Original Article

Ultrasound-Guided Erector Spinae Plane Block: A Comparative Study to Assess its Analgesic Efficacy in Pediatric Patients Undergoing Aortic Coarctation Repair

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Abstract

Background: Effective postoperative analgesia is an important aspect of both anesthetic practice and postoperative outcomes. Thoracotomy for the repair of coarctation of the aorta is a painful surgical procedure; inadequate postoperative analgesia may result in postoperative respiratory complications with the possible prolonged need for oxygen therapy. In addition, paradoxical hypertension is a well-recognized complication of repair. We hypothesize that erector spinae plane block (ESPB) by providing adequate analgesia and blocking sympathetic stimulation may reduce opioid consumption, accelerate weaning of oxygen therapy, and reduce the incidence of early postoperative paradoxical hypertension.

Materials and Methods: Open-labeled randomized controlled trial carried out on 40 patients divided into two groups. Group (B) received ESPB before the skin incision and group (C), the control group received no block.

Results: Patients who received ESPB had significantly less intraoperative fentanyl consumption than the control group (P-value<0.001), and significantly less postoperative fentanyl consumption by 50% than the control group in the first 12 hours 2.025 ±0.273 µg/kg and 4.05 ±0.527 µg/kg respectively (P-value<0.001). while there was no statistically significant difference between both groups regarding the incidence of postoperative vasodilator infusion for paradoxical hypertension (P-value=0.054), the pediatric anesthesia emergence delirium (PAED) (P-value=0.06) nor the time to wean oxygen supply (P-value=0.49).

Conclusion: Erector spinae plane block effectively reduces postoperative pain in pediatric patients undergoing repair of coarctation of the aorta. However, it did not significantly accelerate weaning from oxygen therapy nor reduce the incidence of vasodilator use for postprocedural hypertension.

Keywords: Erector spinae plane block, Thoracotomy, Aortic coarctation, FLACC pain score, Paradoxical hypertension, Weaning

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Introduction

The provision of effective postoperative analgesia is a cornerstone in anesthetic practice. Thoracotomy is recognized as the most painful surgical incision. Effective pain management is essential to facilitate coughing and deep breathing exercise to prevent postoperative pulmonary complications, e.g., atelectasis, pneumonia, and respiratory failure (1), all of which may increase demands for oxygen therapy (2).

Pain management is difficult in premature neonates and infants following thoracotomy. While opioids remain the gold standard for postoperative pain management, they may be hazardous in neonates. Morphine induces apoptosis in brain microglia and neurons (3), and repeated morphine exposure in children under the age of three modifies synaptic plasticity in the mesolimbic system, resulting in long-term effects on synaptic reorganization in areas that regulate motivation, reward, and learning throughout adulthood; these changes are permanent and persist even after morphine is removed (4).

Regional analgesia approaches seem to be superior to other analgesic options, particularly in terms of improved recovery (5). The most common regional procedures for this aim are thoracic epidural analgesia (TEA) and thoracic paravertebral block (TPVB). TEA despite its effectiveness carries the risk of epidural abscess or hematoma in pediatric patients (6). TPVB may be used in place of epidural analgesia during thoracic surgery (7). However, because the children's paravertebral space is narrow, even with ultrasound guidance, TPVB carries the risk of pleural puncture is still present (8).

Forero et al. described the ESPB for the first time in 2016. it has been used for perioperative analgesia in both adult and pediatric patients (9). Being a safer and more accessible alternative to central regional anesthetic procedures, ESPB has grown in popularity (10). Postprocedural paradoxical hypertension is a recognized complication of coarctation repair that is multifactorial but may be due to sympathetic overstimulation especially when occur as early as within the first 24 hours (11).

In our study we aimed to evaluate the effectiveness of unilateral ultrasound-guided ESPB in pediatric patients undergoing thoracotomy for coarctation repair in terms of pain relief, accelerating weaning from oxygen therapy, and reducing the incidence of postprocedural paradoxical hypertension through the sympathetic block. To our knowledge, our study was the first study to evaluate the postoperative duration of oxygen therapy after ESPB in pediatric patients for cardiac surgery and the impact of ESPB on the incidence of paradoxical hypertension in this cardiac operation.

