

# Impact of Ultrasound-Guided Rectus Abdominis Sheath Block on Analgesia and Agitation During the Awakening Period in Children Undergoing Single-Incision Laparoscopic Inguinal Hernia Repair: A Randomized Clinical Trial

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**Purpose:** Inguinal hernia repair (IHR) is one of the most common pediatric surgeries, particularly in early childhood. Postoperative pain from IHR can cause significant psychological and physiological distress in children. This study investigates the efficacy and safety of ultrasound-guided rectus sheath block (RSB) in managing postoperative pain and emergence agitation (EA) in children undergoing single-incision laparoscopic inguinal hernia repair, aiming to improve strategies for postoperative care.

**Patients and Methods:** This single-blind, prospectively, randomized controlled trial enrolled 90 pediatric patients who were randomly assigned to three groups, they were respectively the bilateral rectus abdominis sheath block group under ultrasound guidance (Group R), Local anesthesia infiltration group (Group L) and blank control group (Group C). Primary outcomes included the incidence of EA. Secondary outcomes comprised pain scores, opioid consumption, and adverse events, and Pediatric Anesthesia Emergence Delirium (PAED) scales at various postoperative time points.

**Results:** EA incidence was significantly reduced in Groups R compared to Group C (RR [95% confidence interval] of 0.083 [0.007,0.019],  $P < 0.05$ ). Extubation time in Group R (RSB) was significantly shorter compared to Group C ( $P < 0.05$ ). During skin incision, mean arterial pressure (MAP) and heart rate (HR) were lower in Group R than in Groups L and C, with significant differences noted only between Groups R and C ( $P < 0.05$ ). Postoperative pain scores were significantly reduced in Groups R and L compared to Group C ( $P < 0.05$ ). Additionally, Group R demonstrated prolonged analgesia and reduced opioid consumption.

**Conclusion:** Ultrasound-guided RSB is a safe and effective technique for postoperative analgesia in pediatric single-incision laparoscopic inguinal hernia repair. It provides superior pain relief, reduces EA incidence, and minimizes opioid use. These findings suggest that RSB may be a valuable adjunct to general anesthesia for this specific procedure.

**Keywords:** rectus sheath block, inguinal hernia repair, emergence agitation, postoperative analgesia

## Introduction

Pediatric inguinal hernia repair (IHR) is among the most common procedures in pediatric surgery.<sup>1,2</sup> Traditional laparoscopic IHR offers benefits such as minimal trauma, rapid recovery, short hospital stays, and fewer complications.<sup>3</sup> Recently, single-port laparoscopic techniques have emerged as a minimally invasive alternative,<sup>4</sup> gaining popularity among parents due to reduced trauma, faster recovery, and improved cosmetic outcomes.<sup>5,6</sup> While it is

generally assumed that single-port laparoscopy is less invasive and thus causes less postoperative pain, several studies indicate that postoperative pain levels may be similar or even more intense than in traditional three-port laparoscopy.<sup>7</sup> Single-incision laparoscopic inguinal hernia repair only involves a 2cm incision at the umbilicus between the intercostal nerves T7 and T11, but postoperative pain remains the main complaint of patients. This intense pain can lead to significant psychological and physiological stress in children.

Postoperative analgesia in children is often complicated by emergence agitation (EA), which manifests as crying, moaning, and involuntary movements.<sup>8–10</sup> EA can disrupt diet and sleep, increase risks of bleeding, nausea, vomiting, and even lead to hospital readmissions.<sup>11,12</sup> Moreover, inadequate perioperative analgesia can result in long-term psychological trauma, with some children experiencing persistent pain or even chronic pain long after surgery.<sup>13–16</sup>

Conventional analgesic methods for pediatric abdominal surgery include opioids, local anesthetic infiltration (LAI), and spinal anesthesia. Opioid use,<sup>14</sup> however, carries risks such as respiratory depression, pruritus, nausea, and vomiting.<sup>17</sup> LAI often fails to provide adequate pain relief,<sup>18</sup> while spinal anesthesia can be associated with nerve and vascular complications.<sup>19</sup> Recently, ultrasound-guided rectus abdominis sheath block (RSB) has gained attention as an effective alternative for postoperative analgesia in pediatric patients.<sup>20,21</sup> Common nerve block techniques for pediatric abdominal surgery include ilioinguinal and iliohypogastric nerve blocks (II/IH), transversus abdominis plane block (TAP), quadratus lumborum block (QLB), and Erector spinae plane block (ESP). TAP and ilioinguinal blocks may not reliably cover midline peritoneal stimulation, and deeper blocks such as the QLB or ESP, while providing broader visceral coverage, are more technically challenging in children, carry a different risk profile, and may represent a level of invasiveness not strictly required for a procedure with a primary superficial incision.<sup>21–24</sup> Therefore, the RSB was chosen as a targeted, technically straightforward, and safe block that effectively anesthetizes the precise surgical site.

