Original Article

New dimension on potential factors of successful pediatric peripheral intravenous catheterization

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Key Words
Failure rate; Peripheral intravenous catheterization; Potential factors; Success rate

Background: Peripheral intravenous catheterization (PIVC) is pivotal to pediatric medical care; however, it is a challenging technique for pediatricians, and the parameters affecting successful pediatric PIVC establishment have not been fully investigated.

Methods: This prospective observational study collected data from pediatric patients aged less than 18 years who required PIVC. The participants were categorized into five groups for subgroup analysis: newborn, infant, toddler, pre-school, and student (children and adolescent). Data on demography, biochemistry, and PIVC executors were examined to elucidate the most powerful factors affecting the success of PIVC.

Results: A total of 935 peripheral venous cannulations conducted within 1 year were studied. Age-subgroup analysis showed the highest failure rate (FR) of PIVC in the infant group (18.4%). No significant difference in BMI standard deviation score was noted among the groups (p-value Z 0.430). Compared with those for the success group, more attempts, longer completion time, and more medical staff were needed for the failure group (all p-values < 0.05). A high serum procalcitonin level was correlated with an increased FR (p-value Z 0.016). In addition, the success rate was positively associated with the seniority of the operators, except for the 3-year experienced R3 group (93.5%) showing a higher success rate than the 4-year experienced CR group (84.2%).

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Conclusions: Difficulty in setting up PIVC was the greatest in infants and even greater than that in newborns. Even though seniority was a cardinal factor in successful PIVC, a high FR was still noted despite the lack of continuous and steady practice.

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1. Introduction

Peripheral intravenous catheterization (PIVC) is an important clinical technique providing an indispensable route for fluid resuscitation, medication administration, nutritional supplementation, blood transfusion, and contrast media. Hence, the establishment of PIVC is vital in acute illnesses, especially when facing an emergent situation. In contrast to the high success rate of PIVC in adults, intravenous (IV) cannulations are difficult to set up in children owing to small vessels, poor cooperation, and parental pressure on medical staff. The success rate of establishing PIVC within the first attempt is approximately 77% in adults but only 53% in children. Hence, the difficulty of PIVC is a concerning issue in pediatric health care because it might complicate daily clinical care and induce stressful and tense relationships between the operators and family to a certain extent. Furthermore, studies on successful PIVC focusing on age-subgroup analysis in children are still lacking. If clinicians could decipher how to decrease the failure rate of PIVC in children, then the medical staff can improve pediatric care and gain parents’ trust.

Some predisposing factors might influence the success rate of PIVC in children. For instance, setting up PIVC is harder in younger children than in older ones, and obesity could be a pivotal culprit for increasing the failure rate. Nonetheless, further investigations to clarify other influential parameters are still warranted to increase the success rate of PIVC in children. For example, whether the success rate of pediatric PIVC is positively correlated with patients’ age or whether the consequent notion of a previous study is affected when the patients are discussed in different age subgroups must be clarified. From this viewpoint, additional studies considering age-classified analysis and the seniority of operator experience should be conducted. To date, the association between the success rate of pediatric PIVC and the disease severity and biochemistry data of patients has never been explored, possibly influencing the success of this procedure. Given that articles regarding pediatric PIVC are lacking in Asia, the use of previous findings for extrapolation to Asian children is restricted in view of racial differences. Accordingly, a meticulous study on the age effect, operators’ experience, and the illness of patients is needed to validate the crucial factors affecting the success of pediatric PIVC in Asians.

This work is the largest study of Taiwanese children that aims to comprehensively assess the association between PIVC success rate and potential confounders to unravel the explicit influence of the aforementioned factors. The results clarify new dimensions on the pertinent factors of successful PIVC in children. Rather than newborns, infants appear to be the most difficult group to establish PIVC. Although seniority is crucial, senior PIVC operators might lose their proficiency and decrease their success rate without constant and steady skill practice. In addition, the severity of infection is positively correlated with the failure rate of PIVC. With a profound vision of the success rate of pediatric PIVC, this study improves the understanding of PIVC characteristics for pediatricians and increases the quality and satisfaction of future children’s health care.

