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ORIGINAL ARTICLE

Efficacy and safety of ultrasound-guided bilateral superficial serratus anterior plane block for postoperative analgesia in pediatric ear reconstruction with costal cartilage harvest: a randomized controlled trial

Quanle Liu[1] · Guihua Xiang[1] · Chunmei Chen[1] · Keyu Chen[1] · Yuan Chen[2] · Hang Zhang[2] · Dong Yang[1]

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Abstract

Background Patients with microtia undergoing ear reconstruction with costal cartilage harvest often experience significant postoperative chest pain. The efficacy and safety of ultrasound-guided superficial serratus anterior plane block (SSAPB) in pediatric patients remain unclear.

Methods In this randomized controlled trial, sixty children were randomized to SSAPB or incision infiltration anesthesia (IA) (30 ml of 0.25% ropivacaine each). Primary outcome: group × time interaction on pain NRS trajectories (rest/coughing) over 48 h. Secondary outcomes were patient-controlled intravenous analgesia (PCIA) activations, oral rescue analgesic use, mobilization time, and adverse effects.

Results The interaction effect was non-significant for rest ($p = 0.28$) and coughing ($p = 0.15$). The SSAPB group exhibited significantly lower NRS scores at rest compared to IA, with mean differences (95% CI) of − 0.56 (− 1.02 to − 0.11) at 1 h, − 0.93 (− 1.56 to − 0.30) at 6 h, − 1.10 (− 1.96 to − 0.24) at 12 h, and − 1.17 (− 1.84 to − 0.49) at 24 h ($p < 0.05$ for all). During coughing, mean differences (95% CI) were − 1.03 (− 1.52 to − 0.54) at 1 h, − 0.94 (− 1.42 to − 0.46) at 6 h, − 0.84 (− 1.42 to − 0.26) at 12 h, and − 1.67 (− 2.25 to − 1.09) at 24 h ($p < 0.05$ for all). SSAPB reduced PCIA activations (6 ± 3.5 vs. 12 ± 4.6; $p < 0.001$), rescue analgesics (20% vs. 53%; $p < 0.01$), and accelerated mobilization (20.45 ± 1.76 vs. 23.30 ± 1.94 h; $p < 0.001$). Adverse events were comparable.

Conclusions SSAPB significantly reduces postoperative pain for up to 24 h and decreases analgesic use in children undergoing ear reconstruction with costal cartilage harvest, enhancing pain management and patient satisfaction without increasing adverse effects.

Clinical trial registration ChiCTR2200060242.

Keywords Costal cartilage harvest · Ear reconstruction · Pediatric pain management · Postoperative analgesia · Superficial serratus anterior plane block

✉ Dong Yang
yangdongmazui@163.com

Quanle Liu
491293701@qq.com

Guihua Xiang
xiangguihua318816@163.com

Chunmei Chen
chunmeichen2008@163.com

Keyu Chen
ckysbnk@163.com

Yuan Chen
chenyuan5997@sina.com

Hang Zhang
361723577@qq.com

[1] Department of Anesthesiology, Plastic Surgery Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Shi Jing Shan, Beijing, China

[2] Department of Nursing, Plastic Surgery Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Shi Jing Shan, Beijing, China

Introduction

Microtia, a congenital condition characterized by a small, abnormally shaped auricle, affects approximately 0.81 to 4.34 per 10,000 births globally [1–6]. The gold standard treatment for microtia is ear reconstruction, with autologous reconstruction using costal cartilage being the most widely accepted approach [7, 8]. However, this procedure is often accompanied by significant postoperative pain, particularly within the first 24 to 48 h post-surgery, due to the harvesting of cartilage from multiple ribs, and occasionally from both sides. Such intense pain, if inadequately managed, can negatively affect the patient's mood and overall recovery, posing a particular challenge in pediatric patients under 10 years of age [9], who may already be predisposed to anxiety, low self-esteem, and other psychological difficulties [10].

Despite the critical importance of managing postoperative pain in children following autologous auricular reconstruction, there has been limited advancement in pain management strategies for these cases. The common practice involves a combination of single intraoperative regional infiltration with a local anesthetic agent and patient-controlled intravenous analgesia (PCIA). However, this regimen has not been thoroughly studied, and its effectiveness in providing adequate or sustained pain relief after rib harvesting is uncertain. This sometimes necessitates higher doses of analgesics, which can lead to unwanted side effects. Although techniques such as intercostal nerve block, epidural PCA, and thoracic paravertebral block have proven effective in adult thoracotomy patients, their use in pediatric patients is less common due to technical complexities and potential risks.

Recently, ultrasound-guided serratus anterior block has gained recognition as a safe and effective method for chest analgesia [11]. Preliminary studies suggest that the superficial variant of this block could be successfully adapted for postoperative pain management in adult costal cartilage procedures [12]. However, its efficacy and safety in pediatric patients remain unexplored. *Hypothesis*: We hypothesize that the ultrasound-guided superficial serratus anterior plane block (SSAPB) will provide superior postoperative analgesia compared to traditional infiltration anesthesia (IA) in children undergoing ear reconstruction with costal cartilage harvest. *Aim*: This study aims to evaluate the analgesic efficacy of ultrasound-guided superficial serratus anterior plane block (SSAPB) in children undergoing postoperative ear reconstruction, with a secondary objective of assessing its safety profile in this population.

Methods

This clinical trial was approved by the ethics committee at Medical Ethics Committee of Plastic Surgery Hospital, Chinese Academy of Medical Sciences on May 05, 2022. The study was preregistered on the Chinese Clinical Trial Registry (ChiCTR) with reference number ChiCTR2200060242 on May 23, 2022. Written informed consent was obtained from all patients who agreed to participate. The date of the first patient enrollment was May 25, 2022.