Methods

Trial registration and ethical committee approval

Clinical trials (www.clinicaltrials.gov) database ID no was NCT05132946. After receiving clearance from the faculty of medicine's ethics committee (FAMSU R 167/2021), with ethical committee number (FWA 000017585). Approval of the Ethical Committee of the Faculty of Medicine of our university hospital and written informed consent from all participants or their legal guardians were obtained.

A three-month prospective randomized controlled experiment was done at our university Hospital (cardiothoracic surgery academy) from 30 October 2021 to 31 January 2022.

Eligibility criteria: Patients ranged in age from three months to five years and were of both genders (males and females) presenting for aortic coarctation repair through a left thoracotomy. Before initiating the study, it was important to get written informed consent from parents.

Exclusion criteria: Hypersensitivity to local anesthetics, mental or neurologic abnormalities, critically ill patients before surgery like those with heart failure or needing ventilatory support before surgery secondary to coarctation or any other cause, parental or legal guardian refusal, infection at the injection site, any liver condition, or any coagulopathy.

Sampling Method: By using the PASS 11 program for sample size calculation, setting power at 99%, alpha error at 5%, and after reviewing previous study results, Kaushal et al. (12) showed that means of postoperative fentanyl consumption (μg/kg) for pediatric patients

Table 1: Patients' demographic data of both groups.

	control (Group C)	ESP (Group B)		
	mean ± SD	mean ± SD	T value	P-value
age (months)	9.10 ±1.549	9.35 ±1.892	0.195.	0.846
weight (Kg)	7.49 ±0.825	7.48 ±0.844	-0.008	0.993
height (cm)	69.20 ±3.063	68.75 ±3.154	-0.195	0.846
body surface area (m2)	0.376 ±0.028	0.376 ±0.029	0	1

Patient's gender and congenital anomalies

	control (Group C)		ESP (Group B)				
	n	% Within-group	n	% Within-group	Chi-Square	df	P-value
Male	12.00	60%	13.00	65%	0.11	1.00	0.74
Female	8.00	40%	7.00	35%			

Associated congenital anomalies

	n	% Within-group	n	% Within-group	Chi-Square	df P-value	
Down	2	10%	2	10%	0.00	1	1
None	18	90%	18	90%			

There was no statistical significance between groups regarding all demographic data regarding age, or anthropometric measures

underwent cardiac surgeries under general anesthesia with no block versus those who took general anesthesia with ESPB were (1.08±0.91 versus 5.52±3.27 respectively); based on that, a sample size of at least 40 pediatric patients undergoing aortic coarctation repair surgery (20 patients in each group) will be sufficient to achieve study objective. Group B (ESP) received ESPB, and Group C (control) received no block.

Patients' Interventions and Management: Detailed baseline data including demographics, and comorbidities, were recorded.

Conduct of anesthesia: All patients received a routine preoperative evaluation in the preoperative anesthesia clinic, which included a review of their medical history, a physical examination, and routine investigations such as a complete blood count (CBC), prothrombin time (PT), partial thromboplastin time (PTT), and blood chemistry, and preoperative electrocardiography (ECG). All study participants were fasting according to ASA guidelines.

In the operating room, preoperative sedation with 3 mg/kg nasal midazolam, followed by standard monitoring including an ECG, invasive blood pressure (IBP), pulse oximetry (SpO_2), temperature, and end-tidal CO_2.

After standard monitoring, general anesthesia was induced with sevoflurane 8% in 100% oxygen, an IV access was secured, fentanyl (2 μg/kg) and atracurium besylate 0.5 mg/kg were given, followed by orotracheal endotracheal intubation, then anesthesia maintenance with a mixture of oxygen-air (50/50 percent) and sevoflurane (1-2%). Then the patients were positioned in the right lateral position (surgery position) before surgical draping.

ESP block procedure: In the ESPB group, patients were getting a unilateral ultrasound-guided ESPB using (SonoSite Edge, Bothell, Washington). The technique was described by Holland and Bosenberg (13). In brief After skin cleaning (on the left side), a linear ultrasonic probe with a 5 to 10 MHz transducer was placed.

Counting down from the C7 spinous process to the third thoracic spine, then moving laterally to the left side to visualize left transverse process levels, rotating position transversely to visualize the left lateral tip of the T3 transverse process, then superficially to the acoustic shadow of the transverse processes.