2. Methods

2.1. Patients and settings

This prospective observational study enrolled pediatric patients aged less than 18 years who required PIVC at the emergency department, ordinary ward, neonate intensive care unit, and pediatric intensive care unit in Tri-Service General Hospital in Taiwan from June 2016 to June 2017. This work was approved by the Ethics Committee of the Institutional Review Board of Tri-Service General Hospital, National Defense Medical Center (TSGHIRB No: 1-105-05-088), and informed consent was obtained from the parents and adolescents.
2.2. Data collection

Exclusion criteria were as follows: patients or their parents who refused to participate, requiring more than two executors to set up the PIVC, having central intravenous catheterization, and expired cases. A total of 935 PIVC trials (558 patients) were enrolled to examine the relationships between influential factors and successful PIVC establishment. Demographic data such as chronological age, age categories, sex, body height, body weight, and body mass index (BMI: weight in kilograms divided by the square of patient’s height in meters) were obtained. Given that the wide differences in BMI between age subgroups might cause deviations in analysis, the BMI standard deviation score (BMI-SDS) was used to minimize possible errors and was calculated by the patient’s BMI minus the 50th percentile BMI in that age divided by the standard deviation according to the growth reference of Taiwanese children.12

Biochemistry data, location of PIVC (hands or feet), use of near-infrared technology (NIR) (yes/no), and the seniority of operators were also recorded to clarify the influence of the aforementioned factors on the success rate of PIVC. Given its ability to project a map of the patient’s veins on the surface of the skin, NIR was applied when the vein remained invisible after a tourniquet was employed.

2.3. Definition of variables

The participants were divided into five different groups: newborns (<1 month), infants (1 month–1 year), toddlers (1–3 years), preschoolers (3–6 years), and students (6–18 years). The seniority of PIVC operators was also classified into five different groups: intern and first-year resident (R1), second-year resident (R2), third-year resident (R3), chief resident (CR, 4-year PIVC experience), fellow (5-year PIVC experience), and nurse practitioner (NP, more than 15-year PIVC experience).

One “attempt” was defined as each intravenous (IV) catheterization regardless of its success. Successful PIVC insertion was defined as when the IV catheter could be freely flushed with fluid without any signs of extravasation. The time of PIVC completion was defined as the total time when the needle touched the skin to the catheter being finally fixed. Supporters were defined as the medical staff taking over the first operator who failed to fulfill PIVC.

2.4. Outcome measures

The primary outcome was the number of attempts and the amount of time needed to set up a “successful” PIVC. The number of supporters involved in the PIVC insertion was also evaluated. The secondary outcome was the variables (anthropological data, operators’ experience, the illness of patients) most formidable in affecting the success rate of PIVC.

2.5. Statistical analysis

For descriptive statistics, the mean, standard deviation, number and percentage were used to present the distribution of all variables. For the univariate test, independent t test and chi-square were applied to assess the association between the success and failure groups. Moreover, a multivariate logistic regression model was established to distinguish the potential factors related to the success of PIVC. All statistical analyses were performed using SPSS software v.22.0 (SPSS, Chicago, IL, USA), and two-tailed p-value <0.05 indicated statistical significance.

3. Results

3.1. Demographic characteristics

A total of 1030 trials of IV catheter setup were performed during the study period. Patients refusing to participate (n = 70), critical PIVC requiring more than two executors (n = 18), and expired patients (n = 7) were excluded. A total of 935 trials of PIVC from 558 study subjects were finally enrolled, and most of the PIVC trials were attributed to newborns (n = 585 trials) (Table 1). The mean age of all participants was 20.32 ± 45.25 months, and their BMI-SDS

