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ORIGINAL RESEARCH

Exploring the effectiveness of virtual technology combined with lidocaine cream in pediatric puncture pain management

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Abstract

This study investigates the effectiveness of virtual reality (VR) technology & lidocaine cream in managing pediatric puncture pain. Between February 2023 and February 2024, 150 hospitalized children who participated in pain management were selected from our hospital. Participants were divided into control group, experimental group 1 and experimental group 2, with 50 cases in each group. The control group received conventional nursing care plus lidocaine cream intervention. Experimental group 1 received conventional nursing care plus VR nursing intervention, while experimental group 2 received conventional nursing care combined with both lidocaine cream and VR interventions. The effects of three intervention methods on pediatric pain management were compared. During and after the puncture, pain scores for experimental groups 1 and 2 were lower than the control group, with experimental group 2 showing the lowest scores ($p < 0.05$). Post-puncture, medical fear scores and total scores were significantly lower in experimental groups 1 and 2 compared to the control group, with experimental group 2 having the lowest scores ($p < 0.05$). Satisfaction scores, pain knowledge and attitude scores were significantly higher in experimental groups 1 and 2 than the control group, with experimental group 2 achieving the highest scores ($p < 0.05$). Crying time and puncture time were shorter in experimental groups 1 and 2 than the control group, with experimental group 2 showing the shortest times ($p < 0.05$). The success rate of first-attempt puncture was higher in experimental group 2 than the other two groups ($p < 0.05$). Success rates varied across different age groups, with older children exhibiting higher success rates. The application of VR & lidocaine cream in pediatric puncture pain management effectively reduces pain and medical fear, improves nursing satisfaction, enhances pain knowledge and attitudes and increases the success rate of first-attempt puncture, worthy of clinical promotion.

Keywords

Virtual technology; Lidocaine cream; Pain management

1. Introduction

Puncture procedures are among the most common clinical operations and are essential for treating numerous diseases. However, pediatric patients often experience significant physical pain and discomfort during punctures due to their young age, and this can lead to crying, resistance or refusal of treatment, thereby affecting the progress of the procedure and subsequent treatments. Such adverse reactions not only impact the child's physical state but also disrupt the overall course of therapy and condition management [1]. Therefore, effective pain management during puncture procedures is essential [2] because inadequate pain management can have long-term consequences, including avoidance behaviors and oppositional attitudes towards medical procedures. These behaviors can hinder the progression of nursing interventions, increase the difficulty of nursing and communication, damage the nurse-patient relationship, slow down recovery and negatively affect the child's quality of life and well-being during hospitalization [3]. Thus, identifying appropriate pain management strategies is particularly imperative for hospitalized children.

Conventional procedural pain interventions include pharmacological and non-pharmacological measures, such as topical anesthetics, non-nutritive sucking, glucose administration and play therapy [4]. Only reliance on pharmacological treatment may be insufficient to alleviate all discomfort, while non-pharmacological interventions might not effectively relieve pain, leading to emotional instability and psychological disturbances, thereby impacting subsequent treatments.

Virtual reality (VR) technology employs various techni-

cal means, including computer systems that generate three-dimensional real-time animations and head-mounted displays equipped with motion trackers and data processors [5]. Currently, VR is primarily used for mental health interventions, remote live surgical broadcasts, debridement and rehabilitation for burn patients, organ transplant pain management, cancer patient injections, dental pain interventions and other scenarios [6]. In recent years, VR technology has been widely applied in disease treatment and interventions, achieving favorable outcomes.

Therefore, this study investigates the effect of VR technology combined with lidocaine cream on operant pain intervention in hospitalized children of different ages.

2. Materials and methods

2.1 General information

This study included 150 hospitalized children who voluntarily participated in pain management at our hospital between February 2023 and February 2024 (Fig. 1). The participants were divided into three groups, each containing 50 children, based on the intervention method they underwent: experimental group 1, experimental group 2 and a control group. The baseline characteristics of the patients were comparable across all groups ($p > 0.05$) (Table 1).

Inclusion criteria for the study were as follows: children aged 3–7 years, a pain score of 0 before cannulation, intended for puncturing without scars, allergies or venous thrombosis in the limb [7], and informed consent obtained from both the child and parents, with a signed consent form. Exclusion criteria included children unable to wear virtual reality glasses, children with abnormal coagulation functions [8] and children allergic to lidocaine.