Trapezius, rhomboids, and erector spinae muscles were visualized. A 22-gauge, 50-mm block needle (Visioplex, Vygon) was inserted craniocaudally to touch the T3 transverse process utilizing the in-plane method. Hydro location with 0.5 to 1 mL normal saline confirmed the needle tip in the ESP deep to the erector spinae muscle, the block was given utilizing bupivacaine 0.25 percent with a total volume of 0.5 ml/kg and a maximum dose of 2 mg/kg of bupivacaine.

Insufficient analgesia was determined as heart rate (HR) acceleration or elevation in blood pressure of more than 20% above baseline at any point during the procedure, and fentanyl 1 ug/kg was given. The total amount of fentanyl consumed during surgery was calculated.

After the surgical process, all anesthetics were stopped, and the muscle relaxant was properly reversed. When spontaneous breathing and a proper return of awareness level occurred, extubation was done.

All patients were transferred to the intensive care unit (ICU), where they were fully monitored: an ECG, pulse oximeter, and invasive blood pressure, received nasal oxygen or oxygen mask with the lowest flow that keeps oxygen saturation more than 92%, weaning from oxygen was done by reducing FGF 1 liter/hr as long as $SpO_2 \geq 92\%$, time till the complete cessation of oxygen therapy was recorded.

In the event of hypertension following repair either intraoperative or postoperative in the ICU vasodilators were added targeting a blood pressure value between the 95^{th} and 99^{th} percentile of the age-related nomogram.

Outcomes: The primary outcome was fentanyl consumption (ug/kg) in the first 12 hours after surgery. Secondary outcomes were the FLACC scale (Face, Legs, Activity, Cry, Consolability) for pain assessment (14). After extubation, as well as at 1, 2, 4, 6, 8, 12, 18, and 24 hours.

Time till initial request for rescue analgesia (rescue analgesia was supplied if FLACC 4) in the form of fentanyl in dosage up to 1 μg/kg. The number of patients who needed vasodilators to control postprocedural hypertension either intraoperative or within the first 24 h. Time till weaning from oxygen therapy. Pediatric anesthesia emergence delirium (PAED) score (15) on the entrance to ICU.

Statistical analysis: Values were presented as numbers and proportions or median and range. The distribution of qualitative variables among patient groups was analyzed by the Chi-square test or Fisher's exact test, as indicated. Quantitative variables were checked for normality by the Shapiro-Wilk test. As data were not normally distributed, variables were compared between groups by the Mann-Whitney test. All tests were bilateral and a P-value of 5% is the limit of statistical significance. Analysis was performed by statistical package software IBM- SPSS version 24.

Results

There was a statistically significant less intraoperative fentanyl consumption in the ESP group 2.80 ±0.234 μg/kg when compared with the control group 3.90 ±0.329 μg/kg (P-value <0.001) (Table 2). There was a

Table 2: Patients' intraoperative data of both groups.

	control (Group C)	ESP (Group B)			
	mean ± SD	mean ± SD	T value		P-value
duration of surgery (min)	131.10 ±4.482	127.85 ±5.955	-0.833		0.41
aortic cross-clamp time (min)	33.70 ±2.597	34.55 ±2.321	0.466		0.64
intraoperative blood transfusion (ml/kg)	12.961 ±1.116	12.449 ±0.630	-0.762		0.45
intraoperative fentanyl (µg/kg)	3.90 ±0.329	2.80 ±0.234	-5.200		< **0.001***
time from the end of anesthesia till extubation (min)	14.65 ±0.890	14 ±1.285	0.794		0.43
	% Within-group (n)	% Within-group (n)	Chi-Square	df	P-value
postprocedural hypertension necessitating vasodilator	60% (12)	40% (8)	1.6	1	0.054

Not statistically significant except observed lower intraoperative fentanyl consumption in the ESP group 2.80 ±0.234 ug/kg when compared with the control group 3.90 ±0.329 ug/kg with a P-value <0.001. ESP did not reduce the incidence of the intraoperative nor postoperative need for vasodilator infusion with 60% of patients receiving vasodilator therapy.