| Variables         | Total (n = 935) | Success (n = 827) | Failure (n = 108) | P value |
|-------------------|-----------------|-------------------|-------------------|---------|
| Age (month)       | 20.32 ± 45.25   | 20.59 ± 45.13     | 18.29 ± 46.33     | 0.619   |
| Age group         |                 |                   |                   | 0.153   |
| Newborn           | 585 (62.6%)     | 518 (62.6%)       | 67 (62.0%)        |         |
| Infant            | 103 (11.0%)     | 84 (10.2%)        | 19 (17.6%)        |         |
| Toddler           | 76 (8.1%)       | 69 (8.3%)         | 7 (6.5%)          |         |
| Pre-school        | 79 (8.4%)       | 73 (8.8%)         | 6 (5.6%)          |         |
| Student           | 92 (9.8%)       | 83 (10.0%)        | 9 (8.3%)          |         |
| Sex               |                 |                   |                   | 0.387   |
| Female            | 534 (57.1%)     | 477 (57.7%)       | 57 (52.8%)        |         |
| Male              | 401 (42.9%)     | 350 (42.3%)       | 51 (47.2%)        |         |
| Height (cm)       | 64.40 ± 33.92   | 64.60 ± 34.01     | 62.88 ± 33.33     | 0.619   |
| Weight (kg)       | 8.60 ± 12.94    | 8.57 ± 12.76      | 8.83 ± 14.36      | 0.847   |
| BMI (kg/m²)       | 13.80 ± 6.02    | 13.73 ± 6.12      | 14.33 ± 5.20      | 0.332   |
| BMI-SDS           | −0.65 ± 6.10    | −0.71 ± 6.26      | −0.22 ± 4.76      | 0.430   |

Abbreviation: BMI, body mass index; BMI-SDS, BMI standard deviation score.
was \(-0.65 \pm 6.10\). For gender, the number of female patients (57.1\%) was slightly higher than males (42.9\%).

### 3.2. Factors associated with PIVC implantation

Data associated with IV catheterization, including the insertion site and the use of NIR, were collected to unravel the potential factors of successful PIVC. The most common IV insertion site was hands (91.9\%), and the success rate between hands and feet was not significantly different (763/859, 88.8\% vs. 64/76, 84.2\%; \(p\)-value = 0.308) (Table 2). NIR was used in most attempts (83.5\%), but the success rate of attempts with NIR was higher than that of attempts without NIR (683/781, 87.5\% vs. 144/154, 93.5\%; \(p\)-value = 0.044). Compared with those in the success group, more attempts (1.56 ± 1.40 vs. 2.19 ± 1.89), longer completion time (14.31 ± 20.05 vs. 39.50 ± 61.89), and more supporters for IV cannulation (1.97 ± 0.17) were noted in the failure group (all \(p\)-values < 0.05).

### 3.3. Seniority of the operators and supporters

The medical staffs were divided into five groups: intern + R1, R2, R3, CR + fellow, and NP + registered nurses (RN) to elucidate the relationship between the seniority of the operators and the success rate of PIVC (Table 3). The highest success rate among all the operators was 98.1\% (265/270) in the NP + RN group, and the lowest was noted in the R1 group (77.6\%, 191/246). The success rate was positively correlated with the seniority of the operators, except for the success rate of the R3 group being higher than that of the CR group (93.5\%, 144/154 vs. 84.2\%, 16/19). Owing to the failure of PIVC in the initial operator, 108 trials were completed by the supporters. In addition, only successful PIVCs executed by the supporters were enrolled at the end; thus, the association between the seniority of the supporters and the subsequent success rate was not assessed. Nonetheless, the results still disclosed the NP group (34.3\%) as the major supporter upon the failure of the initial PIVC.

### 3.4. Disease severity and PIVC success rate

Serum biochemistry data were analyzed to determine whether blood sampling and PIVC establishment are simultaneously conducted and to clarify the association between disease severity and PIVC success rate. Six parameters, namely, complete blood count (anemia) (white cell count and hemoglobin), electrolyte hemostasis (indirect assessment of dehydration) (sodium, potassium, and chloride), and infectious status (C-reactive protein (CRP))

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### Table 2 Factors associated with PIVC implantation.

| Variables                        | Total (n = 935) | Success (n = 827) | Failure (n = 108) | \(P\) value |
|----------------------------------|----------------|------------------|------------------|------------|
| Location                         |                |                  |                  |            |
| Hands                            | 859 (91.9\%)   | 763 (92.3\%)     | 96 (88.9\%)      | 0.308      |
| Feet                             | 76 (8.1\%)     | 64 (7.7\%)       | 12 (11.1\%)      |            |
| Non-Infra-Red technology         |                |                  |                  | 0.044      |
| Yes                              | 781 (83.5\%)   | 683 (82.6\%)     | 98 (90.7\%)      |            |
| No                               | 154 (16.5\%)   | 144 (17.4\%)     | 10 (9.3\%)       |            |
| First establishment (attempts)   | 1.63 ± 1.47    | 1.56 ± 1.40      | 2.19 ± 1.89      | < 0.01     |
| Second establishment (attempts)  | 1.82 ± 1.78    |                  |                  |            |
| Complete time (min)              | 17.22 ± 29.31  | 14.31 ± 20.05    | 39.50 ± 61.89    | < 0.01     |
| Numbers of supporter             | 1.97 ± 0.17    |                  |                  | < 0.01     |