Inclusion criteria included patients aged 5 to 12 years, classified as American Society of Anesthesiologists (ASA) grade I or II, scheduled for ear reconstruction surgery under general anesthesia between May 2022 and September 2022, with a treatment plan including cartilage harvest from three ribs (the 6th, 7th, 8th), and no contraindications to peripheral regional anesthesia blocks. Exclusion criteria included contraindications to regional anesthesia, as well as pre-existing chronic pain or cognitive impairment that could interfere with pain assessment.

Simple randomization was performed using a random number table. Starting from the first number in the first row, numbers were sequentially checked. Numbers less than or equal to 60 were marked until 30 marked numbers were obtained. The groups were designated as 'SSAPB' (superficial serratus anterior plane block) and 'IA' (infiltration anesthesia). Subjects corresponding to these 30 numbers were assigned to the SSAPB group, while the remaining subjects were allocated to the IA group. The random allocation sequence for each subject was placed in sequentially numbered, sealed, opaque envelopes. These envelopes were opened only after the subjects were enrolled, ensuring that the appropriate treatment was administered. The randomization key was maintained by an independent third party.

Upon the patient's entry into the operating room, preoxygenation was initiated, followed by standard anesthesia induction. The induction agents used included propofol (2.5 mg/kg), sufentanil (0.3 μg/kg), and cisatracurium (0.15–0.2 mg/kg). Once intubation criteria were met, the anesthesiologist utilized a video laryngoscope to insert an endotracheal tube, with the inner diameter and depth of insertion selected according to individual patient factors. Intraoperative anesthesia depth was monitored, targeting a bispectral index (BIS) of 40–60. Hemodynamic stability was maintained by keeping systolic blood pressure within 20% of baseline values; if it exceeded this range, an additional dose of sufentanil (0.1–0.15 μg/kg) was administered intravenously. Anesthesia was maintained with sevoflurane, oxygen, air, dexmedetomidine, and remifentanil. Routine monitoring adhered to the guidelines of the Association of Anaesthetists[13]. To prevent postoperative nausea and vomiting, prophylactic antiemetics, including ondansetron (0.1–0.15 mg/kg) and dexamethasone (0.1–0.2 mg/kg), were administered 30 min before the end of surgery. Vital signs were continuously recorded using an electronic anesthesia recording system (Networked Anesthesia Monitoring Information Management System, AIMS 6.0, China).

Ultrasound-guided superficial serratus anterior plane blocks (SSAPB) were administered by an experienced anesthesiologist following the induction of anesthesia. Local infiltration was performed intraoperatively by a skilled surgical team member after rib cartilage harvesting. All procedures were conducted by the same surgical team to maintain consistency. Group allocation was revealed by opening sealed envelopes after anesthesia induction. The blocks were administered under strict aseptic conditions as per the randomization protocol before the surgery began. Both nerve blocks and local infiltration involved 30 ml of 0.25% ropivacaine (total dose 75 mg). The fixed volume of 30 ml was selected based on three key considerations: firstly, anatomical rationale: Cadaveric studies show injectate volume primarily determines serratus anterior block spread [14]. Specifically, Biswas et al. [14] showed that increasing the volume from 20 to 40 ml significantly enhances anterior chest wall coverage, with 20 ml achieving a mean spread area of 41.4 cm^2 and 40 ml doubling this to 93.1 cm^2. Our choice of 30 ml represents an intermediate volume, balancing: 1.Longitudinal coverage: A 20 ml injection typically covers 4 intercostal levels (T3-T7), while 30 ml is expected to extend this to 5–6 levels (T2-T8), sufficient for rib cartilage harvesting targeting T5-T8 dermatomes. 2.Axial spread: The 30 ml volume is projected to achieve an injectate spread area of approximately 70 cm^2 (based on linear interpolation between 20 and 40 ml data)[14], ensuring adequate infiltration of the lateral cutaneous branches of the intercostal nerves. Sencondly, Pharmacological safety: The total ropivacaine dose (75 mg) corresponds to 1.5–3.75 mg/kg across our cohort (patient weight range: 20–50 kg). While this exceeds the 3 mg/kg threshold in patients < 25 kg ($n = 7$), no signs of systemic toxicity (e.g., tinnitus, perioral numbness) were observed. Continuous intraoperative hemodynamic monitoring was implemented for all cases. Thirdly, Safety precautions: For pediatric patients under 25 kg, the injection was fractionated into two aliquots (15 ml each) with 5-min intervals between doses to mitigate peak plasma concentrations, in accordance with institutional pediatric anesthesia protocols. The fixed volume of 30 ml was selected based on standard clinical practice at our institution, where 75 mg of ropivacaine has been routinely used for local infiltration in pediatric ear reconstruction with costal cartilage harvest. All blocks were performed using a 22-gauge echogenic needle (Ning Chuang, China; 80 mm) with the assistance of an ultrasound machine (Mindray, China) and a linear transducer (9–12 MHz).

Patients randomized to the IA group received a local infiltration block as follows: After rib harvesting was completed, patients were positioned supine. The surgeon then injected 15 ml of 0.25% ropivacaine under direct visualization into one side of the surgical site, followed by the same method and dosage on the opposite side.

Patients randomized to the SSAPB group received the block as follows: Patients were positioned supine with the arm abducted to 90 degrees. The surgical site was bilaterally marked on the rib cartilage by the operating physician. The anesthesiologist sterilized the skin at the puncture site with 75% alcohol. An ultrasound probe was placed sagittally along the axillary midline on one side, aligned with the marked rib cartilage and underlying rib. The latissimus dorsi (superficial and posterior) and serratus anterior (deep and inferior) muscles were identified overlying the rib. Using an in-plane technique under ultrasound guidance, 15 ml of 0.25% ropivacaine were injected into the superficial plane of the serratus anterior muscle. The procedure, including injection volumes, was then repeated on the contralateral side.

