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Effect of scalp nerve block on postcraniotomy analgesia in children: a randomized, controlled trial

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Abstract

Objective Effective postoperative pain management is critical for pediatric craniotomies. Scalp nerve block (SNB) interventions present a potential solution, yet their comparative benefits in preoperative and postoperative settings remain unclear. This study investigated the analgesic effects of SNB in pediatric craniotomy patients by comparing preoperative versus postoperative administration.

Methods This randomized trial included 180 children (1–12 years) who underwent elective craniotomy and were assigned to the preoperative, postoperative, or nonblocking control group. The outcomes included cumulative sufentanil use, pain scores (1, 2, 4, 24, 48 h postoperation), rescue medicine utilization, postoperative complications (24, 48 h), and hospitalization length. The primary outcome was total sufentanil use within 24 h postsurgery.

Results Total sufentanil use ($\mu g \cdot kg^{-1}$) in the postoperative block group was significantly lower than that in the nonblocking control group at 1 h ($P < 0.001$, 95% CI [-0.024 to -0.006]), 2 h ($P < 0.001$, 95% CI [-0.054 to -0.020]), 4 h ($P < 0.001$, 95% CI [-0.089 to -0.032]), 24 h ($P < 0.001$, 95% CI [-0.192 to -0.047]), and 48 h ($P = 0.010$, 95% CI [-0.208 to -0.022]) postoperation. Additionally, sufentanil use in the preoperative block group was significantly lower than that in the nonblocking control group at 1 h ($P = 0.004$, 95% CI [-0.021 to -0.003]), 2 h ($P < 0.001$, 95% CI [-0.043 to -0.010]), and 4 h ($P = 0.002$, 95% CI [-0.069 to -0.013]). Within 24 h postoperation, the use of sufentanil in the postoperative block group was significantly lower than that in the preoperative block group ($P = 0.014$, 95% CI [-0.157 to -0.013]).

Conclusion Compared with preoperative SNB or nonblocking, postoperative SNB significantly reduces postoperative sufentanil use within 24 h for pediatric patients undergoing craniotomy, highlighting its potential as an effective analgesic intervention in this population.

Trial registration The trial was registered at the Chinese Clinical Trial Registry (ChiCTR1800017386) on 27/07/2018, under the title "A study of scalp nerve block for neurosurgical analgesia in children with craniotomy."

Keywords Postoperative analgesia, Scalp nerve block, Children, Craniotomy, Randomized controlled trial

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Introduction

Postcraniotomy pain presents notable clinical challenges, and inadequate management may result in complications, including agitation, intracranial hypertension, seizures, hematoma, chronic pain, and, in severe cases, mortality [1–4]. Although the incidence of postcraniotomy pain in children is lower than that in adults, reaching approximately 40%, even with multimodal analgesia, it demands attention, especially in younger children who may struggle to experience pain, risking insufficient analgesia [5, 6]. Opioids, common in pediatric postoperative pain management, carry risks of adverse effects such as nausea, vomiting, altered neurological exams, and respiratory depression [7]. Regional blocks, including the scalp nerve block (SNB), have emerged as effective multimodal analgesic options for reducing opioid use in various pediatric surgeries [8–10].

SNB offers analgesia by blocking sensory conduction in both the superficial and deep layers of the scalp, making it an optimal choice for regional blocks in craniotomy [11–14]. Ropivacaine can be safely utilized in children for this purpose [15, 16]. Depending on the incision approach, six pairs of nerves—supraorbital, supratrochlear, auriculotemporal, zygomaticotemporal, greater occipital, and lesser occipital—can be blocked [17]. However, the analgesic efficacy of preoperative and postoperative SNB remains a subject of debate in pediatric patients. Preoperative SNB aligns with the theory of "preemptive analgesia," reducing the release of inflammatory substances and blocking neural transmission before tissue damage [18]. Additionally, preoperative SNB has been shown to be beneficial for reducing the need for intraoperative anesthesia [19, 20]. Nonetheless, given the extended duration of craniotomy procedures and the pharmacological properties of ropivacaine, the optimal duration of preoperative SNB remains uncertain. Postoperative SNB efficiently alleviates immediate postcraniotomy pain and has demonstrated satisfactory postoperative analgesia in adults [21, 22]. Determining the optimal timing for SNB administration has the potential to enhance postcraniotomy analgesia in pediatric patients.

This study directly compared the analgesic effects of preoperative SNB, postoperative SNB, and nonblocking controls in pediatric craniotomy patients. This investigation aimed to clarify the differences between SNB administered before or after surgery, shedding light on optimizing analgesic strategies in this vulnerable patient population.

Methods

Inclusion and exclusion criteria

The inclusion criterion included children aged 1–12 years (American Society of Anesthesiologists [ASA] physical status class I-III) who were scheduled for elective craniotomy tumor resection. The exclusion criteria included cardiac or pulmonary insufficiency, airway abnormalities, reactive airway diseases, inability to be weaned from endotracheal intubation postsurgery, abnormal liver and/or kidney function (alanine aminotransferase, aspartate aminotransferase, blood urea nitrogen, or creatinine levels ≥ 1.5 times the reference values), participation in other clinical trials, inability or unwillingness to provide informed consent, preexisting mental illness or use of antipsychotic drugs, and suboccipital mid-craniotomy for tumor resection.

Randomization and blinding

An independent researcher conducted patient screening and enrollment. After providing informed consent, eligible children were randomized at a 1:1:1 ratio into three groups. The random allocation schedule, generated using Stata 15.1 (StataCorp, USA), was sealed in opaque envelopes labeled with serial numbers. Only the anesthesiologists performing the SNB had access to the allocation information by opening the envelopes. Patients, anesthesiologists, and follow-up researchers were all blinded to the allocation.

Intervention

Eligible children were randomly assigned to three groups: preoperative SNB (Group B, Before Surgery), postoperative SNB (Group A, After Surgery), and Nonblocking Control (Group N). Trained anesthesiologists, ensuring double-blinding, entered the operating room twice. They performed SNB—either after anesthesia induction presurgery or at the end of surgery during the emergence of anesthesia—based on the allocated information. To maintain blinding, a 29 G (0.33×16 mm) syringe needle was used, resulting in a nearly invisible wound. The anesthesiologist temporarily exited the operating room and covered the dressing in the corresponding area.