2.2 Intervention methods

The control group received conventional nursing care and a compound lidocaine cream (Tongfang Pharmaceutical Group Co. Ltd, H20063466, Beijing, China). Before the puncture, nurses calmed the child using toys, cartoons or conversation, depending on the child's emotional state. The puncture site on the child's limb was checked to ensure it was free from any skin damage. Then, the skin was cleaned with warm water, and after identifying the puncture point, the compound lidocaine cream was applied uniformly within a 2 cm radius around the central point at a thickness of 1 mm. Next, this area was covered using a sterile transparent film for 30 minutes to ensure the effectiveness of the medication. After 30 minutes, the cream was washed off, the area disinfected and the puncture performed.

For experimental group 1, the children received the same conventional care as the control group plus a VR nursing intervention. During the puncture process, a VR all-in-one machine (iQIYI's VR machine, 8K panoramic video, customized iQUT giant screen, Chongqing, China) was used to play videos. Nurses equipped and adjusted the VR headset for the children, allowing them to immerse completely in the virtual world without needing any controllers. Display content and interactive forms were chosen based on the children's cognitive levels. The VR experience included various modes: (1) Panoramic roaming mode: videos such as forest parks, underwater worlds and Arctic penguins were shown. For example, a 360° full perspective of an underwater tunnel simulated walking inside it, with seas overhead and stepping on the deep seafloor, bringing the entire ocean close. (2) Interactive video mode: the child's eye and head movements controlled the branching of video playback. (3) VR game mode: the game "Arca's Path" was selected, a peaceful and relaxing puzzle game set against a background of plants, trees and flowers with soothing music. This aimed to transport the child into an almost zen-like world. The child controlled the game by gazing in different directions to navigate through the environment. Therapists monitored the content of the VR headset in real-time through mobile wireless screen casting, thus controlling the entire pain intervention process for the child.

For experimental group 2, the children received conventional care combined with both lidocaine cream and VR intervention. This process was managed entirely by pediatric specialist nurses who assessed veins, chose appropriate veins for puncture, anesthetized, prepared the skin, selected puncture points, disinfected, punctured and either placed catheters or withdrew needles. The conventional care provided was the same as previously described. Before puncturing, compounded lidocaine cream was applied for 40–50 minutes (application method same as the control group). After applying the lidocaine cream, the children wore the VR headset to attract their attention during the preparation of materials (VR intervention process same as experimental group 1). To prevent symptoms such as dizziness or palpitations during the fitting process, a pre-fitting experiment was conducted. If discomfort occurred, the headset was immediately removed, and vital signs were monitored and observed.

2.3 Observation indicators

(1) Pain level: the face-legs-activity-cry-consolability (FLACC) scale [9] was used to measure children's procedural pain before the operation, during the operation, and 5 minutes after the operation. Specifically, a score of 0 means the patient reports no pain; a score of 1–3 indicates mild pain that is tolerable; a score of 4–6 signals moderate pain that is noticeable but does not interfere with sleep and is bearable; a score of 7–10 represents severe pain that is intolerable. (2) Medical fear: the Children's Medical Fear Scale (CMFS) [10] was used to assess the degree of medical fear in children before and after puncturing. The CMFS includes four dimensions with a total of 17 items: fear of medical operations (4 items), fear of the medical environment (4 items), fear of interpersonal relationships (4 items) and self-fear (5 items). Each item is scored on a three-level scale from "not afraid" to "very afraid", scoring from 1 to 3 points for each, with a total score ranging from 17 to 51 points. The higher the score, the greater the degree of medical fear. (3) Nursing satisfaction: a self-designed satisfaction questionnaire assessed the parents' satisfaction with the nursing care for their child's procedural pain. The contents include timeliness, accuracy, reasonableness and effectiveness. Each entry is scored using