Blocks were performed under general anaesthesia consistent with routine practice; therefore, patients were masked to their group allocation, and hence no dermatomal sensory testing of immediate block efficacy was done. Investigators involved in data collection were also masked to the patients' group allocation and did not have access to the randomisation until after data analysis was complete. Therefore, the study was designed as a double-blind trial.

Following surgery, patients in both groups received Patient-Controlled Intravenous Analgesia (PCIA) consisting of sufentanil (1.5 μg/kg), tropisetron (0.2 mg/kg), and normal saline (total volume 100 ml). The PCIA was administered with a basal infusion rate of 2 ml/h, a bolus dose of 0.5 ml, and a 15-min lockout interval. Patients were transferred to the Post-Anesthesia Care Unit (PACU) after surgery and were moved to the ward once they met PACU discharge criteria. In the PACU, sufentanil (0.1 μg/kg) was administered intravenously as needed for postoperative pain management until the Verbal Rating Scale (VRS) pain score was ≤ 2, in accordance with hospital policy.

The primary outcomes included Numeric Rating Scale (NRS) scores during rest and coughing at 1, 6, 12, 24, and 48 h post-operation. Postoperative evaluations were conducted by a blinded nurse. During nighttime assessments, trained parents of pediatric patients assisted with scoring and data recording. The NRS was used on a scale from 0 to 10, where 0 indicated no pain, 1–3 indicated mild pain, 4–6 indicated moderate pain, 7–9 indicated severe pain, and 10 indicated the worst imaginable pain. To ensure age-appropriate pain assessment: (1) Preoperative training—Parents and children received standardized NRS scale instructions with visual aids and practice sessions. (2) Pediatric validation—The NRS is reliable for children ≥ 5 years, correlating well with other pain scales. (3) Nighttime assessment—Parents were trained to interpret behavioral cues (e.g., facial expressions, crying) per pediatric guidelines. For safe PCIA use: (1) Education—Children and parents were instructed on PCIA operation and pain relief recognition. (2) Safety checks—Nurses monitored pump settings and patients every 2 h. (3) Rescue analgesia—If NRS ≥ 4 after two PCIA boluses within 1 h, or if NRS ≥ 3 with explicit request, a 250 mg acetaminophen tablet was given, with a second dose allowed after 6 h if needed.

Secondary outcomes included the number of PCIA pump compressions, utilization of oral rescue analgesics within 48 h post-surgery, the dose of rescue sufentanil administered in the PACU, time to first ambulation, NRS scores for ear pain at 1, 6, 12, 24, and 48 h post-surgery, incidence of opioid-related side effects (such as postoperative nausea and vomiting [PONV], dizziness, headache, pruritus, respiratory depression), and complications related to the serratus anterior plane block (SAPB) (e.g., pneumothorax, local anesthetic toxicity).

Hemodynamic parameters were monitored electronically, recording the highest and lowest blood pressure (BP) values and heart rates (HRs).

The sample size was calculated in G Power 3.1.9.7 using a repeated measures ANOVA (within-between interaction) model. Key parameters were: 1. Primary target: Detect a minimum clinically important difference (MCID) of 1.0 in 24 h NRS scores (effect size $f = 0.23$, derived from pilot data: MCID = 1.0, SD = 2.1, $n = 15$). 2. Statistical power: 90% ($\beta = 0.1$), with $\alpha = 0.05$ (two-tailed). 3. Correlation among measures: 0.32 (autocorrelation from 5 postoperative assessments). 4. Attrition rate: 30%, based on an institutional audit of pediatric trials. This yielded 60 participants (30/group) to ensure ≥ 42 analyzable cases after attrition.

Statistical analysis was performed using SPSS version 23.0. All comparisons were two-tailed, with a significance level set at $P < 0.05$. The Shapiro–Wilk test and probability-probability plots were used to assess the normality of continuous variables. Parametric data were compared using the independent samples t-test or repeated measures analysis of variance (ANOVA), while non-parametric data were analyzed using the Mann–Whitney U test. Data were summarized as mean (SD) or median (25–75% range) as appropriate. Categorical data were compared using the chi-square test or Fisher's exact test.

Repeated measures ANOVA was selected for analyzing NRS scores (1–48 h) due to its established suitability for balanced designs with limited time points. While linear mixed models (LMM) better handle missing data and variability, their complexity was unnecessary given our study's minimal missing data and low temporal sampling density. ANOVA provided straightforward interpretation of group-time interactions, ensuring analytical adequacy for this dataset.

Results

The Consolidated Standards of Reporting Trials (CONSORT) flow diagram for this trial is illustrated in Fig. 1. A total of 60 patients who met the inclusion criteria were randomly assigned to either the SSAPB group or the IA group. All patients completed the postoperative follow-up successfully, with no dropouts reported.

Baseline characteristics, including age, gender, height, weight, weight-based ropivacaine dose(3 mg/kg), ASA classification, duration of surgery, length of harvested rib cartilage, and intraoperative doses of sufentanil and remifentanil are presented in Table 1. The two groups were well-balanced in terms of these variables, as expected in a randomized controlled trial. Descriptive statistics (mean ± standard deviation or percentage) were used to summarize the data, and no formal hypothesis testing was performed, as recommended for baseline characteristics in RCTs.

NRS scores at rest and during coughing were recorded at 1, 6, 12, 24, and 48 h postoperatively, is shown in Table 2. Both groups exhibited a gradual increase in pain scores, peaking at 24 h, and subsequently decreasing from 24 to 48 h (see Fig. 2). No significant interaction effect between time and group was observed ($p > 0.05$). At 1, 6, 12, and 24 h, the SSAPB group had significantly lower NRS scores compared to the IA group ($p < 0.05$). At 48 h, the difference between the groups was not statistically significant ($p > 0.05$). (see Table S1).