### Table 3 The seniority of medical staff for PIVC establishment.

| Variables            | Total (n = 935) | Success (n = 827) | Failure (n = 108) | \(P\) value |
|----------------------|----------------|------------------|------------------|------------|
| Operator             |                |                  |                  |            |
| Intern + Resident 1  | 246 (26.3\%)   | 191 (23.1\%)     | 55 (50.9\%)      | <0.001     |
| Resident 2           | 245 (26.2\%)   | 210 (25.4\%)     | 35 (32.4\%)      |            |
| Resident 3           | 154 (16.5\%)   | 144 (17.4\%)     | 10 (9.3\%)       |            |
| CR + Fellow          | 19 (2.0\%)     | 16 (1.9\%)       | 3 (2.8\%)        |            |
| NP + RN              | 270 (28.9\%)   | 265 (32.1\%)     | 5 (4.6\%)        |            |
| Supporter            |                |                  |                  |            |
| Resident 1           | 17 (1.8\%)     | 12 (1.5\%)       | 5 (4.6\%)        |            |
| Resident 2           | 16 (1.7\%)     | 11 (1.3\%)       | 5 (4.6\%)        |            |
| Resident 3           | 10 (1.1\%)     |                  | 6 (5.6\%)        |            |
| CR                   | 11 (1.2\%)     |                  | 6 (5.6\%)        |            |
| Fellow               | 12 (1.3\%)     |                  | 6 (5.6\%)        |            |
| NP                   | 37 (4.0\%)     |                  | 11 (10.2\%)      |            |
| Intern               | 6 (0.7\%)      |                  |                  |            |
| RN                   | 11 (1.2\%)     |                  |                  |            |

Abbreviation: CR, chief resident; NP, nurse practitioner; RN, registered nurse.
and procalcitonin (PCT), were analyzed (Table 4). The results revealed no significant difference in hemogram and biochemistry data between the success and failure groups, except for PCT (4.70 ± 2.11 ng/mL vs. 23.43 ± 12.40 ng/mL; p-value = 0.016).

3.5. Multivariate predictive factors of failed PIVC establishment at the first attempt

Table 5 shows the multivariate logistic regression model used to determine the influential factors of the success rate of PIVC. Compared with that in the pre-school and student groups, the aOR of PIVC failure was 2.60 (95% CI: 1.08–6.27, p-value = 0.034) in the infant group. The failure rate showed a significant relationship with the grading of seniority, and the CR fellow group had a higher failure rate than the R3 group (aOR 0.30 vs. 0.14). Furthermore, NIR was found to be an effectual auxiliary tool to decrease the failure rate by 58% (aOR: 0.42, 95% CI: 0.18–0.99, p-value = 0.047).

4. Discussion

Setting up PIVC is harder in children than in adults but is a crucial skill for pediatric practitioners to manage ill children. This study disclosed that considerable time (14.31 ± 20.05 min) was needed for successful PIVC in children at the first attempt, and almost threefold longer (39.50 ± 61.89 min) was needed to resettle the PIVC. Herein, the difficulties of PIVC establishment, such as a high failure rate and laborious process, reiterated the importance of improving the understanding of the potential factors of successful PIVC. Although some studies investigated the above-mentioned issues, the present work involving multifaceted influential parameters added a new dimension to establish PIVC and provide an instructive view for further research.