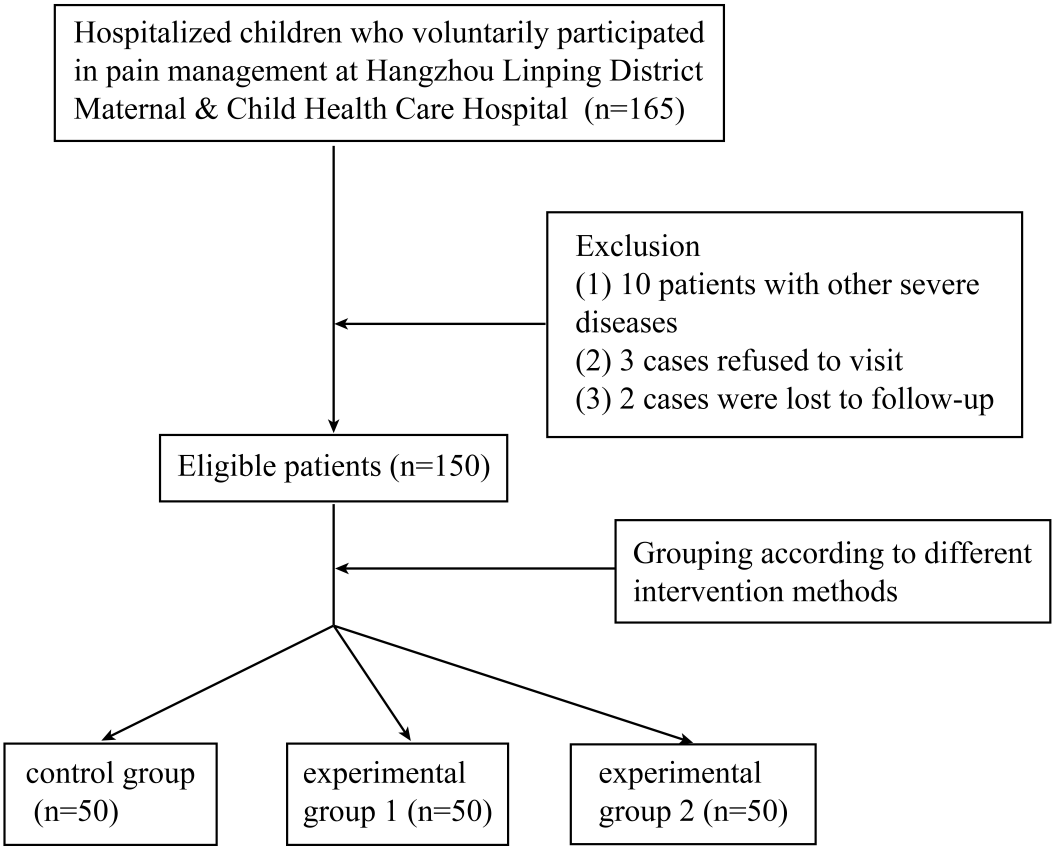

FIGURE 1. Flow chart of the study design and grouping.

TABLE 1. Comparison of general information among the three groups.

Group	n	Gender (Male/Female)	Age (yr)	Puncture frequency
Control group	50	25/25	6.70 ± 2.49	1.24 ± 0.43
Experimental group 1	50	26/24	6.68 ± 2.70	1.20 ± 0.40
Experimental group 2	50	23/27	6.55 ± 2.58	1.20 ± 0.38
χ^2/F	-	0.373	0.049	0.164
p	-	0.830	0.952	0.849
Group	n	Heart rate (beats/min)	Breathing (times/min)	Oxygen saturation (%)
Control group	50	105.34 ± 8.04	27.24 ± 3.04	98.35 ± 0.47
Experimental group 1	50	104.20 ± 8.48	27.16 ± 3.31	98.42 ± 0.51
Experimental group 2	50	106.16 ± 7.89	26.64 ± 3.46	98.55 ± 0.55
F	-	0.731	0.495	1.972
p	-	0.483	0.611	0.143

a 4-level scale from "not satisfied" to "extremely satisfied", with each level scoring 10 to 25 points, respectively and a total score ranging from 10 to 100 points. (4) Pain knowledge and attitudes: a survey questionnaire on parental pain management knowledge and attitudes was administered. The Knowledge and Attitudes Survey Regarding Pain (KASRP) [11] covers four dimensions: pain knowledge, pain assessment, pain medication and pain interventions, with 40 items in total. Each item has a maximum score of 1 point, with a total score of 40 points. A higher score indicates better parental understanding and attitudes towards pain management. (5) Clinical indicators: crying time, puncture time and the first-attempt success rate for venipuncture were recorded.

2.4 Statistical methods

Statistical analysis was performed using SPSS 22.0 software (IBM, Armonk, NY, USA). Measurement data conforming to a normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm sd$), and comparisons were made using variance analysis (F-test). Count data were described as percentages (%) and compared using the chi-square test (χ^2). A p-value of < 0.05 was considered statistically significant.