Children in Groups B and A received 0.3% ropivacaine (Naropina®, AstraZeneca AB, Sweden) for SNB. Due to the proximity of the supratrochlear nerve to the supraorbital nerve and the proximity of the zygomaticotemporal nerve to the auriculotemporal nerve, a uniform local anesthetic technique was applied to all the children. Specific blocking techniques included blocking the supraorbital nerve at the supraorbital notch (0.05 ml/kg) and adjusting the needle direction to the midline for supratrochlear nerve blocking (0.05 ml/kg); blocking the auriculotemporal nerve 1–1.5 cm anterior to the superior border of the pinna (0.05 ml/kg) and adjusting the needle direction to the lateral orbital rim for zygomaticotemporal nerve blocking (0.05 ml/kg); and blocking the greater and lesser occipital nerves at the medial 1/3 and lateral 2/3 along the superior nuchal line between the inion and mastoid process (0.1 ml/kg). The total blocking volume

was recorded by the anesthesiologist who performed the SNB. Group N received an equivalent volume of saline for the block. Please refer to Additional file 1 for a detailed illustration of the SNB procedure.

Anesthesia Management

Upon arrival in the operating room, standard monitoring was initiated, encompassing noninvasive parameters such as blood pressure (BP), heart rate (HR), and pulse oximetry saturation (SpO_2). Invasive arterial pressure, end-tidal carbon dioxide partial pressure ($PETCO_2$), and anesthesia gas monitoring were performed after anesthesia induction. Before induction, the responsible anesthesiologist administered midazolam (0.025–0.075 $mg{\cdot}kg^{-1}$) and methylprednisolone (0.1–0.2 $mg{\cdot}kg^{-1}$) intravenously. General anesthesia induction involved sufentanil (0.5 $\mu g{\cdot}kg^{-1}$), propofol (2–3 $mg{\cdot}kg^{-1}$), and cis-atracurium (0.1–0.2 $mg{\cdot}kg^{-1}$ or rocuronium 0.4–0.6 $mg{\cdot}kg^{-1}$). Postintubation, mechanical ventilation adopted a volume-controlled mode, with a tidal volume of 8–10 $ml{\cdot}kg^{-1}$ and a respiratory rate of 14–20 breaths/minute. Total intravenous infusion anesthesia was maintained with 0.1–0.2 μg·kg-1·min^{-1} Remifentanil and 8–10 $mg{\cdot}kg^{-1}{\cdot}h^{-1}$ propofol, and the patients were adjusted for analgesic requirements during the procedure. No additional muscle relaxants were administered postanesthetic induction. Intraoperatively, interventions were applied as needed to maintain the mean arterial pressure (MAP) and HR within 30% of the baseline values. Propofol and remifentanil infusions ceased at surgery completion. After extubation, patients were transferred to the postoperative care unit (PACU), and subsequent relocation occurred based on their condition, either to the ward or intensive care unit (ICU).

Analgesic regimen

No ideal pain assessment scale exists for children. We primarily used the Faces Pain Scale-Revised (FPS-R) [23] to assess pain intensity in children of all ages. Considering that the FPS-R is more suitable for children older than 3 years, the Face, Legs, Activity, Crying, Consolability (FLACC) [24] score was added to describe pain intensity in infants and preschoolers. The Numerical Rating Scale (NRS) score was also included for school-aged children to describe pain intensity subjectively.

An electronic analgesia pump (Apona® electronic infusion pump ZZB-I-150, APON Medical Technology Co., Ltd., Jiangsu, China) was applied after the discontinuation of remifentanil. Before patients left the operating room, the anesthesiologist controlled the electronic analgesia pump. In the PACU, ICU, or ward, preschool children aged 1–6 years received nurse-controlled analgesia, where the nurse pushed the button on the electronic analgesia pump when the children expressed pain, had an FLACC score > 3, or had an FPS-R score > 3. The assessment was paused during the patient's sleep period. Patient-controlled analgesia was used in children aged 7–12 years who were trained to operate an electronic analgesia pump before the operation. The electronic analgesia pump regimen involved diluting 2 $\mu g{\cdot}kg^{-1}$ of sufentanil and 0.3 $mg{\cdot}kg^{-1}$ of ondansetron with normal saline to a total volume of 100 ml, which was administered through the analgesia pump for the first 48 h postsurgery. There was no background infusion dose, and the electronic analgesia pump was set to provide a 2 ml (0.04 $\mu g{\cdot}kg^{-1}$) on-demand bolus with a lock-out period of 30 min for each valid button press.

Rescue medication

Acetaminophen served as a remedial medication within the analgesic pump lockout time. It was administered when children reported intolerable pain, the FLACC score was > 5, or the FPS-R score was > 6. For children weighing ≥ 50 kg, a single dose of 1 g was given, with a maximum daily dose of 2 g. For children weighing < 50 kg, the dosage was 15 $mg{\cdot}kg^{-1}$, with a minimum dosing interval of at least 6 h [25, 26]. If intolerable pain or excessive pain scores persisted 15 min after acetaminophen infusion, the events were reported to the follow-up physicians. Depending on analgesic pump usage, physicians might add opioids, as recorded in the CRF.

Outcome measurement

The primary outcome was total sufentanil use within 24 h postoperation, which was extracted from the electronic analgesia pump data. Secondary outcomes included (1) sufentanil use at 1 h, 2 h, 4 h, and 48 h postsurgery; (2) Pain scores were recorded at 1 h, 2 h, 4 h, 24 h, and 48 h by the follow-up researchers; (3) The incidence of moderate to severe pain was recorded during the intervals of 0–1 h, 1–2 h, 2–4 h, 4–24 h, and 24–48 h by the attending nurses in the PACU, ICU, or ward; (4) rescue medicine use within 48 h postsurgery; (5) incidence of postoperative complications (agitation, postoperative nausea and vomiting (PONV), respiratory depression, neurosurgery-related complications, and SNB-related complications such as local hematoma, infection, or nerve injury at blocking sites) at 24 h and 48 h postoperation; and (6) length of stay after surgery.