Secondary outcomes indicated differences between the groups. The SSAPB group had fewer patient-controlled analgesia (PCA) pump activations during the first 24 h ($p < 0.05$). In this group, 6 patients required oral rescue analgesics, compared to 16 patients in the infiltration group ($p < 0.05$). In the PACU, the SSAPB group received significantly lower doses of rescue sufentanil compared to the IA group ($p < 0.05$). Additionally, the time to first ambulation was shorter in the SSAPB group ($p < 0.05$). Patient satisfaction with postoperative pain relief was significantly higher in the SSAPB group ($p < 0.05$). However, there were no significant differences in ear NRS scores between the groups ($p > 0.05$). (see Table 2).

Regarding adverse events, neither group experienced respiratory depression, and no block-related complications such as pneumothorax or local anesthetic toxicity were reported in

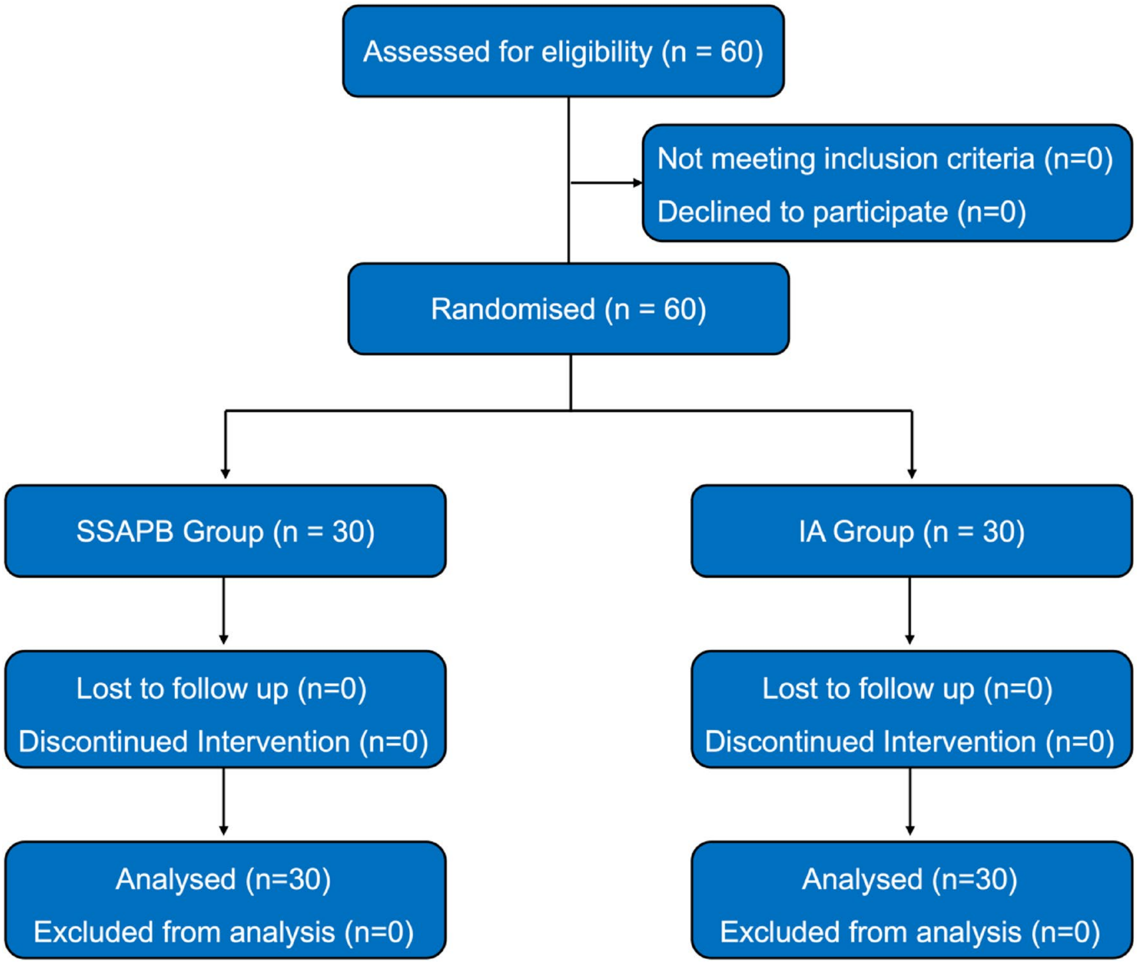

Fig. 1 CONSORT flowchart illustrating the study design. Assessed for eligibility(n = 60); Excluded (n = 0): Failure to meet inclusion criteria (n = 0), Parental refusal (n = 0); Randomized(n = 60): SSAPB group (n = 30), IA group (n = 30); Lost to follow-up: (n = 0); Analyzed(n = 60): SSAPB group: (n = 30), IA group: (n = 60). *CONSORT* Consolidated Standards of Reporting Trials, *SSAPB* Superficial Serratus Anterior Plane Block, *IA* Infiltration Anesthesia

the SSAPB group. Mild nausea and vomiting were observed in 3 patients in the SSAPB group and 5 patients in the IA group, with no statistically significant difference between the groups ($p > 0.05$). No other adverse reactions were noted. (see Table 3).

Discussion and conclusions

In this single-center, randomized controlled prospective study, ultrasound-guided bilateral superficial serratus anterior plane block (SSAPB) was found to safely and effectively alleviate postoperative pain at the rib cartilage harvest site in patients undergoing ear reconstruction surgery. Compared to the IA group, the SSAPB group demonstrated a significant reduction in NRS scores from 1 to 24 h postoperatively. Additionally, pediatric patients in the SSAPB group mobilized earlier, and their families reported higher satisfaction with postoperative pain management.