3. Results

3.1 Comparison of pain levels

During and after the puncture procedure, the pain scores for experimental groups 1 and 2 were lower than the control group, and the pain scores for experimental group 2 were lower than experimental group 1 ($p < 0.05$) (Table 2).

3.2 Medical fear scores

After puncturing, we found that the medical fear scores for both individual dimensions and the total score for experimental groups 1 and 2 were lower than the control group, and the scores for experimental group 2 were lower than experimental group 1 ($p < 0.05$) (Table 3).

3.3 Nursing satisfaction and pain knowledge and attitudes

The satisfaction scores and pain knowledge and attitudes scores for experimental groups 1 and 2 were found to be significantly higher than the control group, and the scores for experimental group 2 were higher than experimental group 1 ($p < 0.05$) (Table 4).

3.4 Crying time and first-attempt success rate for venipuncture

The crying times and puncture times for experimental groups 1 and 2 were lower than those for the control group, with the times for experimental group 2 being lower than those for experimental group 1 ($p < 0.05$). The first-attempt success rate for venipuncture was higher for experimental group 2 than for experimental group 1 and the control group ($p < 0.05$) (Table 5). The success rate of puncturing varied with different age groups; the older the child, the higher the success rate of puncturing (Table 6).

4. Discussion

Procedural pain refers to short-term discomfort typically caused by invasive operations or diagnostic procedures, such as venipuncture, bone marrow aspiration, lumbar puncture and the insertion of chemotherapy pumps. Children who experience repeated procedural pain may suffer both immediate and long-term adverse effects, including post-traumatic stress disorder, sleep disturbances, physiological responses, depression, hormonal imbalances, cognitive-behavioral changes and other psychological sequelae [12]. In extreme cases, this can lead to neurogenic shock or suicidal ideation. Therefore, appropriate pain intervention is critically important for hospitalized children. Despite extensive research on pediatric procedural pain, effective interventions remain scarce in clinical practice. Pain comprises sensory, emotional and cognitive dimensions, making pharmacological treatment alone insufficient to alleviate all discomfort. Thus, it is essential to adopt scientifically validated intervention measures to reduce pain during procedures.

Modern medicine considers pain to be a complex phenomenon characterized as an unpleasant subjective sensation associated with actual or potential tissue damage, and involving sensory, emotional and cognitive processes [13]. Current approaches to pain relief primarily involve methods such as acupoint massage and analgesic drugs, which have shown significant efficacy. As a psychological intervention, VR technology can effectively distract attention and alleviate pain during invasive procedures due to its high safety and efficiency [14]. It has been reported that VR technology, a potent non-pharmacological analgesic approach in clinical practice, can significantly reduce pain and discomfort in children and plays an important role in pediatric pain management. Compared to pharmacological treatments, VR offers advantages such as low risk, ease of use, no pain and no adverse reactions, and it can significantly lower children's objective pain scores [15].

Additionally, lidocaine cream has been widely used for pain relief before various invasive procedures and is considered suitable for children [16]. The results of our present study indicated that during and after the puncture, the pain scores in experimental group 2 were lower than those in the control group and experimental group 1, suggesting that the combination of compound lidocaine cream and VR technology can effectively reduce patients' pain during treatment. Compound lidocaine cream, commonly used for pain control during pediatric venipuncture in clinical practice, provides effective surface anesthesia by topical application, blocking superficial sensory nerves and preventing the formation of pain reflexes, thereby achieving pain relief. VR technology reduces pain sensitivity through the activation of higher cognitive functions such as focus, attention, and memory, enhancing the patient's engagement with pleasant stimuli and having significantly fewer side effects compared to pharmacological analgesia. Furthermore, the use of virtual videos as an intervention has proven to be more effective than mobile videos [17].

TABLE 2. Comparison of pain levels among the three groups of patients ($\bar{x} \pm sd$, points).

Group	n	Before puncture	During puncture	5 minutes after puncture
Control group	50	0	2.50 ± 0.73	1.10 ± 0.67
Experimental groups 1	50	0	1.94 ± 0.68	0.88 ± 0.59
Experimental group 2	50	0	1.02 ± 0.51	0.60 ± 0.49
F	-	4.610	66.720	9.083
p	-	0.143	<0.001	<0.001

TABLE 3. Comparison of medical fear scores between the two groups of patients ($\bar{x} \pm sd$, points).