Sample size and statistical analysis

Based on our experience and retrospective results, we estimated that the postoperative average sufentanil use within 24 h without SNB would be 0.20 ± 0.132 $\mu g{\cdot}kg^{-1}$. Preoperative SNB was expected to decrease sufentanil use by 20%, while postoperative SNB would lead to a 40% reduction. With 80% power and a two-sided α level of 0.017 (0.05/3), we determined that 54 subjects per group

were needed. Factoring a 10% dropout rate, we recruited 60 patients per group, totaling 180 patients, calculated using PASS 15.0 (NCSS, USA).

The statistical analyses were performed with SPSS 27.0 (SPSS Inc., Chicago, IL, USA). The data are presented as the mean±standard deviation (SD, x±s), median and interquartile range (IQR, 25–75% percentile), or number (%). Analysis of variance (ANOVA) and the Dunnett-T3 test were applied for normally distributed continuous variables, while the Kruskal-Wallis H test was used for nonnormally distributed data. Repeated measures ANOVA was employed for data measured at multiple time points. The chi-square test and Fisher's exact test were used to compare proportions. We conducted a stratified analysis based on age. Statistical significance among the three groups was set at a P value <0.05, with a significance level for multiple comparisons adjusted to $P<0.0167$ following Bonferroni adjustment.

Results

A total of 264 pediatric patients were consecutively screened, and 166 patients were finally statistically analyzed. The Consolidated Standards of Reporting Trials (CONSORT) specific diagram is shown in Fig. 1. The baseline characteristics of the pediatric patients are presented in Table 1 and were comparable among the three groups.

Perioperative parameters

The surgical characteristics of the pediatric patients are detailed in Table 2. The average surgery duration across the three groups showed no significant differences and was less than six hours. The results indicated that intraoperative remifentanil use (mg) in Group B was significantly lower than that in Group A (1.19 [0.81–1.66] vs. 1.66 [1.07–2.41], $P=0.003$) and Group N (1.19 [0.81–1.66] vs. 1.37 [1.17–2.46], $P=0.008$), with comparable use between Group A and Group N. No significant differences were observed in other indicators among the three groups.

Outcome variables

Sufentanil use

As shown in Table 3; Fig. 2, repeated-measures ANOVA revealed an increase in sufentanil use over time, with significant differences between time points. The primary outcome showed that total sufentanil use within 24 h post-surgery was significantly less in Group A compared to Group B ($P=0.014$, 95% CI [-0.157 to -0.013]) and Group N ($P<0.001$, 95% CI [-0.192 to -0.047]).

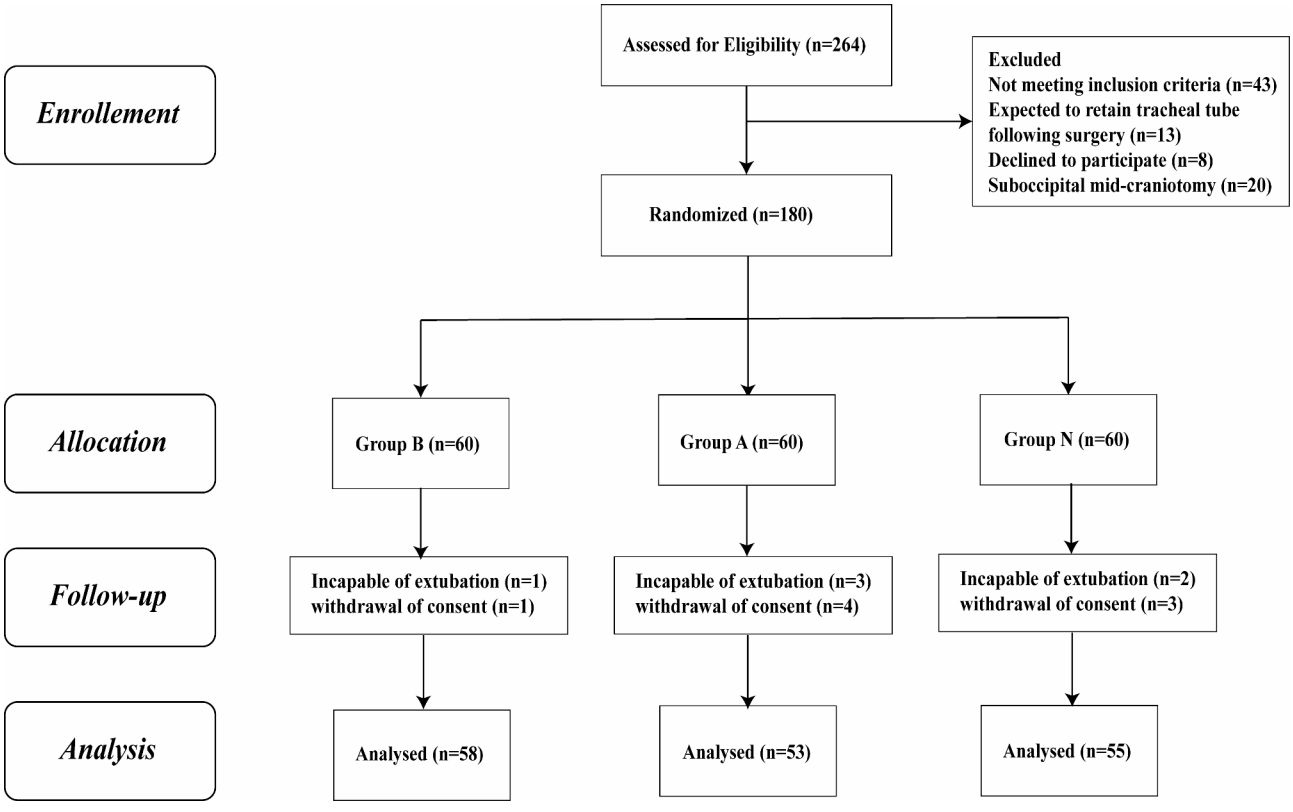

Fig. 1 CONSORT diagram
Group B = perioperative (Before surgery) scalp nerve block group; Group A = postoperative (After surgery) scalp nerve block group; Group N = Nonblocking control group

Table 1 Baseline characteristics of the children who received preoperative scalp nerve block, postoperative scalp nerve block or nonblocking surgery