The serratus anterior plane block (SAPB) technique was first introduced by Blanco et al. in 2013 [11] and has since been used for analgesia in breast surgeries [15–18], thoracoscopic procedures [19], and rib fracture management [20]. This fascial plane block targets the lateral cutaneous branches of the intercostal nerves [11, 21], providing analgesia to the anterolateral chest wall. The intercostal nerves, branches of the spinal nerves, are situated within the neurovascular bundle of the intercostal spaces, with 11 nerves on each side running between the innermost and internal intercostal muscles. The lateral cutaneous branches emerge on the thoracoabdominal wall's lateral aspect, piercing through the internal and external intercostal muscles. Before penetrating the serratus anterior muscle, these branches divide into anterior and posterior divisions, with the anterior branch running between the superficial layer of the serratus anterior

Table 1 Comparison of patient and surgical characteristics

Variable	SSAPB group	IA group
Age(yr)	8.43 (1.501)	8.03 (1.542)
Gender		
Male	21 (70%)	20 (67%)
Female	9 (30%)	10 (33%)
Height(cm)	135.79 (1.76)	136.00 (1.89)
Weight(kg)	32.66 (1.59)	31.31(1.43)
Weight-Based Ropivacaine Dose (3 mg/kg) (mg)	99.20 (26.14)	92.30 (21.25)
American Society of Anesthesiologists physical status (I/II)	30/0	30/0
Duration of surgery (h)	4.75 (0.67)	4.55 (0.67)
Duration of anaesthesia (h)	5.42 (0.67)	5.22 (0.67)
Affected ear		
Left	11 (37%)	9 (30%)
Right	19 (63%)	21 (70%)
Intraoperative sufentanil (μg)	12.92 (2.61)	12.23 (2.13)
Intraoperative remifentanil(mg)	0.95(0.13)	0.91 (0.13)
Costal cartilage length	23.10 (0.92)	23.20 (0.93)

Data are expressed as mean (standard deviation) or n (%).

and the deep layer of the latissimus dorsi. The intercostal nerves extend anteriorly within their respective intercostal spaces, passing through the transversus thoracis muscle near the sternum and terminating as anterior cutaneous branches. The skin medial to the midclavicular line is innervated by the anterior branches of the lateral cutaneous branches and the terminal anterior cutaneous branches of the intercostal nerves [22]. Fascial plane blocks primarily provide analgesia through the diffusion of local anesthetics, blocking the nerves within these planes and adjacent tissues. This technique offers a viable alternative to other regional anesthesia methods, such as paravertebral or intercostal nerve blocks. In ear reconstruction surgeries, where the 6th, 7th, and 8th costal cartilages are often harvested, performing a superficial serratus anterior plane block at the corresponding sites effectively blocks the lateral cutaneous branches of the intercostal nerves, thereby alleviating postoperative pain. This principle explains the observed reduction in postoperative NRS scores and the decreased need for analgesics in pediatric patients undergoing SSAPB in this study.

The application of the superficial serratus anterior plane block (SSAPB) in costal cartilage harvest procedures was first reported in 2021 [12], demonstrating its potential for this application. That same year, Prabhat Tewari highlighted the use of SSAPB in pediatric ASD repair via median sternotomy [23]. Our research team previously confirmed the safety and efficacy of the deep serratus anterior plane block in pediatric costal cartilage harvest [24]. In this study, we employed SSAPB for pediatric costal cartilage harvest and found that NRS scores, our primary outcome measure, were significantly lower in the SSAPB group at 1, 6, 12, and 24 h postoperatively, both at rest and during coughing. By 48 h, the scores between the two groups were similar. This finding aligns with Yi's study, which demonstrated reduced postoperative pain scores with SAPB at 1 h (MD − 0.6, 95% CI − 1.17 to − 0.04, $I^2 = 92\%$), 4–6 h (MD − 1.16, 95% CI − 1.87 to − 0.45, $I^2 = 90\%$), and 12 h (MD − 0.71, 95% CI − 1.35 to − 0.08, $I^2 = 86\%$)[25]. At 48 h, the difference between the groups was not statistically significant ($p > 0.05$). This can be attibuted to the general trend of postoperative pain reduction after 48 h, as most patients

Table 2 Secondary outcomes

	SSAPB group	IA group	P value
PCA press	6 (3.5)	12 (4.6)	0.000
Use of oral rescue analgesics	6 (20%)	16 (53%)	0.039
Rescue sufentanil dose in PACU(μg)	0.80 (1.69)	1.97 (2.13)	0.022
First time out of bed(h)	20.45 (1.76)	23.30 (1.94)	0.000
Patient satisfaction socre	8.17 (1.23)	6.63 (1.27)	0.000
Postoperative NRS score for the ear			
1 h	0.40 (0.563)	0.43 (0.626)	0.829
6 h	0.60 (0.675)	0.57 (0.626)	0.843
12 h	0.93 (0.944)	0.97 (0.765)	0.881
24 h	0.47 (0.571)	0.60 (0.724)	0.432
48 h	0.27 (0.450)	0.27 (0.446)	1.000

Data are presented as mean (standard deviation) or n (%). Patient Satisfaction Score: The patient (or family) satisfaction score is assessed on a 0–10 scale to evaluate satisfaction with postoperative analgesia. A score of 0 indicates extreme dissatisfaction; 1–3 represents dissatisfaction; 4–6 indicates moderate satisfaction, reflecting a neutral overall experience; 7–8 denotes satisfaction, indicating a generally positive experience; and 9-10 reflects high satisfaction, indicating an excellent overall experience.

PCA Patient-Controlled Analgesia, *NRS* numerical rating scale.