First, the difficult intravenous access (DIVA) score is a well-known and widely accepted tool to assess the difficulty of PIVC; in some studies, DIVA illustrated that the difficulty of pediatric PIVC is disproportionate to age. Although the age <1-year had the highest DIVA score in the age category, no further age-subgroup analysis was conducted for this unique age. In line with the concept of DIVA score, our results showed the failure rate of PIVC increased when the patients’ age was less than 1 year old; however, a higher failure rate was noted in infants (1 month-old to 1 year old) than in newborns (<1 month-old). This intriguing finding could be partially explained by the thicker subcutaneous fat in infants compared with that in newborns. Given that the thick subcutaneous fat might blur out the folded skin and vessels, the increased failure rate of PIVC was noticed at

Table 4  Biochemistry data associated with disease severity.

| Variables | Total | Success | Failure | P value |
|-----------|-------|---------|---------|---------|
| Hb (g/dL) | 14.71 ± 3.18 | 14.65 ± 3.17<sup>a</sup> | 15.25 ± 3.22<sup>b</sup> | 0.190 |
| WBC (10<sup>3</sup>/μL) | 13.23 ± 6.66 | 13.24 ± 6.76<sup>a</sup> | 13.15 ± 5.71<sup>b</sup> | 0.924 |
| Na<sup>+</sup> (mmol/L) | 136.64 ± 3.06 | 136.59 ± 3.02<sup>c</sup> | 137.19 ± 3.50<sup>d</sup> | 0.258 |
| K<sup>+</sup> (mmol/L) | 4.80 ± 0.96 | 4.80 ± 0.96<sup>e</sup> | 4.81 ± 0.94<sup>d</sup> | 0.936 |
| Cl<sup>-</sup> (mmol/L) | 103.11 ± 3.43 | 103.15 ± 3.33<sup>g</sup> | 102.75 ± 4.46<sup>h</sup> | 0.755 |
| CRP (mg/dL) | 1.24 ± 2.57 | 1.17 ± 2.27<sup>e</sup> | 1.92 ± 4.34<sup>h</sup> | 0.240 |
| PCT (ng/mL) | 5.89 ± 13.29 | 4.70 ± 2.11<sup>i</sup> | 23.43 ± 12.40<sup>g</sup> | 0.016 |

Abbreviation: Hb, hemoglobin; WBC, white blood cells; Na<sup>+</sup>, sodium; K<sup>+</sup>, potassium; Cl<sup>-</sup>, chloride; CRP, C-reactive protein; PCT, procalcitonin.

<sup>a</sup> n = 487.  
<sup>b</sup> n = 54.  
<sup>c</sup> n = 351.  
<sup>d</sup> n = 36.  
<sup>e</sup> n = 346.  
<sup>f</sup> n = 72.  
<sup>g</sup> n = 8.  
<sup>h</sup> n = 423.  
<sup>i</sup> n = 48.  
<sup>j</sup> n = 44.  
<sup>k</sup> n = 30.

Table 5  Multivariate predictive factors of failed PIVC establishment at the first attempt.

| Variables | aOR | 95% CI | P value |
|-----------|-----|--------|---------|
| Age group Pre-school + Student | Ref. | | |
| Newborn | 1.75 | 0.80–3.85 | 0.163 |
| Infant | 2.60 | 1.08–6.27 | 0.034 |
| Toddler | 0.89 | 0.32–2.47 | 0.822 |
| Non-Infra-Red technology Yes vs. No | 0.42 | 0.18–0.99 | 0.047 |
| Grade operator Intern + Resident 1 | Ref. | | |
| Resident 2 | 0.50 | 0.31–0.82 | 0.006 |
| Resident 3 | 0.14 | 0.06–0.30 | <0.001 |
| CR + Fellow | 0.30 | 0.07–1.27 | 0.103 |
| NP + RN | 0.05 | 0.02–0.12 | <0.001 |

Abbreviation: aOR, adjusted odds ratio; CR, chief resident; NP, nurse practitioner; RN, registered nurse.
such unique age despite the assistance of NIR. In addition, infants are relatively powerful, and PIVC cannot be performed by one executor similar to that in newborns. Thus, the difficulty of PIVC might be increased in infants.

Second, this study disclosed that the most experienced NP had the highest success rate (98.1%), whereas the success rate of inexperienced R1 was the lowest (77.6%). This result echoed the positive relation between the success rate of PIVC and the seniority of operators.22,23 Meanwhile, the success rate of the R3 group was unexpectedly higher than that of the CR group (93.5% vs 84.2%). This finding might be partly due to the number of PIVC establishment cases in the R3 group being eight times higher than that in the CR group.24 When the pediatric resident becomes a senior, the role of CR is transferred from clinical practitioners to decision-makers to gradually decrease the resident’s practice of clinical procedures.22 Therefore, the lack of adequate and continuous skill training might cause the low success rate of PIVC in the CR group despite their seniority. In support of this speculation, the number of PIVC establishment dramatically decreased from the R1 group (246) to the CR group (19) as listed in Table 3. The NP group had the highest practicing amount of PIVC (270) and maintained a stable and high success rate. In summary, seniority and uninterrupted skill practice are important to the success of PIVC.