	Group B (*n* = 58)	Group A (*n* = 53)	Group *N* (*n* = 55)	*P* value
Demographics				
Sex (male) (n, %)	37 (63.8)	33 (62.3)	30 (54.5)	0.565
Age (yr)	6.00 [3.75-10.0]	6.00 [3.00-9.50]	6.00 [3.00–9.00]	0.852
BMI ($kg{\cdot}m^{-2}$)	17.2 ± 4.67	17.6 ± 2.55	17.6 ± 3.36	0.842
Weight (kg)	27.4 ± 15.0	26.6 ± 13.2	25.7 ± 12.3	0.799
ASA (I/II/III)	14/44/0	15/38/0	11/44/0	0.601
Tumor types (n, %)				0.773
Glioma	18 (31.0)	17 (32.1)	16 (29.1)	
Craniopharyngioma	18 (31.0)	19 (35.8)	20 (36.4)	
Ependymoma	3 (5.20)	0 (0.00)	3 (5.50)	
Embryonal tumors	5 (8.60)	1 (1.90)	4 (7.30)	
Vascular malformation	6 (10.3)	7 (13.2)	5 (9.10)	
Others	8 (13.8)	9 (17.0)	7 (12.7)	
WHO classification (n, %)				0.208
I	40 (69.0)	40 (75.5)	40 (72.7)	
II	8 (13.8)	12 (22.6)	9 (16.4)	
III	5 (8.60)	1 (1.90)	3 (5.50)	
IV	5 (5.60)	0 (0.00)	3 (5.50)	
Maximum tumor size in diameter (mm)	40.3 ± 17.8	36.9 ± 15.0	40.2 ± 17.9	0.507
Craniotomy history (n, %)	8 (13.8)	5 (9.40)	5 (9.10)	0.668
V-P Shunt (n, %)	14 (24.1)	9 (17.0)	9 (16.7)	0.525
Craniotomy incision (n, %)				0.953
Bifrontal Coronal	18 (31.0)	23 (43.4)	21 (38.2)	
Forehead	17 (29.3)	10 (18.9)	11 (20.0)	
Frontotemporal	11 (19.0)	10 (18.9)	9 (16.4)	
Frontal parietal	6 (10.3)	4 (7.50)	6 (10.9)	
Temporal occipital	3 (5.20)	4 (7.50)	3 (5.50)	
Parietal occipital	1 (1.70)	1 (1.90)	3 (5.50)	
Temporal-parietal occipital	2 (3.40)	1 (1.90)	2 (3.60)	
Blocking volume (ml)	8.00 [7.00–9.00]	8.00 [6.00–9.00]	8.00 [7.00–9.00]	0.729

Abbreviations: Group B = perioperative (Before surgery) scalp nerve block group; Group A = postoperative (After surgery) scalp nerve block group; Group N = Nonblocking control group; RR = respiratory rate; HR = heart rate; MAP = mean arterial blood pressure; VP shunt = ventriculoperitoneal shunt

The baseline data were comparable among the three groups

Additionally, sufentanil use was significantly less in Group A than in Group N at all measured intervals: 1 h ($P<0.001$, 95% CI [-0.024 to -0.006]), 2 h ($P<0.001$, 95% CI [-0.054 to -0.020]), 4 h ($P<0.001$, 95% CI [-0.089 to -0.032]), and 48 h ($P=0.010$, 95% CI [-0.208 to -0.022]). Group B also showed significantly less sufentanil use compared to Group N at 1 h ($P=0.004$, 95% CI [-0.021 to -0.003]), 2 h ($P<0.001$, 95% CI [-0.043 to -0.010]), and 4 h ($P=0.002$, 95% CI [-0.069 to -0.013]). No significant differences were observed between Group A and Group B at 1 h, 2 h, 4 h, or 48 h.

Additional file 2 analyzes the increase in sufentanil use to better illustrate consumption over time. The increase in sufentanil use in Group A was significantly lower than in Group N during the intervals 0–1 h ($P<0.001$, 95% CI [-0.024 to -0.006]), 1–2 h ($P<0.001$, 95% CI [-0.035 to -0.009]), 2–4 h ($P=0.007$, 95% CI [-0.041 to -0.005]), and 24–48 h ($P=0.016$, 95% CI [-0.111 to -0.008]). Additionally, the increase in sufentanil use in Group A was significantly lower than in Group B during the interval 4–24 h ($P=0.006$, 95% CI [-0.117 to -0.015]).

Additional file 3 presents an analysis of gender differences in sufentanil consumption. Results showed no significant difference in sufentanil use between males and females within each group. However, subgroup analysis revealed that for male patients, cumulative sufentanil consumption at 2 and 4 h was significantly lower in Group B compared to Group N. In Group A, consumption was lower at 2, 4, 24, and 48 h compared to Group N, and at 24 h, it was also lower in Group A compared to

Table 2 Surgical characteristics of children who underwent preoperative scalp nerve block, postoperative scalp nerve block or nonblocking

	Group B (*n* = 58)	Group A (*n* = 53)	Group *N* (*n* = 55)	*P* value
Duration of operation (min)	274 [246–315]	276 [232–324]	289 [237–352]	0.348
Duration of anesthesia (min)$^{\Delta}$	341 [310–377]	340 [299–388]	352 [300–420]	0.402
Spontaneous respiratory recovery time$^{\Delta}$	11.1 ± 12.5	11.5 ± 7.78	10.8 ± 9.37	0.931
Extubation time$^{\Delta}$	20.4 ± 12.9	23.8 ± 12.1	20.8 ± 11.7	0.288
Total dose of propofol (mg)	770 [548–1085]	780 [570–1185]	780 [580–1300]	0.634
Total dose of Sufentanil (μg)	15.0 [11.8–23.3]	16.0 [11.3–21.5]	16.0 [10.0-22.5]	0.999
Total dose of Remifentanil (mg)	1.19 [0.81–1.66] †,‡	1.66 [1.07–2.41]	1.37 [1.17–2.46]	**0.005***
Estimated bleeding volume (ml)	100 [50.0-200]	100 [100–150]	100 [80.0-200]	0.851
Urine volume (ml)	500 [300–800]	450 [400–700]	500 [350–700]	0.704
Crystalloids (ml)	800 [600–1100]	800 [600–1000]	700 [600–1100]	0.829
Colloids (n, %)	46 (79.3)	42 (79.2)	42 (76.4)	0.912
Colloids (ml)	200 [150–263]	200 [100–300]	200 [100–400]	0.489
Blood transfusion				
Plasma infusion (n, %)	10 (17.2)	12 (22.6)	13 (23.6)	0.668
RBC infusion (n, %)	16 (27.6)	17 (32.1)	19 (34.5)	0.720
Blood transfusion volume				
Plasma infusion (ml)	150 [100–200]	100 [100–100]	100 [100–175]	0.232
RBC infusion (ml)	130 [130–228]	130 [130–130]	130 [130–130]	0.667