This study aims to investigate the impact of ultrasound-guided RSB on analgesia and emergence agitation in children following single-port laparoscopic inguinal hernia repair. By evaluating the safety and efficacy of ultrasound-guided RSB in this setting, this study seeks to provide evidence-based guidance for clinical practice, with the goal of introducing new strategies for managing postoperative pain and emergence agitation in pediatric patients.

## Methods

### Patients

This prospective study enrolled 90 pediatric patients scheduled for elective inguinal hernia repair at the Affiliated Hospital of Nantong University between May and October 2023. Ethical approval was granted by the Institutional Review Board of the Affiliated Hospital of Nantong University (Approval No. 2021-K036), and the trial was registered prospectively with ClinicalTrials.gov (NCT05820503).

Inclusion criteria were as follows: patients aged 5 to 12 years and classified as American Society of Anesthesiologists (ASA) physical status I or II. Exclusion criteria included: history of significant drug allergies or contraindications; dysfunction of major organs (heart, lungs, liver, or kidneys) or presence of systemic disease; severe neurological disorders or psychiatric illness; and cases involving non-single-port laparoscopic surgery.

### Randomization and Blinding

A total of 90 patients meeting the inclusion criteria were randomly assigned to one of three groups using a random number method: Group R (ultrasound-guided bilateral rectus abdominis sheath block), Group L (local anesthesia infiltration), and Group C (control). Investigators involved in statistical analyses used a computerized random-number generator to obtain random sequences, and placed them into sealed, opaque, and sequentially numbered envelopes. After the participant had entered the operating room, the anesthesia investigator opened the envelope to obtain a random sequence. Parents of all participants agreed to their children's involvement in the study and signed the informed consent form. This anesthesiologist is no longer involved in research or patient care. Anesthetists who performed postoperative patient assessments, surgeons, physical therapists, acute pain nurses, and researchers were blinded to treatment group assignment. All blocks were performed by attending pediatric anesthesiologists with more than 5 years of experience in

ultrasound-guided regional anesthesia. All surgeries were performed by the same pediatric surgical team using a standardized technique. All data collected were kept strictly confidential, with no disclosure of personal information.

## Anesthesia

Upon entering the operating room, all children were routinely monitored for noninvasive blood pressure (NIBP), heart rate (HR), oxygen saturation (SpO<sub>2</sub>), and electrocardiography (ECG). Following venous access establishment, Anesthesia was induced with midazolam (0.1 mg/kg), propofol (2 mg/kg), sufentanil (0.3 µg/kg) and cisatracurium (0.1 mg/kg). After endotracheal intubation, mechanical ventilation was initiated, with a tidal volume set at 8 mL/kg, a respiratory rate of 20–25 breaths/min, and an end-tidal CO<sub>2</sub> (PetCO<sub>2</sub>) maintained between 35–45 mmHg. Anesthesia maintenance was achieved through a combination of propofol, remifentanyl, and sevoflurane (1–2%), BIS was maintained at 40–60, with HR and blood pressure fluctuations controlled within 20% of baseline values.

For patients in Group R, after anesthesia induction, the child was positioned supine and the abdominal area disinfected with iodophor. An ultrasound probe (HFL38x/13-6 MHz Transducer; SonoSite Inc., Bothell, WA, USA) was positioned laterally or paracentrally around the umbilicus to identify the double-layered structure formed by the posterior sheath and parietal peritoneum of the rectus abdominis muscle. Under ultrasound guidance, a needle (22G×50mm) was advanced into the posterior rectus sheath (Figure 1), and after confirming no blood aspiration, 0.25% ropivacaine hydrochloride (0.3 mL/kg) was administered bilaterally for a rectus sheath block.

In Group L, following surgery, the surgeon injected 0.5% ropivacaine hydrochloride (0.3 mL/kg) into the surgical incision for local anesthesia infiltration. Group C received no additional analgesic intervention.