Our results showed that the success rate of PIVC with NIR was lower than that without NIR (87.5% vs. 93.5%). According to the DIVA score, two parameters of “vein visible after tourniquet” and “vein palpable after tourniquet” were also predictor variables of PIVC.18 NIR was applied when the vessels remained invisible even after the use of tourniquets. The results revealed the great difficulty of performing pediatric PIVC in the NIR-needed group, echoing the essence of the DIVA score to some extent. Meanwhile, previous studies reported that NIR assistance does not affect the success rate of common PIVC but could substantially attenuate the failure rate of difficult pediatric PIVC.29,30 No remarkable association between body weight (or BMI-SDS) and successful pediatric PIVC was observed in the current and previous studies.9 However, Nafiu et al. studied patients with obesity (BMI ≥95th) or normal weight (BMI < 85th) and found the success rate of pediatric PIVC was lower in the obese group than in the normal group (39.6% vs 55.2%).28 Therefore, the current and previous studies indicated that even though seniority rather than BMI posed a crucial role in setting up pediatric PIVC, extreme obesity (BMI ≥95th) might still aggravate the failure rate of PIVC in children.

Although disease severity could be a potential factor influencing the success rate of pediatric PIVC, it has seldom been investigated. Vital signs such as blood pressure and heart rate have been regarded as parameters to evaluate the relationship between disease severity and adult PIVC success rate but turned out to be irrelevant.29 This study first focused on serum biochemistry data as the variables of disease severity to elucidate whether anemia, electrolyte imbalance, and infection (CRP and PCT) affect PIVC in children. The results showed that PCT was significantly higher in the failure group than in the success group. Given that PCT is a more sensitive biomarker than CRP in septic patients,30 performing PIVC might be difficult in patients with severe infection in view of poor peripheral perfusion.31 However, further studies are warranted to confirm our findings.

This study has some limitations. Given that most of the participants were newborns and infants, the uneven composition of patient groups might lead to statistical bias. In addition, we excluded the extreme data of PIVC established by more than two executors to save resources such as time and medical staff. This condition might have underestimated the original failure rate and failed to reflect the real clinical situation. Not every patient requires blood sampling while PIVC is being set up; thus, only 541 out of 935 trials were analyzed for disease severity through biochemical data. Herein, the missing data (42.1%, 394/935) might prevent us from fully understanding the precise effect of patients’ underlying condition on PIVC. Owing to racial differences, our study is representative of Taiwanese children and might be not extrapolated to Western countries. Nevertheless, this work still enriches the new dimensions on establishing PIVC, especially the limited studies in Asia.

5. Conclusion
PIVC has been a challenge for pediatricians, and its high failure rate might cause a tense relationship between parents and medical staff. This study demonstrated that the arduous pediatric PIVC in patients with obesity, infants, and severe sepsis (high PCT) might be improved by the senior staff. Although seniority is positively associated with the success rate of pediatric PIVC, failure rate could increase with lack of sustained practice. Therefore, continuously training talented executors to perform pediatric PIVC is pivotal to improve the success rate of PIVC and attenuate the operating time. These new perspectives on PIVC in children might improve the efficiency of clinical work and the quality of pediatric health care in the future.

Ethics approval and consent to participate
This article was approved by the Ethics Committee of the Institutional Review Board of Tri-Service General Hospital, National Defense Medical Center (TSGHIRB No: 1-105-05-088).

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Authors’ contributions
CHC conceptualized the study, collected data, drafted the initial manuscript, and reviewed and revised the manuscript. CCL, CYL, YCC, CHT, and KHH collected data, carried out the initial analyses, and revised and reviewed the manuscript. CML conceptualized the study, coordinated and supervised data collection, and provided critical editing and revision to the final drafts of the report.
Consent for publication

The patients and their parents agreed to the use of their clinical data for publication and academic research and provided written informed consent.

Declaration of competing interest

The authors declare that they have no competing interests.

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