Abbreviations and Descriptions: Group B = perioperative (Before surgery) scalp nerve block group; Group A = postoperative (After surgery) scalp nerve block group; Group N = Nonblocking control group; Duration of anesthesia (min)$^{\Delta}$: Period from anesthesia induction to extubation; Spontaneous respiratory recovery time$^{\Delta}$: Period from the end of the operation to the patient's spontaneous respiratory emergence; Extubation time$^{\Delta}$: Period from the end of the operation to removal of the endotracheal tube. Total dose of sufentanil (μg) $^{\Delta}$: Intraoperative sufentanil was not administered from the beginning of the dural suture to the end of surgery to reduce the cumulative effect that could interfere with the results

*: $P < 0.05$, according to the Kruskal–Wallis H test among the three groups

‡: $P < 0.0167$ indicates a significant difference compared with Group N according to the Bonferroni correction

†: $P < 0.0167$ indicates a significant difference compared with Group A according to the Bonferroni correction

Group B. For female patients, only at 2 h was sufentanil consumption lower in Group A than in Group N.

Pain scores

The FPS-R was used for all pediatric patients, and the results are displayed in Table 3; Fig. 3. Repeated measures ANOVA demonstrated significant time and time*group interaction effects. FPS-R scores varied with time, with all three groups showing significantly lower pain scores at 48 h than at 1 h, 2 h, 4 h, and 24 h. Simple effects analysis indicated that the FPS-R scores of Group A at 1 h (P=0.002, 95% CI[-1.587 to -0.276]), 2 h (P=0.008, 95% CI[-1.483 to -0.178]), and 4 h (P<0.001, 95% CI[-1.534 to -0.370]) were significantly lower than those of Group N. No significant differences were detected among the three groups at 24 h and 48 h.

Results for Face, Legs, Activity, Crying, Consolability (FLACC) scores for preschoolers aged 1–6 years and Numerical Rating Scale (NRS) scores for school-age children aged 7–12 years are presented in Additional file 4. Group A had significantly lower FLACC scores than Group N at 4 h (P<0.001, 95% CI[-1.745 to -0.358]). The NRS scores of Group A were significantly lower than those of Group N at 1 h (P<0.001, 95% CI [-2.684 to -0.605]), 2 h (P<0.001, 95% CI [-2.589 to -0.719]), and 4 h (P<0.001, 95% CI [-2.656 to -0.805]). Additionally, the NRS scores of Group A were significantly lower than those of Group B at 4 h (P=0.0166, 95% CI [-1.952

Table 3 Outcome analysis of children receiving preoperative scalp nerve block, postoperative scalp nerve block or nonblocking

	Group B (*n* = 58)	Group A (*n* = 53)	Group *N* (*n* = 55)	*P* value
Primary outcome				
Total Sufentanil use within 24 h (μg·kg^{-1})	0.20 ± 0.15	0.12 ± 0.12†,‡	0.24 ± 0.19	**< 0.001***
Secondary outcomes				
Total Sufentanil use (μg·kg^{-1})				
~ 1 h	0.01 ± 0.02†	0.01 ± 0.02†	0.02 ± 0.02	**0.003***
~ 2 h	0.03 ± 0.03†	0.02 ± 0.03†	0.06 ± 0.05	**< 0.001***
~ 4 h	0.06 ± 0.05†	0.04 ± 0.05†	0.10 ± 0.08	**< 0.001***
~ 48 h	0.24 ± 0.19	0.15 ± 0.17 †	0.27 ± 0.23	**0.010***
The Faces Pain Scale-Revised scores				
1 h	1.69 ± 1.33	1.38 ± 1.46†	2.31 ± 1.45	**0.003***
2 h	2.09 ± 1.43	1.66 ± 1.36†	2.49 ± 1.43	**0.010***
4 h	1.72 ± 1.09	1.32 ± 1.52†	2.27 ± 1.13	**< 0.001***
24 h	1.09 ± 1.19	0.96 ± 1.11	1.18 ± 1.19	0.618
48 h	0.28 ± 0.70	0.25 ± 0.71	0.29 ± 0.71	0.943
Incidence of moderate to severe pain intensity (n, %)				
~ 1 h	9 (15.5)	6 (11.3)	17 (30.9)	**0.024***
~ 2 h	20 (34.5)†	14 (26.4)†	34 (61.8)	**< 0.001***
~ 4 h	28 (48.3)†	17 (32.1)†	40 (72.7)	**< 0.001***
~ 24 h	31 (53.4)†	19 (35.8)†	42 (76.4)	**< 0.001***
~ 48 h	31 (53.4)†	20 (37.7)†	43 (78.2)	**< 0.001***
Total amount of rescue medicines (48 h)				
Acetaminophen (g)	3.65	3.20	4.40	0.402
Acetaminophen (n, %)	6 (10.3)	5 (9.40)	9 (16.4)	0.480
Postoperative complications (within 24 h) (n, %)				
ALL	15 (25.9)	14 (26.4)	19 (34.5)	0.550
Agitation (n, %)	10 (17.2)	7 (13.2)	14 (25.5)	0.256
PONV (n, %)	6 (10.3)	5 (9.40)	10 (18.2)	0.345
Respiratory depression (n, %)	0 (0.00)	0 (0.00)	3 (5.50)	0.066
Neurosurgery related complications (n, %)	4 (6.90)	3 (5.70)	3 (5.50)	0.941
SNB-related complications	0 (0.00)	0 (0.00)	0 (0.00)	/
Postoperative complications (within 48 h) (n, %)				
ALL	16 (27.6)	14 (26.4)	21 (38.2)	0.345
Agitation (n, %)	11 (19.0)	8 (15.1)	15 (27.3)	0.281
PONV (n, %)	7 (12.1)	5 (9.40)	12 (21.8)	0.178
Respiratory depression (n, %)	0 (0.00)	0 (0.00)	3 (5.50)	0.066
Neurosurgery related complications (n, %)	6 (10.3)	3 (5.70)	3 (5.50)	0.524
SNB-related complications	0 (0.00)	0 (0.00)	0 (0.00)	/
Length of hospitalization (day)	10.5 [8.00–14.0]	10.0 [7.50–13.0]	10.0 [7.00–14.0]	0.520