## Assessment of Outcomes

The primary outcome measure was the incidence of agitation among participants. The secondary outcomes were pain scores, opioid consumption, side effects, and Pain score at 48 hours after surgery. Upon admission to the Post-Anesthesia Care Unit (PACU), postoperative pain levels were assessed using the Face, Legs, Activity, Crying, Consolability (FLACC) pain scale (0–10 points) and the Wong-Baker Pain Rating Scale (FACES) (0–10 points) at 0, 1, 2, 4, 6, 12, 24, 36, and 48 hours after surgery. The recovery status and level of agitation were evaluated at 5, 10, 20, and 30 minutes post-extubation using the Pediatric Anesthesia Emergence Delirium (PAED) scale (0–20 points), with the highest score recorded. PAED score of ≥10 indicated emergence agitation during recovery.

Pain scores were maintained at ≤4 points, and any score exceeding 4 triggered rescue analgesia with intravenous tramadol at 2 mg/kg. Data collected included the time to first rescue analgesia, total postoperative analgesic use, operative duration, recovery time, extubation time, PACU length of stay, and incidence of adverse events. All data were gathered by trained evaluators and analyzed by professional statisticians.



**Figure 1** Ultrasound images after rectus sheath block. The arrow points to the path of the needle.

**Abbreviations:** RAM, rectus abdominal muscle; LA, local anesthetic.

## Sample Size Calculation

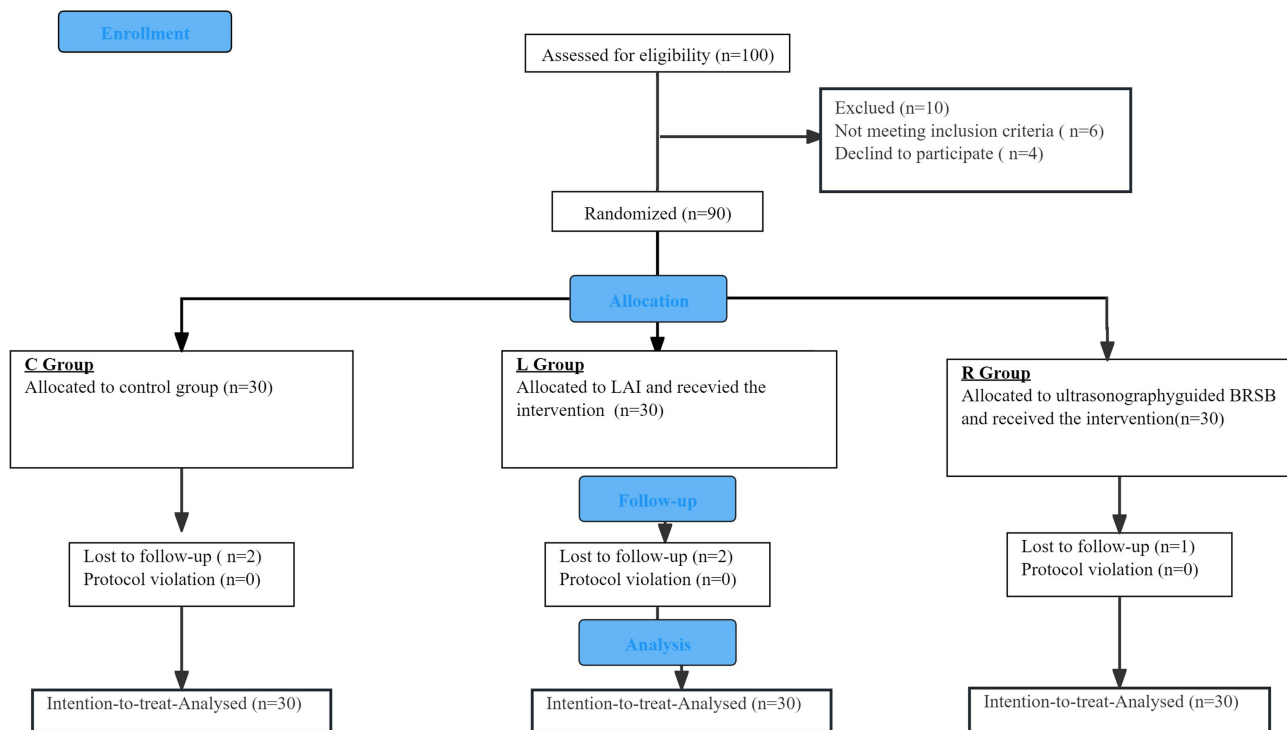
This study was a randomized controlled trial with three groups: the experimental group, the intervention group, and the blank control group. The primary outcome measure was the incidence of postoperative agitation among participants, based on estimates from relevant literature and preliminary experiments. The anticipated incidence of agitation was 8% in the experimental group, 18% in the intervention group, and 50% in the blank control group. With a significance level of  $\alpha=0.05$  (two-sided) and a power of 90%, the required sample size for the three groups was calculated using PASS 16 software. The total sample size needed was 75 participants, which, after accounting for a 20% potential loss to follow-up or withdrawal, resulted in a minimum target of 90 participants overall, with at least 30 participants per group.