Group	n	Fear of medical environment		Fear of interpersonal relationships		Self fear		Medical operation fear		Total score	
		Before puncture	After puncture	Before puncture	After puncture	Before puncture	After puncture	Before puncture	After puncture	Before puncture	After puncture
Control group	50	8.42 ± 1.87	7.68 ± 2.30	7.40 ± 1.79	6.22 ± 1.74	6.32 ± 1.65	5.86 ± 1.73	6.94 ± 1.54	6.20 ± 1.48	29.08 ± 2.79	25.96 ± 3.52
Experimental groups 1	50	8.52 ± 1.71	6.56 ± 1.75	7.32 ± 1.67	5.68 ± 0.97	6.40 ± 1.66	4.88 ± 1.27	6.58 ± 1.59	5.82 ± 1.31	28.82 ± 3.39	22.94 ± 2.81
Experimental groups 2	50	8.72 ± 2.06	4.60 ± 1.51	7.56 ± 1.63	4.34 ± 0.62	6.50 ± 1.32	3.98 ± 1.17	6.82 ± 1.79	4.60 ± 1.13	29.60 ± 3.45	17.52 ± 2.46
F	-	0.328	34.287	0.259	32.287	0.169	22.197	0.622	20.222	0.759	104.156
p	-	0.721	<0.001	0.772	<0.001	0.845	<0.001	0.538	<0.001	0.470	<0.001

TABLE 4. Nursing satisfaction and pain knowledge and attitudes ($\bar{x} \pm sd$, points).

Group	n	Satisfaction score	Pain knowledge and attitude score
Control group	50	78.62 ± 2.61	19.64 ± 4.69
Experimental groups 1	50	81.04 ± 3.09	23.72 ± 3.94
Experimental groups 2	50	90.64 ± 3.53	31.96 ± 4.08
F	-	210.347	109.075
p	-	<0.001	<0.001

TABLE 5. Crying time and first-attempt success rate for venipuncture.

Group	n	Crying time (min)	Puncture time (s)	One time success rate of venous puncture (%)
Control group	50	0.82 ± 0.25	30.50 ± 6.67	40 (80.00)
Experimental groups 1	50	0.25 ± 0.10	16.30 ± 4.28	44 (88.00)
Experimental groups 2	50	0.11 ± 0.08	13.60 ± 3.50	48 (96.00)
χ^2/F	-	268.885	164.721	6.061
p	-	<0.001	<0.001	0.048

TABLE 6. Comparison of puncture success rates across different age groups (n (%)).

Group	$1 < \bar{x} \leq 5$	$5 < \bar{x} < 10$
Control group	15/20 (75.00)	25/30 (83.33)
Experimental groups 1	21/25 (84.00)	23/25 (92.00)
Experimental groups 2	22/24 (91.67)	26/26 (100.00)

Furthermore, compared to playing videos on cell phones, VR headsets provide an immersive experience through visual, auditory, and tactile sensations that shield the child's eyes from directly witnessing the puncture process, which can potentially intensify emotions such as tension. This effectively distracts the patient's attention away from pain, thereby enhancing the analgesic effect [18]. The combination of lidocaine cream and VR can have a synergistic effect, strengthening pain relief. Additionally, this combination has been highly recognized by both parents and children for its engaging interactive approach and efficient intervention method, creating an excellent medical experience. Therefore, the combined intervention is more effective than using lidocaine cream or VR technology alone.

After puncturing, the medical fear scores for both individual dimensions and the total score for experimental group 2 were lower than those of the control group and experimental group 1. This indicates that the combination of lidocaine cream and VR can effectively reduce children's medical fear. When children experience reduced pain after applying compound lidocaine cream, their fear and resistance toward pain also decrease, thereby improving cooperation during the procedure. However, since pain during the procedure is influenced by multiple factors, medication alone is not sufficient. For children who do not cooperate or exhibit negative emotions, games can be used to relieve psychological pressure, lessen fear and increase cooperation. In VR therapy, children can choose videos they like to watch, with puncture-related knowledge subtly integrated through simple introductions and encouragement for the child to try. As children become immersed, their sense of self-satisfaction, self-awareness, self-evaluation, and self-regulation abilities continuously increase, thus reducing anxiety, eliminating fear of puncture, and improving compliance. VR interventions also bridge the distance between the child and the doctor, fostering trust and fondness towards the doctor, ensuring the smooth progress of the procedure, and improving the medical experience for the child and their family [19].