Abbreviations: Group B = perioperative (Before surgery) scalp nerve block group; Group A = postoperative (After surgery) scalp nerve block group; Group N = Nonblocking control group

*: $P < 0.05$, according to repeated-measures ANOVA and chi-square test among the three groups

†: $P < 0.0167$, the difference was significant compared with Group N by Bonferroni adjustment

‡: $P < 0.0167$, the difference was significant compared with Group B by Bonferroni adjustment

to -0.152]). The NRS scores of Group B were also significantly lower than those of Group N at 1 h ($P = 0.004$, 95% CI[-2.424 to -0.382]).

Moderate to severe pain

Moderate to severe pain, defined as experiencing at least one episode with FPS-R, FLACC, or NRS score > 3 during follow-up, was significantly different among the three groups within 1 h, 2 h, 4 h, 24 h, and 48 h after the operation. Further analysis revealed that the incidence in Group A was significantly lower than that in Group N within 2 h ($P < 0.001$, OR = 0.49, 95% CI [0.34 to 0.73]), 4 h ($P < 0.001$, OR = 0.42, 95% CI [0.27 to 0.66]), 24 h ($P < 0.001$, OR = 0.40, 95% CI [0.25 to 0.66]), and 48 h ($P < 0.001$, OR = 0.39, 95% CI [0.23 to 0.65]). Additionally, the incidence in Group B was significantly lower than

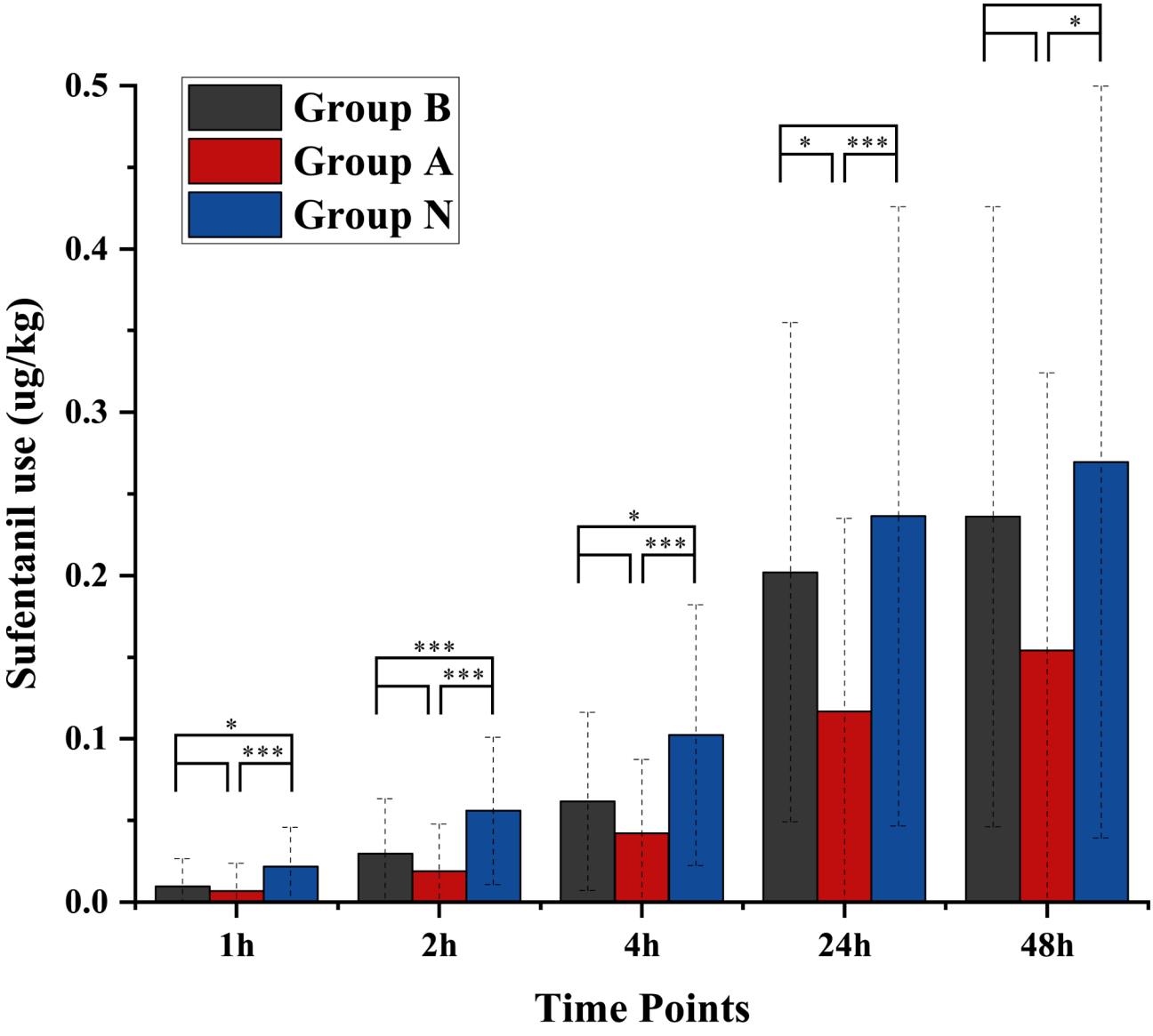

Fig. 2 Sufentanil use (μg·kg^{-1}) of children receiving preoperative scalp nerve block, postoperative scalp nerve block or nonblocking
Group B = perioperative (Before surgery) scalp nerve block group; Group A = postoperative (After surgery) scalp nerve block group; Group N = Nonblocking control group.* $P < 0.0167$; *** $P < 0.001$

that in Group N within 2 h ($P=0.004$, OR=0.57, 95% CI [0.38 to 0.84]), 4 h ($P=0.008$, OR=0.57, 95% CI [0.36 to 0.90]), 24 h ($P=0.011$, OR=0.57, 95% CI [0.35 to 0.92]), and 48 h ($P=0.006$, OR=0.53, 95% CI [0.32 to 0.88]). No differences were detected between Group A and Group B within 1 h, 2 h, 4 h, 24 h, or 48 h, and no differences were detected among the three groups within 1 h according to the Bonferroni adjustment. The incidence of moderate to severe pain at each time interval (i.e., 0–1 h, 1–2 h, 2–4 h, 4–24 h, 24–48 h) for both preschool children aged 1–6 years and school-aged children aged 7–12 years is presented in Additional File 5.