## Data Analysis

All indicators were analyzed according to the intention-to-treat principle and in accordance with the statistical principle to ensure the robustness of the conclusions. Data analysis was performed using SPSS version 26.0. Normality was assessed using the Shapiro–Wilk test. Continuous data were analyzed using independent samples *t*-test or Mann–Whitney-*U* test, as appropriate. Normally distributed continuous variables were expressed as mean  $\pm$  standard deviation and analyzed using ANOVA. Categorical variables were compared using the  $\chi^2$ -test or Fisher’s exact test. Mean group differences and relative risk (RR) were reported with 95% confidence interval (95% CI),  $P<0.05$  was considered statistically significant.

## Result

A total of 90 patients were enrolled in this study, with random assignment to the respective treatment groups. Ten patients were excluded due to loss to follow-up, refusal to participate, or failure to receive the assigned intervention (Figure 2). There were no statistically significant differences in age, sex, weight, height, or ASA classification among the three groups ( $P > 0.05$ ) (Table 1).



**Figure 2** A flow diagram of inclusion and exclusion criteria according to the CONSORT (Consolidated Standards of Reporting Trials) statement.

**Table 1** Patient Characteristics and Surgery Data

	Group C (n=30)	Group L (n=30)	Group R (n=30)	P-value
Age, y	8.07±1.89	8.13±1.87	8.13±1.87	0.804
Sex, male/ female	14/16	15/15	15/15	0.732
Weight, Kg	24.52±3.69	24.67±3.86	24.67±3.86	0.646
Height, cm	130.20±7.29	131.93±9.71	131.93±9.71	0.741
ASA I/II	30/0	29/1	29/1	0.600

**Note:** Data are express as mean ± SD and number.

**Abbreviation:** ASA, American Society of Anesthesiologists.

## Primary Outcome

EA incidence was significantly reduced in Groups R compared to Group C (RR [95% confidence interval] of 0.083 [0.007,0.019],  $P < 0.05$ ), with no significant difference in EA incidence between groups R and L ( $P > 0.05$ ) (Table 2).

## Secondary Outcomes

The FACES, FLACC, and PAED scores for groups R and L were significantly lower than those of group C ( $P < 0.05$ ). No significant differences in FACES, FLACC, and PAED scores were observed between groups R and L ( $P > 0.05$ ) (Table 2).

The duration of stay in the Post-Anesthesia Care Unit (PACU) was significantly shorter for groups R and L compared to group C ( $P < 0.05$ ). Additionally, the extubation time for group R was significantly shorter than that of group C ( $P < 0.05$ ). However, no significant differences were observed in extubation time or PACU stay duration between groups R and L ( $P > 0.05$ ). There were also no significant differences in operation time or recovery time among the three groups ( $P > 0.05$ ) (Table 3).

**Table 2** The Postoperative Pain and Restlessness of the Patients During the Recovery Period Were Recorded

	Group C (n=30)	Group L (n=30)	Group R (n=30)	P-value
Face pain score	1.93±1.23	1.06±1.14 <sup>a</sup> (-1.467, -0.266) †	0.87±1.13 <sup>a</sup> (-1.668, -0.466) †	<0.01
FLACC Score	1.83±1.37	0.90±0.96 <sup>a</sup> (-1.487, -0.380) †	0.83±0.83 <sup>a</sup> (-1.553, -0.447) †	<0.01
PAED Score	9.03±3.85	6.43±3.06 <sup>a</sup> (-4.192, -1.008) †	6.03±2.15 <sup>a</sup> (-4.592, -1.408) †	<0.01
Incidence of EA	12(40.0%)	3(10.0%) (0.061, 1.028) †	1(3.3%) <sup>a</sup> (0.007,0.919) †	0.016

**Notes:** Data were expressed as mean ± SD or percentage. Compared with group C, <sup>a</sup> $P < 0.05$ . †Compared to Group C, Bonferroni-adjusted 95% confidence intervals(CI).