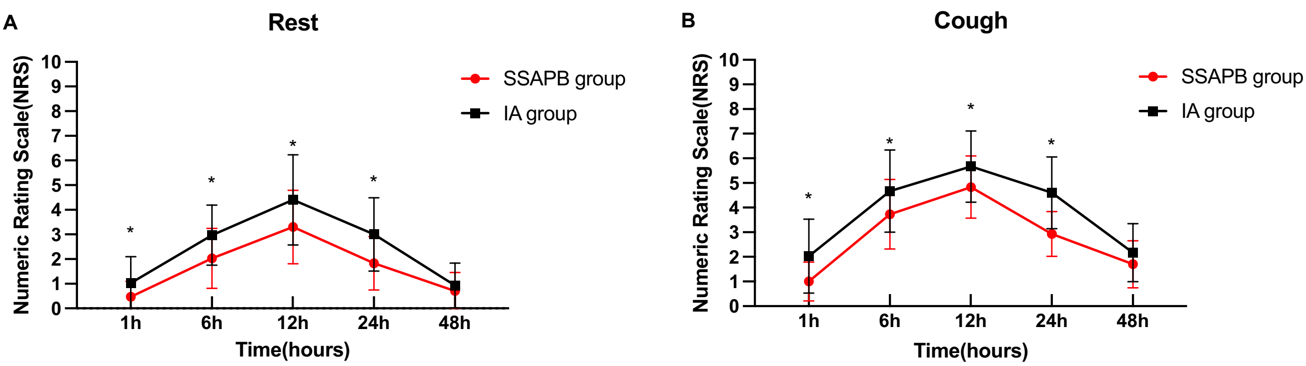

Fig. 2 Postoperative NRS scores of the chest while rest (**A**) and coughing (**B**) in the two groups. **A** Resting State: Both SSAPB and IA groups exhibited progressive increases in pain scores, peaking at 24 h (SSAPB: 1.83 ± 1.085 vs IA: 3.00 ± 1.486), followed by gradual declines from 24 to 48 h. The SSAPB group demonstrated significantly lower NRS scores than the IA group at 1, 6, 12, and 24 h ($P < 0.05$). No intergroup difference was observed at 48 h ($P > 0.05$). **B** Coughing State: Both groups showed parallel pain evolution patterns during coughing, with peak scores at 24 h (SSAPB: 2.93 ± 0.907vs IA: 4.60 ± 1.453). The SSAPB group maintained superior pain control versus the IA group from 1 to 24 h ($P < 0.05$), with no statistical significance at 48 h ($P > 0.05$). NRS Scale: The NRS was used on a scale from 0 to 10, where 0 indicated no pain, 1–3 indicated mild pain, 4–6 indicated moderate pain, 7–9 indicated severe pain, and 10 indicated the worst imaginable pain

Table 3 Postoperative complications in each group

	SSAPB group	IA group	P value
PONV	3 (10%)	4 (13%)	0.688
Dizziness or headache	0 (0%)	0 (0%)	NS
Pruritus	0 (0%)	0 (0%)	NS
Local anesthetic toxicity	0 (0%)	0 (0%)	NS
Pneumothorax	0 (0%)	0 (0%)	NS

Data are expressed as mean (standard deviation) or n (%). Complications are reported as any incidents over the 48-h observation period of the study. There were no significant differences between the two groups. *SSAPB* superficial serratus anterior plane block group, *IA* infiltration anesthesia group, *PONV* post operative nausea and vomiting.

begin to experience pain relief at this time, regardless of the intervention used.

Our results are consistent with previous findings on the deep serratus anterior plane block [24]. However, we observed higher NRS scores at 12 and 24 h with SSAPB compared to the deep serratus anterior plane block. This may be attributed to the deeper plane of the deep serratus anterior plane block, situated between the serratus anterior and the external intercostal muscles. The proximity of the external intercostal muscles to the injected local anesthetic, combined with their role in inspiration, might facilitate more comfortable diaphragmatic breathing due to reduced movement [22].

For both deep and superficial serratus anterior plane blocks, NRS scores during coughing were higher than at rest. This is likely because forced expiration involves deeper intercostal muscles (innermost and internal intercostals), which are less accessible to local anesthetics and thus less effectively blocked, resulting in persistent pain during coughing. In contrast, the IA group showed significantly higher NRS scores at rest and during coughing compared to both serratus anterior plane block groups. This may be due to the limited diffusion of local anesthetic with direct muscle injection and its rapid absorption due to the muscle's rich vascular supply.

We employed the numerical rating scale (NRS) for pain assessment due to its clear categorization, relative simplicity, and ease of use, which is particularly suitable for our study population of school-aged children (5–12 years old). This age group can more readily understand and complete the NRS. Additionally, we used the number of patient-controlled analgesia (PCA) pump presses as a comparative measure to evaluate the relationship between postoperative pain and PCA usage. Given that our hospital uses mechanical PCA pumps with limited dosing precision, the number of pump presses provided a more accurate reflection of the patient's pain experience. In the SSAPB group, fewer PCA pump presses were recorded within the first 24 h, and fewer patients required oral analgesic rescue. Moreover, the SSAPB group exhibited a shorter time to first ambulation postoperatively, which contributed to earlier recovery and a reduced hospital stay.

Complications associated with the superficial serratus anterior plane block (SSAPB) are rare. This is primarily because SSAPB is a plane block where local anesthetic is injected into a well-defined compartment [26], situated away from major blood vessels and guided by clear anatomical landmarks.

In our study, a fixed 75 mg dose of ropivacaine (30 ml of 0.25%) resulted in weight-normalized doses of 2.10–2.60 mg/kg for most patients. However, 7 children under 25 kg (20 kg, n = 2; 21 kg, n = 1; 22 kg, n = 2; 24 kg, n = 2) exceeded 3 mg/kg (e.g., 3.75 mg/kg at 20 kg). No systemic toxicity (arrhythmias, perioral numbness, CNS symptoms) was observed. To mitigate risks, we applied: (1) fractionated dosing—30 ml split into two 15 ml injections at 5-min intervals; (2) continuous monitoring (ECG, SpO_2, $EtCO_2$) until PACU discharge; (3) adherence to our center's validated pediatric anesthesia protocol, used safely in thousands of cases. These results suggest fixed-dose regimens can be safe with proper precautions, but future studies should explore tiered dosing (e.g., 2.5 mg/kg for < 30 kg, 75 mg for ≥ 30 kg) to enhance safety.