Rescue medicine use

Table 3 presents the amount of rescue medicines used within 48 h after the operation. Due to the limited use of rescue medicines, the results are represented in terms of the total dosage and proportion of users. A total of 20 children in the three groups used rescue medicines, with no significant difference in dosage or number of users among the three groups.

Postoperative complications and length of hospitalization

Postoperative complications recorded included agitation, PONV, respiratory depression, neurosurgery-related complications, and SNB-related complications at 24 h and 48 h after the operation, as shown in Table 3.

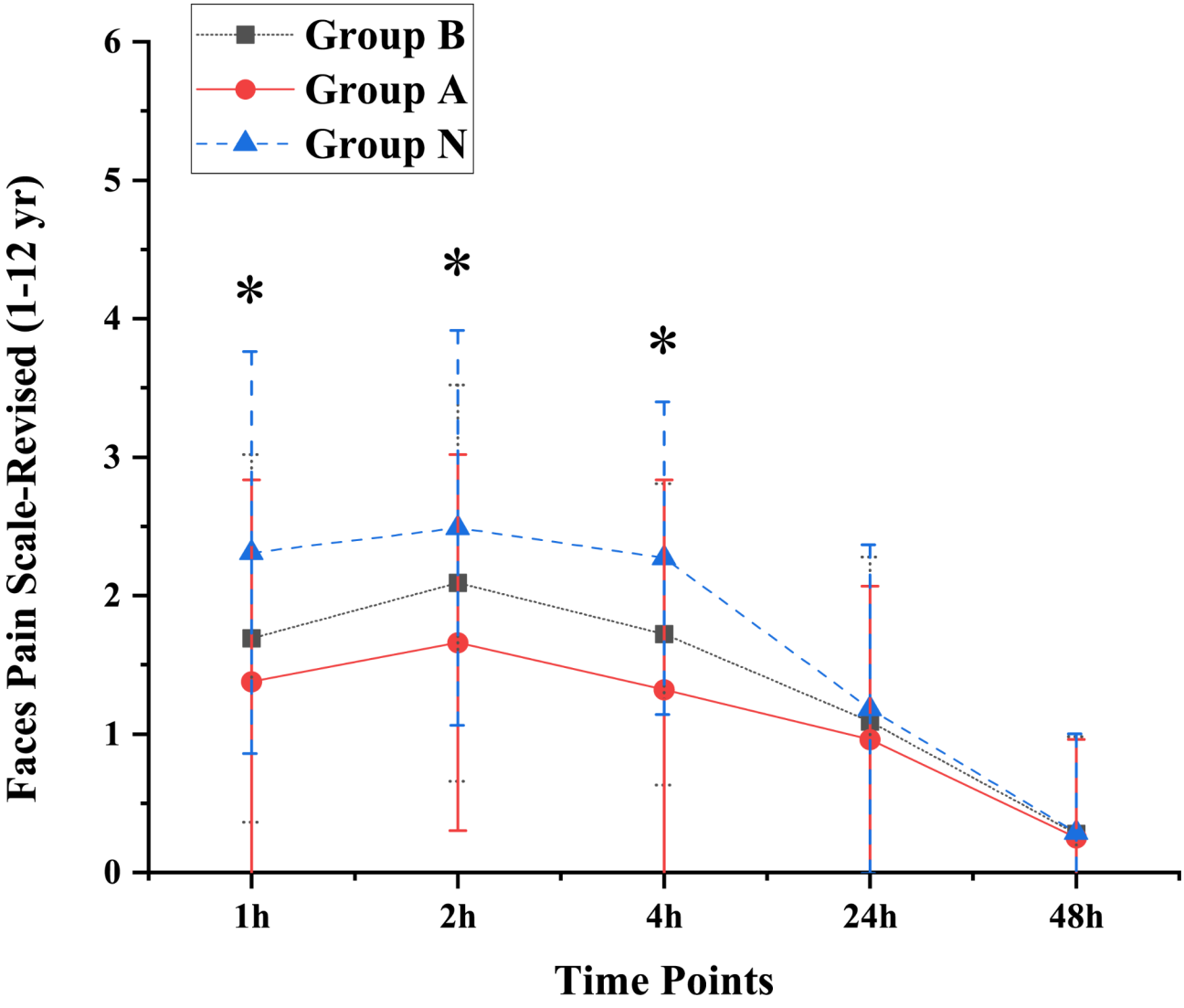

Fig. 3 The Faces Pain Scale - Revised for children receiving preoperative scalp nerve block, postoperative scalp nerve block or nonblocking
Group B = perioperative (Before surgery) scalp nerve block group; Group A = postoperative (After surgery) scalp nerve block group; Group N = Nonblocking control group
Group B was significantly lower than Group N according to the Bonferroni correction ($P < 0.0167$)
* Group A is significantly lower than Group N according to Bonferroni adjustment ($P < 0.0167$)
F Group A was significantly lower than Group B according to the Bonferroni correction ($P < 0.0167$)

There was no significant difference in the incidence of postoperative complications among the three groups on the first day or second day after the operation, and no patient experienced SNB-related complications within 48 h. Moreover, there was no significant difference in the length of hospitalization among the three groups according to Kaplan–Meier analysis ($P = 0.520$).

Discussion

Our study revealed that, compared to no block, postoperative SNB reduces sufentanil use within 1 h, 2 h, 4 h, 24 h, and 48 h, while preoperative SNB reduces sufentanil use within 1 h, 2 h, and 4 h. Notably, postoperative SNB significantly decreases sufentanil use within 24 h compared to preoperative SNB. Additionally, postoperative SNB yielded lower FPS-R scores and NRS (ages 7–12) scores than nonblocking at 1 h, 2 h, and 4 h and lower FLACC (ages 1–6) scores than nonblocking at 4 h. Both postoperative SNB and preoperative SNB reduced the incidence of moderate to severe pain within 2 h, 4 h, 24 h, and 48 h compared to no block. Importantly, there was no significant difference among the three groups in terms of rescue medicine use, postoperative complications, or length of hospitalization.