**Abbreviation:** EA, Emergence agitation.

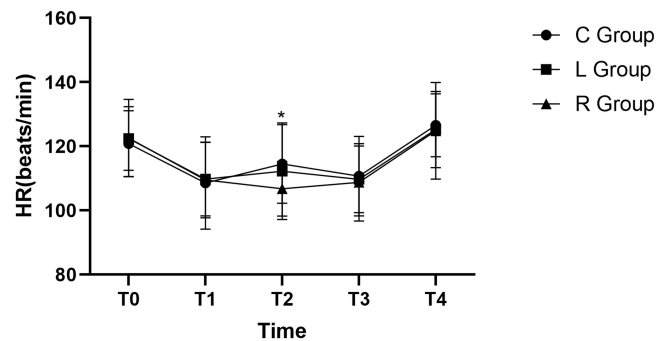
**Table 3** Operation and Recovery of Patients

	Group C (n=30)	Group L (n=30)	Group R (n=30)	P-value
Duration of surgery, min	35.63±8.23	35.93±5.79	34.63±7.20	0.762
Time of recovery, min	10.33±2.56	9.87±2.33	9.27±2.27	0.229
Time to extubation, min	11.16±2.00	10.63±1.82	9.93±1.98 <sup>a</sup>	0.016
Length of PACU stay, min	41.66±7.21	34.97±4.03 <sup>a</sup> (-9.768, -3.631) †	32.33±6.24 <sup>a</sup> (-12.401, -6.264) †	<0.001

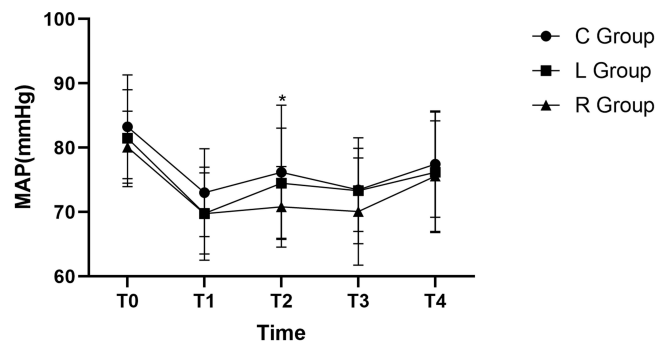
**Notes:** Data are express as mean ± SD; Compared with group C, <sup>a</sup> $P < 0.05$ ; †Compared to Group C, Bonferroni-adjusted 95% confidence intervals(CI).

Intraoperative hemodynamics were compared across the groups, with Mean Arterial Pressure (MAP) and Heart Rate (HR) recorded at various time points: admission (T0), anesthesia induction (T1), skin incision (T2), end of surgery (T3), and end of anesthesia (T4). At T2, both MAP and HR were lower in group R compared to groups L and C; however, statistical significance was reached only when comparing group R with group C ( $P < 0.05$ ). No significant differences were found among the groups at T0, T1, T3, and T4 ( $P > 0.05$ ) (Figures 3 and 4).

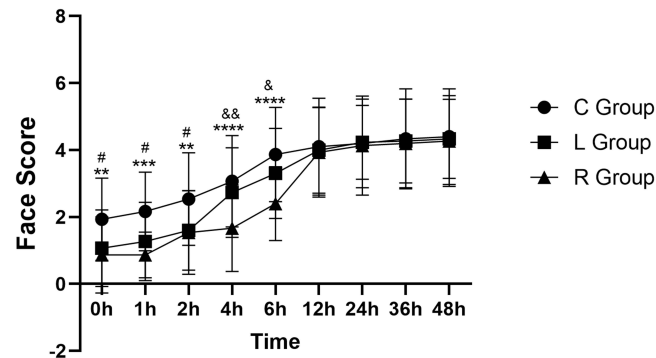
When compared to group C, the FLACC and FACES pain scores in group R were significantly decreased at 0, 1, 2, 4, and 6 hours post-surgery ( $P < 0.05$ ). Similarly, group L exhibited lower FLACC and FACES pain scores at 0, 1, and 2 hours after surgery compared to group C ( $P < 0.05$ ). Additionally, group R showed reduced FLACC and FACES pain scores at 4 and 6 hours post-surgery compared to group L ( $P < 0.05$ ) (Figures 5 and 6).