The analgesic efficacy of the superficial serratus anterior plane block (SSAPB) can vary depending on the type of surgery. This variation may be due to potential disruption of the serratus anterior muscle's integrity and differences in the surgical incision site, which can affect the diffusion and distribution of the anesthetic [27]. Blanco's studies [11], conducted on healthy volunteers without surgical incisions, observed different patterns of drug diffusion and distribution compared to those in surgical patients. This discrepancy helps explain the variations in SSAPB effectiveness reported across different studies.

This study utilized the superficial serratus anterior plane block (SSAPB) for pediatric costal cartilage harvest. Compared to paravertebral blocks and other techniques, SSAPB is simpler to perform, safer, and associated with fewer complications [28].

Several limitations must be noted. Firstly, we did not assess the preoperative psychological state of the patients and their parents, which could influence postoperative pain scores due to psychological and parental factors. Pain is a multidimensional phenomenon affected by emotions, anxiety, prior pain experiences, and postoperative nausea and vomiting (PONV) [29, 30]. The absence of these assessments may introduce bias into our results.

Secondly, the block was performed under general anesthesia, precluding a formal skin assessment of block efficacy and increasing the possibility of incomplete block effectiveness. However, performing peripheral nerve blocks under ultrasound guidance after general anesthesia is standard clinical practice, ensuring the relevance of our findings to broader clinical contexts.

Thirdly, the non-significant interaction effect may reflect inadequate power for this exploratory analysis, though the study was sufficiently powered for its primary clinical target (24 h NRS).

Lastly, while the 30 ml dose of 0.25% ropivacaine used in this study was effective for pain management following costal cartilage harvesting, three key considerations regarding dosing strategy require clarification. First, the fixed-dose regimen may exceed the 3.0 mg/kg maximum recommended dose for lighter-weight patients, though it's noteworthy that 75 mg (30 ml of 0.25%) remains below the 5.0 mg/kg safety threshold demonstrated in recent pediatric regional anesthesia studies [31]. Second, our clinical observation of accelerated weight gain in microtia patients post-tissue expansion suggests that weight-based dosing during subsequent surgical stages might paradoxically require higher absolute doses than our fixed regimen. Finally, while we intentionally adopted standardized dosing to maintain procedural consistency across treatment groups and align with institutional protocols, this approach precluded precise pharmacokinetic analysis. Future multicenter trials should incorporate weight-stratified dosing regimens with therapeutic drug monitoring to better characterize the safety profile across pediatric morphometric subgroups. These limitations notwithstanding, our findings provide preliminary evidence supporting the clinical feasibility of SSAPB for this surgical context.

Our research team has confirmed the safety and efficacy of both deep and superficial serratus anterior plane blocks for postoperative analgesia in pediatric costal cartilage harvest. However, the comparative effectiveness of these methods remains unclear, with differing opinions in the literature. This will be a crucial area for future research.