The transitional analgesic effect of SNB for craniotomy in adults has been supported by previous studies,

although the findings differ slightly from our results in children. Nguyen et al. reported a reduction in visual analog scale scores within 24 h after craniotomy in adults with postoperative SNB treated with 0.75% ropivacaine [19]. A meta-analysis by Guilfoyle et al. in adults concluded that both preoperative and postoperative SNB significantly decreased pain scores within 8 h and 12 h, respectively, postoperatively and reduced opioid consumption in the first 24 h after surgery [21]. Similarly, a recent study in children revealed that preoperative SNB effectively reduced FLACC pain scores and fentanyl consumption within 8 h postoperatively [27]. While our results align with the overall analgesic benefits of SNB, differences in study design, sample sizes, and outcome measures may contribute to variations in findings. We used sufentanil consumption from the analgesia pump as the primary outcome measure to quantify pain severity. Fixed-time pain scores served as secondary measures to support pain evaluation and ensure proper analgesia management. Our study suggested that postoperative SNB provides prolonged analgesia, bridging the gap between the waning effects of intraoperative opioids and incisional pain relief and leading to significantly reduced sufentanil consumption at various time points. Notably, the time interval with the highest growth rate of moderate to severe pain occurred between 1 h and 2 h postoperatively, around the time when intraoperative opioid effects were diminishing. The analgesic effect of preoperative SNB was mainly observed within 4 h postoperatively, possibly underestimating its duration due to a lack of assessment at 6–8 h. Postoperative SNB offered slightly superior analgesia compared to preoperative SNB. The significant difference in 24 h sufentanil use between preoperative and postoperative SNB can be attributed to a substantial increase in sufentanil dosage in preoperative SNB between 4 and 24 h postoperatively. Based on the findings of the above studies, we estimate that the effective duration of SNB is approximately 12–24 h. The elimination half-life of ropivacaine is approximately 4 h, while the surgery duration for children ranged from 4 to 6 h. Although the preoperative SNB provided effective preemptive analgesia and reduced intraoperative opioid use, the prolonged craniotomy duration likely limited the analgesic effect of ropivacaine, potentially leading to rebound pain and increased postoperative sufentanil consumption [28]. Additionally, tissue injury to the scalp during surgery may impact the distribution and absorption of local anesthetics. Administering SNB postoperatively, after the completion of surgery, may avoid these interferences and maintain a longer effective concentration. Both preoperative and postoperative SNB align with Kissin's broad definition of preemptive analgesia, preventing central sensitization caused by inflammatory damage from before the incision to the early postoperative period [29]. Gender is a significant factor influencing postoperative pain in children. We analyzed the impact of gender on sufentanil consumption and found that the advantages of postoperative SNB were more pronounced in male patients. This could be due to the smaller number of female patients, which may have resulted in an insufficient sample size for a reliable comparison. Additionally, boys tend to exhibit a stronger neuroendocrine response, leading to a higher perception of postoperative pain [30].

Our investigation of the safety of SNB in children revealed no increase in postoperative complications or prolonged hospitalization. Importantly, none of the 111 children who underwent SNB, both preoperatively and postoperatively, experienced SNB-related complications such as local hematoma, infection, or nerve injury at the blocking sites. These findings support the safe application of SNB in children, underscoring its analgesic benefits. Although preoperative incision infiltration is a common transitional analgesic method following craniotomy, our study suggested that it is inferior to SNB in terms of analgesic efficacy [27, 28].

Limitations of our study include the broad age range of the children (1–12 years) and the variability in growth and development, particularly in preschool children, who may pose challenges in accurate pain assessment. Further research with a larger sample size is needed to address this limitation. A significant limitation of our study is the lack of additional follow-up points between 4 and 24 h, such as at 6, 12, and 18 h. This omission may have impacted our ability to accurately assess the duration of the SNB effect. Additionally, fixed-time pain scores may not accurately capture the real-time pain experience of pediatric patients. In future studies, we will consider employing more specialized personnel or using AI-based facial recognition systems to provide a more detailed record of patients' pain experiences. We also did not employ ultrasound-assisted SNB, which could enhance block accuracy; however, the thin scalp nerves in children make ultrasound imaging challenging, and the increased cost and anesthesia time associated with ultrasound use may outweigh the benefits.

Our study concluded that SNB effectively reduces postoperative sufentanil use and the incidence of moderate to severe pain in children undergoing craniotomy. Furthermore, postoperative SNB exhibited superior analgesic efficacy compared to preoperative SNB within the first 24 h postoperatively.

Abbreviations

SNB	Scalp nerve block
ASA	American Society of Anesthesiologists
PACU	Post-Anesthesia Care Unit
ICU	Intensive Care Unit
ANOVA	Analysis of Variance
FPS-R	Faces Pain Scale-Revised

FLACC	Face, Legs, Activity, Crying, Consolability
NRS	Numerical Rating Scale
$PETCO_2$	End-Tidal Carbon Dioxide Partial Pressure
BP	Blood Pressure
HR	Heart Rate
SpO_2	Pulse Oximetry Saturation
MAP	Mean Arterial Pressure
CRF	Case Report Form
CONSORT	Consolidated Standards of Reporting Trials

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-024-02822-0.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

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Author contributions
XJ and WX conceived and designed the study. YW and LL^1 were responsible for writing and revising the manuscript. LL^2 and YF contributed to patient recruitment and randomization. BL was responsible for the clinical anaesthesia and data collection. YL were responsible for the data management and statistical analyses. All authors read and approved the final manuscript. Note: LL^1 is Lu Li and LL^2 is Ling Li.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This single-center, prospective, double-blinded, randomized controlled trial received approval from the Institutional Review Board of Beijing Tiantan Hospital, Capital Medical University (IRB No. KY 2018-078-02; August 23, 2018). The study period spanned from September 2018 to October 2020, with the first patient recruited on September 13, 2018. All children obtained written informed consent from their guardians, and school-aged children aged 7 years and older also provided their own informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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