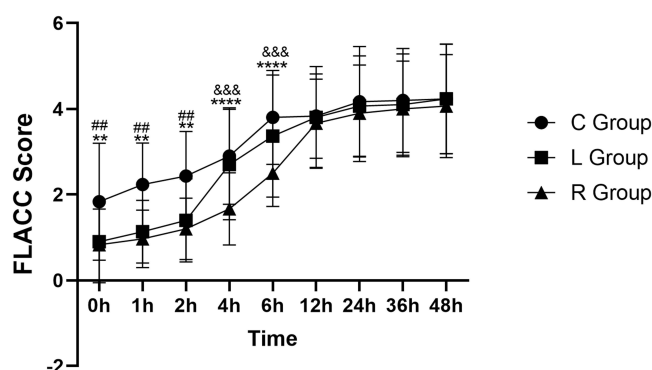
**Figure 3** Comparison of Perioperative heart rate. A line graph represents the results.  
**Notes:** \* $P < 0.05$ , Group R was compared with group C.



**Figure 4** Comparison of Perioperative mean arterial pressure. A line graph represents the results.  
**Notes:** \* $P < 0.05$ , Group R was compared with group C.



**Figure 5** The FACES pain scores of the three groups were compared 48 hours after surgery, A line graph represents the results.  
**Notes:** \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ ; \*\*\*\* $P < 0.0001$ , group R compared with group C; # $P < 0.05$ , group L compared with group C; & $P < 0.05$ ; &&  $P < 0.01$ , group R compared with group L.  
**Abbreviation:** FACES, the Wong-Baker Pain Rating Scale.



**Figure 6** The FLACC pain scores of the three groups were compared 48 hours after surgery, A line graph represents the results.

**Notes:** \*\* $P < 0.01$ ; \*\*\*\* $P < 0.0001$ , group R compared with group C; ### $P < 0.01$ , group L compared with group C; &&& $P < 0.001$ , group R compared with group L.

**Abbreviation:** FLACC, the Face, Legs, Activity, Crying, Consolability.

Postoperative analgesic use was compared among the groups, revealing that four children in group R and two in group L did not require analgesics following surgery. The time to first rescue analgesia was significantly longer in group R compared to both groups L and C ( $P < 0.05$ ), while group L also had a longer time to first rescue analgesia than group C ( $P < 0.05$ ). The dosage of postoperative analgesics in group R was significantly lower than that in groups L and C ( $P < 0.05$ ), and group L required less postoperative analgesic medication compared to group C ( $P < 0.05$ ) (Table 4).

Adverse reactions were evaluated across the groups. In group C, there were three patients with nausea, three with vomiting, and two with pruritus; in group L, one patient experienced nausea, two had vomiting, and one had pruritus. Notably, group R reported no serious adverse reactions. There were no occurrences of delayed recovery or respiratory depression in any group, with no significant differences found among the groups ( $P > 0.05$ ) (Table 5).

## Discussion

Currently, ultrasound-guided RSB is widely utilized for analgesic treatment in adults; however, its application in pediatrics remains controversial. This study demonstrates that ultrasound-guided RSB not only significantly reduces postoperative pain in children but also decreases the occurrence of EA and the need for postoperative analgesics. Given children's heightened sensitivity to pain stimuli and their limited ability to express discomfort, we employed both pediatric behavioral pain scores and the Wong-Baker FACES pain scale to more accurately assess postoperative pain levels.

In a study by Aasvang et al,<sup>25</sup> among 651 patients evaluated for chronic pain after inguinal hernia repair, 13.5% of children experienced chronic pain, with 2% suffering from moderate to severe pain. Fregoso et al,<sup>26</sup> identified that the

**Table 4** The Use of Analgesic Drugs in Children 48h After Surgery

	Group C (n=30)	Group L (n=30)	Group R (n=30)	P-value
The time of first rescue analgesia (min)	17.3±3.9	35.4±4.7 <sup>a</sup>	73.±8.4 <sup>ab</sup>	<0.001
48 h analgesic dose(mg)	151.9±1.4	131.7±10.8 <sup>a</sup>	91.±11.9 <sup>ab</sup>	<0.001

**Notes:** Data are express as mean ± SD; Compared with group C, <sup>a</sup> $P < 0.05$ ; Compared with group L, <sup>b</sup> $P < 0.05$ .