In conclusion, this single-center, double-blind RCT shows that ultrasound-guided SSAPB significantly reduces NRS scores at 24 h postoperatively compared to incision infiltration anesthesia, offering a promising approach for managing donor site pain after costal cartilage harvest.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Canfield MA, Langlois PH, Nguyen LM, et al. Epidemiologic features and clinical subgroups of anotia/microtia in texas. Birth Defects Res A. 2009;85:905–13. https://doi.org/10.1002/bdra.20626.
2. Deng K, Dai L, Yi L, et al. Epidemiologic characteristics and time trend in the prevalence of anotia and microtia in China. Birth Defects Res A. 2016;106:88–94. https://doi.org/10.1002/bdra.23462.
3. Harris J, Källén B, Robert E. The epidemiology of anotia and microtia. J Med Genet. 1996;33:809–13. https://doi.org/10.1136/jmg.33.10.809.
4. Shaw GM, Carmichael SL, Kaidarova Z, et al. Epidemiologic characteristics of anotia and microtia in california, 1989–1997. Birt Defects Res A Clin Mol Teratol. 2004;70:472–5. https://doi.org/10.1002/bdra.20042.
5. Forrester MB, Merz RD. Descriptive epidemiology of anotia and microtia, hawaii, 1986–2002. Congenit Anom. 2005;45:119–24. https://doi.org/10.1111/j.1741-4520.2005.00080.x.
6. Suutarla S, Rautio J, Ritvanen A, et al. Microtia in Finland: comparison of characteristics in different populations. Int J Pediatr Otorhi. 2007;71:1211–7. https://doi.org/10.1016/j.ijporl.2007.04.020.
7. Ma Y, Lloyd MS. Systematic review of medpor versus autologous ear reconstruction. J Craniofac Surg. 2022;33:602–6. https://doi.org/10.1097/SCS.0000000000008130.
8. Zim SA. Microtia reconstruction: an update. Curr Opin Otolaryngo. 2003;11:275–81. https://doi.org/10.1097/00020840-200308000-00011.
9. Tahiri Y, Reinisch J. Porous polyethylene ear reconstruction. Clin Plast Surg. 2019;46:223–30. https://doi.org/10.1016/j.cps.2018.11.006.
10. Horlock N, Vögelin E, Bradbury ET, et al. Psychosocial outcome of patients after ear reconstruction: a retrospective study of 62 patients. Ann Plas Surg. 2005;54:517. https://doi.org/10.1097/01.sap.0000155284.96308.32.
11. Blanco R, Parras T, McDonnell JG, et al. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. Anaesthesia. 2013;68:1107–13. https://doi.org/10.1111/anae.12344.
12. Şahin A, Baran O, Gültekin A, et al. Serratus anterior plane block for tertiary revision rhinoplasty with rib cartilage harvest. J Clin Anesth. 2021;73: 110292. https://doi.org/10.1016/j.jclinane.2021.110292.
13. Checketts MR, Alladi R, Ferguson K, et al. Recommendations for standards of monitoring during anaesthesia and recovery 2015: association of anaesthetists of great britain and ireland. Anaesthesia. 2016;71:85–93. https://doi.org/10.1111/anae.13316.
14. Biswas A, Castanov V, Li Z, *et al.* Serratus plane block: a cadaveric study to evaluate optimal injectate spread. *Reg Anesth Pain Med*. 2018;1–6. https://doi.org/10.1097/AAP.0000000000000848
15. Makkar J, Singh N, Bhat A, et al. Analgaesic efficacy of single-injection serratus anterior plane block for breast surgery: a systematic review, meta-analysis and trial sequential analysis of randomised controlled trials. Indian J Anaesth. 2023;67:343. https://doi.org/10.4103/ija.ija_919_22.
16. Arora S, Ovung R, Bharti N, et al. Efficacy of serratus anterior plane block versus thoracic paravertebral block for postoperative analgesia after breast cancer surgery - a randomized trial. Brazilian J Anesthesiol (English Edition). 2022;72:587–92. https://doi.org/10.1016/j.bjane.2021.09.017.
17. Jain D, Bhoi D, Chhabra A, et al. Analgesic efficacy of superficial versus deep serratus plane block for modified radical mastectomy under general anaesthesia: A randomised comparative study. Indian J Anaesth. 2022;66:307. https://doi.org/10.4103/ija.ija_149_22.
18. Jayadeep I, Srinivasan G, Sethuramachandran A, et al. Comparison of the analgesic efficacy of ultrasound-guided superficial serratus anterior plane block with deep serratus anterior plane block in patients undergoing modified radical mastectomy: a randomized clinical trial. Cureus. 2022;14: e30828. https://doi.org/10.7759/cureus.30828.
19. Kim S, Bae C-M, Do YW, et al. Serratus anterior plane block and intercostal nerve block after thoracoscopic surgery. Thorac Cardiov Surg. 2021;69:564–9. https://doi.org/10.1055/s-0040-1705152.
20. Schnekenburger M, Mathew J, Fitzgerald M, et al. Regional anaesthesia for rib fractures: A pilot study of serratus anterior plane block. Emerg Med Aust. 2021;33:788–93. https://doi.org/10.1111/1742-6723.13724.
21. Kelava M, Alfirevic A, Bustamante S, et al. Regional anesthesia in cardiac surgery: an overview of fascial plane chest wall blocks. Anesth Analg. 2020;131:127–35. https://doi.org/10.1213/ANE.0000000000004682.
22. Mayes J, Davison E, Panahi P, et al. An anatomical evaluation of the serratus anterior plane block. Anaesthesia. 2016;71:1064–9. https://doi.org/10.1111/anae.13549.
23. Tewari P, Hajela K, Ahmad S. Bilateral superficial serratus anterior plane block in a pediatric patient for post-operative analgesia undergoing asd repair via median sternotomy- A case report. Ann Card Anaesth. 2022;25:116. https://doi.org/10.4103/aca.aca_113_21.
24. Chen C, Xiang G, Chen K, et al. Ultrasound-guided bilateral serratus anterior plane block for postoperative analgesia in ear reconstruction after costal cartilage harvest: a randomized controlled trial. Aesth Plast Surg. 2022;46:2006–14. https://doi.org/10.1007/s00266-022-03027-x.
25. He Y, Li Z, Xu M, *et al.* Single-injection serratus anterior plane block for cardiothoracic surgery via thoracotomy in children: a systematic review and meta-analysis of randomised controlled trials. *bmjpo*. 2023;7:e001912. https://doi.org/10.1136/bmjpo-2023-001912
26. Finnerty DT, McMahon A, McNamara JR, et al. Comparing erector spinae plane block with serratus anterior plane block for minimally invasive thoracic surgery: a randomised clinical trial. Br J Anaesth. 2020;125:802–10. https://doi.org/10.1016/j.bja.2020.06.020.
27. Abdallah FW, Cil T, MacLean D, et al. Too deep or not too deep?: a propensity-matched comparison of the analgesic effects of a superficial versus deep serratus fascial plane block for ambulatory breast cancer surgery. Region Anesth Pain M. 2018;43:480–7. https://doi.org/10.1097/AAP.0000000000000768.
28. Xie C, Ran G, Chen D, et al. A narrative review of ultrasound-guided serratus anterior plane block. Ann Palliat Med. 2021;10:700–6. https://doi.org/10.21037/apm-20-1542.
29. Von Baeyer CL, Spagrud LJ. Systematic review of observational (behavioral) measures of pain for children and adolescents aged 3–18 years. Pain. 2007;127:140–50. https://doi.org/10.1016/j.pain.2006.08.014.
30. Birnie KA, Hundert AS, Lalloo C, et al. Recommendations for selection of self-report pain intensity measures in children and adolescents: a systematic review and quality assessment of measurement properties. Pain. 2019;160:5. https://doi.org/10.1097/j.pain.0000000000001377.
31. Chaudhary V, Chauhan S, Choudhury M, et al. Parasternal intercostal block with ropivacaine for postoperative analgesia in pediatric patients undergoing cardiac surgery: a double-blind,

randomized, controlled study. J Cardiothorac Vasc Anesth. 2012;26:439–42. https://doi.org/10.1053/j.jvca.2011.10.012.

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