VR can be used to transform the treatment environment for children by incorporating themes of fun and playfulness to capture their attention and alleviate the psychological fear associated with medical procedures, thereby improving their mental state. Satisfaction scores, as well as knowledge and attitudes about pain, are significantly higher in experimental group 2 compared to the control group and experimental group 1. This demonstrates that combining VR with lidocaine cream significantly enhances parental satisfaction with the entire procedural process. The immersive experience created by VR reduces physical pain and, through human-computer interaction, increases children's interest and engagement. Although VR does not block pain signals, it mitigates pain perception through advanced central processes such as attention, emotion and memory. Since pain perception requires attention, diverting the patient's attention to VR slows their response to pain signals, thereby reducing both pain perception and medical fear. This approach promotes a more positive attitude toward puncture treatments, thereby increasing parental satisfaction. Children's curiosity is effectively engaged by VR technology, which helps them ignore external pain and cooperate more actively with nurses during procedures. Therefore, parents report higher satisfaction with nursing interventions due to their children's cooperation and enthusiasm. Throughout the treatment process, healthcare professionals also educate and train parents about pain-related knowledge. As a result, parents in experimental group 2 demonstrate a high level of understanding and mastery of pain management knowledge and

attitudes.

The Crying and puncture times in experimental groups 1 and 2 are lower than in the control group, with group 2 having shorter times than group 1. The first-attempt success rate for venipuncture was found to be higher in group 2 than in group 1 and the control group. Compound lidocaine cream, a low-solubility oil-water mixture, can penetrate quickly and completely into the patient's skin. It offers advantages such as good adhesiveness and penetration, rapid onset, mild local irritation and high utilization. Only a small amount of the drug needs to be applied locally, resulting in minimal systemic effects on the child. The immersive and interactive nature of VR is more effective than music therapy because attention to engaging stimuli can alleviate anxiety and improve emotional states due to the limited capacity of personal attention [20]. The combination of lidocaine and VR significantly reduces children's pain perception, lowers their pain scores and decreases the time nurses spend preparing for and conducting punctures. Therefore, children's crying time is greatly reduced, and the puncture process proceeds smoothly. The number of punctures required is fewer, and the success rate on the first attempt is higher than for children who used only VR or lidocaine cream alone.

Dalir *et al.* [21] reported that virtual reality technology captures patients attention by immersing them in a simulated computer world. Given the brain's limitations in processing information, this technology engages multiple sensory inputs simultaneously, which in turn reduces the patient's focus on pain signals and alleviates pain sensation [21]. Moreover, Almajed *et al.* [22] conducted an experiment evaluating the effectiveness of virtual reality technology in managing pain and anxiety levels in 4–6 years old children during dental surgery. He found that game-based VR systems were the most effective and yielded the most positive results in children's medical interventions. This effectiveness is attributed to the children's full participation and interaction with the games, making VR particularly valuable for mitigating pain and anxiety [22].

In addition, the combination of lidocaine and VR has broadened its application, extending its use across all pediatric systems in the hospital and even into obstetrics and gynecology departments. The use of lidocaine and VR does not increase the risk of allergies or affect vision in children, ensuring good safety. However, the relatively small sample size in this study may introduce bias in the results. Future research should increase the sample size and conduct multicenter studies to enhance the accuracy and generalizability of the findings.

5. Conclusions

In summary, the combination of virtual reality technology and lidocaine cream in managing pediatric puncture pain effectively reduces pain, decreases medical fear, improves nursing satisfaction, enhances parental mastery of pain knowledge and attitudes, reduces crying and increases the success rate of first-attempt venipuncture. This approach is worthy of clinical promotion.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

JMW and XFX—designed the study and carried them out; prepared the manuscript for publication and reviewed the draft of the manuscript. JMW, XFX, HW, XLS, SYC, HHS, LLW and XFZ—supervised the data collection. JMW, XFX, HW, XLS, SYC and HHS—analyzed the data. JMW, XFX, HW and XLS—interpreted the data. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Hangzhou Linping District Maternal & Child Health Care Hospital (Approval no. LLSC-KYKT-2022-0090-A). Informed consent was obtained from both the child and parents, with a signed consent form.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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