**Table 5** Adverse Events in Patients

	Group C (n=30)	Group L (n=30)	Group R (n=30)	P-value
Nausea	3(10.0%)	1(3.3%)	0	0.160
Vomiting	3(10.0%)	2(6.7%)	1(3.3%)	0.227
Pruritus	2(6.7%)	1(3.3%)	0	0.355
Delay in awakening	0	0	0	NA
Respiratory depression	0	0	0	NA

strength of pain memory during the early postoperative period is a critical factor in the development of chronic pain, underscoring the necessity for early pain intervention. Our study utilized prophylactic nerve blocks for preemptive analgesia before surgery, recognizing that while this may delay the surgical procedure, it holds significant value. Our findings indicated that after prophylactic nerve block, mean arterial pressure and heart rate during skin incision in group R were lower than in groups L and C, resulting in more stable hemodynamics. It is essential to strictly adhere to the indications and contraindications for prophylactic nerve block techniques. Factors such as the surgical site, operation duration, and the patient's age, weight, and overall health must be thoroughly considered when selecting an appropriate nerve block technique.

The II/IH technique can provide effective analgesia without interfering with respiratory function, thereby reducing anesthesia-related risks.<sup>27,28</sup> However, due to its limited coverage, it is often necessary to combine it with other nerve block techniques for optimal pain relief. TAP target the intercostal nerves (T7–T12, iliohypogastric, and ilioinguinal nerves), but their coverage for midline incisions (eg, laparoscopic umbilical ports) is suboptimal.<sup>24</sup>

With the clinical application of QLB, several limitations have become apparent. The onset of the block typically requires a considerable duration, usually ranging from 15 to 30 minutes.<sup>22</sup> This delay is associated with the time needed for the local anesthetic to diffuse from the fascial space surrounding the quadratus lumborum muscle to the thoracic paravertebral space. Additionally, there is a risk of local anesthetic toxicity, as a significant volume of the anesthetic may remain in the fascial space, preventing it from fully reaching the intended site of effect.<sup>29</sup>

RSB is more targeted for midline incisions, such as those in single-incision laparoscopic surgery.<sup>30</sup> It provides localized blockade of the terminal branches of the intercostal nerves running within the rectus sheath, ensuring effective pain relief for the umbilical region. Its coverage multiple nerves. The anterior branches of the nerves at the T6 to T11 levels traverse between the internal oblique and transversus abdominis muscles,<sup>20,31,32</sup> reaching the midline of the abdomen via the rectus sheath, thereby providing comprehensive analgesia in the periumbilical region. Given that a single injection may not adequately cover all nerve segments, it is understandable that some patients in the RSB group may still require supplemental opioid analgesics. Additionally, due to children's poor compliance and the proximity of various nerves and vessels, there is an increased risk of tissue damage during the puncture process. The inability of children to articulate their feelings during the puncture heightens the risk of bleeding and mispuncture. However, advancements in ultrasound visualization technology have significantly improved the safety and precision of nerve block punctures. Proper technique requires careful calculation of drug dosages and concentrations to avoid excessive medication use.

Emergence agitation in children poses a considerable challenge for clinical anesthesiologists and can be triggered by various adverse stimuli, with pain being the primary factor.<sup>9,11</sup> In our study, the incidence of EA was lower in groups R and L compared to the control group, and pain scores upon awakening were also significantly reduced in these groups. The shorter PACU stay for groups R and L compared to the control group allowed children to reunite with their parents sooner, enhancing their sense of security and comfort.

Research on the pathogenesis of EA is still limited, and no definitive conclusions have been reached. Several hypotheses have been proposed in pediatric studies,<sup>33</sup> with the neuroinflammation hypothesis being the most prevalent. This theory suggests that underlying diseases may cause systemic inflammation, surgical trauma and anesthesia can disrupt the blood-brain barrier and activate microglia, releasing pro-inflammatory cytokines like IL-1 $\beta$ , IL-6, and TNF- $\alpha$ . These cytokines increase neural excitability in key brain regions such as the thalamus and prefrontal cortex, leading to disorganized neural activity during recovery. The immature pediatric brain is particularly vulnerable to neuroinflammation, amplifying its behavioral effects and contributing to EA.<sup>34,35</sup> Oxidative stress is another key factor. Volatile anesthetics, such as sevoflurane, promote reactive oxygen species (ROS) production, leading to neuronal damage, mitochondrial dysfunction, and disrupted neurotransmission (eg, GABA and glutamate signaling). In children, underdeveloped antioxidant defenses, including enzymes like superoxide dismutase, make their brains more susceptible to anesthesia-induced oxidative stress. Oxidative stress further enhances neuroinflammatory responses, creating a feedback loop that exacerbates neural dysregulation and agitation.<sup>36</sup> Neuroendocrine responses also contribute to EA. Surgical and anesthetic stress activate the hypothalamic-pituitary-adrenal (HPA) axis, increasing cortisol and catecholamine levels. These stress hormones influence arousal pathways, particularly in the reticular activating system, leading to heightened arousal during emergence. Immature HPA axis regulation in children amplifies this stress response, causing hyperarousal

and behavioral dysregulation.<sup>37</sup> The interplay between neuroinflammation, oxidative stress, and neuroendocrine dysregulation creates a vicious cycle of neural dysfunction, with heightened excitability in areas responsible for arousal, emotion regulation, and sensory processing (eg, the amygdala and thalamus). This results in the characteristic symptoms of EA, such as crying, restlessness, and confusion.

