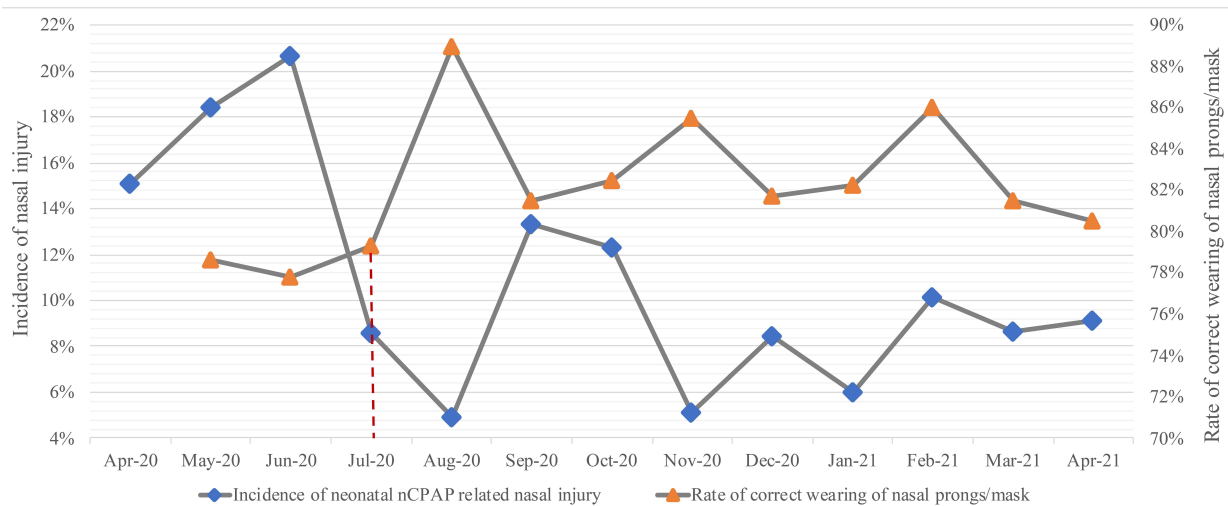


FIGURE 3. Changes in the rate of correct nasal prong/mask wearing and the incidence rate of nasal injury throughout the improvement process.

4. Discussion

The direct result of our education of the nurses was an improvement in the correct rate of wearing nasal prongs/masks. In addition to this significant improvement, we found that the rate of nasal injury was remarkably reduced. Therefore, we believe that wearing nasal prongs/masks correctly is an important factor in reducing nasal injury. Moreover, standardizing nasal prongs/masks is an easy-to-implement intervention method involving no additional cost, which is beneficial to neonates. We believe that it is worthy of promotion.

The quality improvement project increased the rate of correct nasal prong/mask use among the charge nurses through training and examinations. However, a single centralized training and examination could not induce everyone to change their previously consolidated behavior in relation to nasal prong/mask wearing. Thus, since the beginning of the quality improvement project, we continuously provided 1-on-1 instruction to answer the charge nurses' questions regarding

nasal prong/mask wearing. This allowed the barriers that hindered the nurses from correctly using nasal prongs/masks to be resolved in a timely manner, bridging the gap between the knowledge and practice of the standard wearing method.

There are many risk factors for nasal injury, which include not only the incorrect wearing of nasal prongs/masks but also low gestational age, low birth weight, inappropriately sized nasal prongs/masks, and so on [5]. Some of these factors (such as low gestational age and the duration of noninvasive ventilation) cannot be changed, but others (the way in which prongs/masks are worn, the use of barrier dressing, etc.) can. To minimize the rate of nasal injury, other interventions should be performed in conjunction with correct prong/mask wearing. The nasal protection measures that our ward insisted on included the use of double-layer hydrocolloid dressings to separate the prongs from the skin and cod liver oil. Although research has shown that the alternate use of masks and prongs can protect the nasal skin of patients, we clinically found that masks leak easily and that their ventilation effect is poor in

some serious patients; therefore, not all the patients alternated between the use of masks and prongs. In addition, although some ventilators have matching cloth caps that are used to fix their pipes, we found that the size range of ventilators is limited in clinical use; moreover, not all are suitable for all infants, especially for premature infants with low gestational age. In such cases, the cloth caps are often too large to fix the pipes, and the tube easily shifts when cloth caps are used, even with slight movement, thus causing unnecessary pressure on the nose and requiring nurses to spend extra time refixing. Therefore, we chose a mesh cap with a certain level of elasticity and a padded cotton towel folded over the edge between the mesh cap and skin contact, where pressure may be higher, to distribute the pressure around the edges and thus protect the skin from injury. While our approach protects infants' skin to a certain extent, it is not necessarily the best choice, and we are simply maximizing the protection of these babies with the resources currently available.

5. Limitations

The relationship between the correct rate of wearing nasal prongs/masks and the rate of nasal injury was not statistically analyzed due to a lack of one-to-one matched data on whether nasal prongs/masks were being worn correctly and whether nasal injuries occurred. This correlation can only be roughly estimated from the trend of the line chart and the comparison of data from before and after the improvement.

6. Conclusions

Standardizing the way in which nasal prongs/masks are worn can reduce the incidence of nasal injury with low costs and relatively high benefits; thus, this approach is worth promoting. In terms of changing and standardizing nurses' behavior in relation to the use of nasal prongs/masks, providing them with support and answering their questions are as important as unified training in the context of making standardized wearing a daily routine.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

YHW, XL and XLW—designed the research study. YHW, XMG—performed the research. XL, XMG and YLH—analyzed the data. YHW and XL—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study has been approved by the Ethics Committee of West China Second Hospital of Sichuan University (No. 2022130). Parental consent has been obtained.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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