To address these mechanisms, potential interventions include anti-inflammatory agents (eg, dexmedetomidine), antioxidants (eg, N-acetylcysteine), and strategies to modulate stress responses, such as regional anesthesia or preoperative psychological preparation. Understanding these pathophysiological factors provides a basis for reducing EA in pediatric patients. However, the clinical manifestations of EA in children vary and often fluctuate over time. Currently, EA diagnosis relies on neuropsychological scales, which can differ significantly across settings and complicate the diagnostic process, making it labor-intensive and time-consuming. Abnormal levels of inflammatory factors have been associated with EA, and identifying specific biomarkers for early prediction and diagnosis remains an urgent challenge in clinical practice.<sup>38</sup>

Multimodal analgesia involves using multiple methods to effectively manage pain, often combining intravenous analgesics with nerve blocks.<sup>39</sup> In this study, tramadol was employed for rescue analgesia. Our results indicated that the time to first rescue analgesia was significantly longer in group R compared to groups L and C. Within 48 hours post-surgery, children in group R required the least amount of postoperative analgesics, with statistically significant differences compared to groups L and C, further corroborating the effectiveness of RSB in postoperative analgesia.

Previous studies have shown that ultrasound-guided RSB significantly reduces postoperative pain in children undergoing umbilical hernia repair,<sup>31</sup> demonstrating its safety and efficacy. Our findings also confirm that ultrasound-guided RSB effectively alleviates postoperative pain in children following single-port laparoscopic inguinal hernia repair while reducing the incidence of EA. For future research, we encourage clinicians to integrate ultrasound-guided RSB into clinical practice, paying particular attention to the specific needs of pediatric patients. This includes precise drug dosage calculations, rational analgesic protocols, and thorough monitoring of EA. Additionally, further investigation into advanced ultrasound-guided devices and refined block techniques is warranted.

## Limitations

This study has several limitations. Firstly, the sample size was relatively small and did not encompass children of all age ranges, which may affect the generalizability of the findings. Secondly, the follow-up duration was limited, preventing us from observing the occurrence of chronic pain and other potential adverse reactions in the postoperative period and inflammatory markers associated with agitation were not studied. Furthermore, while powered for the primary outcome, the sample size may be insufficient to detect rarer adverse events or smaller differences in secondary outcomes. In future research, it would be beneficial to increase the sample size and consider a multi-center study design to achieve more representative and comprehensive results.

## Conclusion

In conclusion, ultrasound-guided RSB effectively reduces the incidence of postoperative agitation and pain scores, improves postoperative analgesia in children undergoing single-port laparoscopic inguinal hernia repair. Specifically, RSB effectively extends the duration of analgesia, and decreases the requirement for postoperative opioids, all while demonstrating fewer adverse reactions. Given these findings, ultrasound-guided RSB is a safe and effective analgesic technique that these findings suggest that RSB may be a valuable adjunct to general anesthesia for this specific procedure, but they require validation in larger, multi-center studies to confirm generalizability.

## Abbreviations

RSB, rectus sheath block; IHR, Inguinal hernia repair; EA, emergence agitation; ASA, American Society of Anesthesiology; TAP, transversus abdominis plane block; QLB, quadratus lumborum block; HPA, hypothalamic-pituitary-adrenal; PAED, Pediatric Anesthesia Emergence Delirium; PACU, Post-Anesthesia Care Unit; FLACC, Face, Legs, Activity, Crying, Consolability; FACES, Wong-Baker Pain Rating Scale.

## Data Sharing Statement

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

## Ethics Approval and Consent to Participate

Study approval was obtained from the Institutional Review Board of Ethics Committee of Affiliated Hospital of Nantong University (registration number 2021-K036) and the PODCAST trial is registered with clinicaltrials.gov, number NCT05820503. The informed consent of all minors was signed by their guardians, who agreed to conduct this research. The trial was conducted in accordance with the Declaration of Helsinki.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors declare no competing interests in this work.

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