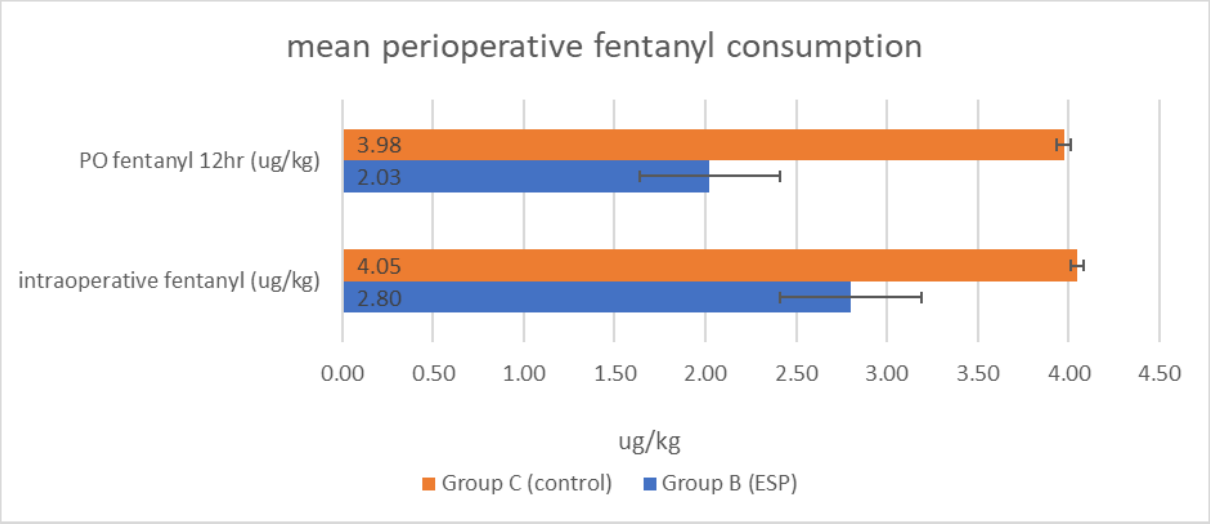

Figure 1. Perioperative fentanyl consumption (µg/kg) intraoperative and during the first 12 hours postoperative.

statistically significant less postoperative fentanyl consumption in the ESP group 2.025 ±0.273 µg/kg when compared with the 4.05 ±0.527 µg/kg in the first 12 hours (P-value <0.001). with a median time to the first call of rescue-analgesia that occurred earlier in the control group 2 hours postoperative versus 6 hours in the ESPB group (P-value <0.001) (Table 3) and (Figure 1). There was a statistically significant

Table 3: Patients' postoperative data of both groups.

	control (Group C)	**ESP (Group B)**			
	mean ± SD	**mean ± SD**	**T value**		**P-value**
duration of surgery (min)	131.10 ±4.482	127.85 ±5.955	-0.833		0.41
aortic cross-clamp time (min)	33.70 ±2.597	34.55 ±2.321	0.466		0.64
intraoperative blood transfusion (ml/kg)	12.961 ±1.116	12.449 ±0.630	-0.762		0.45
intraoperative fentanyl (µg/kg)	3.90 ±0.329	2.80 ±0.234	-5.200		**< 0.001***
time from the end of anesthesia till extubation (min)	14.65 ±0.890	14 ±1.285	0.794		0.43
	% Within-group (n)	% Within-group (n)	Chi-Square	df	P-value
postprocedural hypertension necessitating vasodilator	60% (12)	40% (8)	1.6	1	0.054

The Group of patients who received ESP have lower postoperative fentanyl consumption by 50% than the control group in the first 12 hours 2.025 ±0.273 ug/kg and 4.05 ±0.527 ug/kg respectively with P-value <0.001. with a median time of the first call of rescue-analgesia occurred earlier in the control group with a median time of 2 hours postoperative and 6-hour median in the ESPB group with a P-value <0.001.

difference between both groups regarding FLACC score at different time intervals in the first 24 hours (Table 4), and (Figure 2) shows statistical significance with a P-value <0.05 utilizing the Mann-Whitney test for FLACC pain score at a different time interval during the first 24 hours.

There was no statistical significance between groups regarding all demographic data regarding age, gender, anthropometric measures, or, associated congenital anomalies (Table 1). There was no statistically significant difference between both groups regarding the number of patients developing hypertension necessitating vasodilator therapy (p-value 0.054) (Table 2). There was no statistically significant difference between both groups regarding PAED score (P-value = 0.06) (Table 3). There was no statistically significant difference between both groups regarding time to wean from oxygen therapy (P-value = 0.49) (Table 3).

Discussion

The anesthetic goals in fast-tracking children undergoing heart surgery include short extubation time and provision of adequate perioperative analgesia without significant respiratory depression (16).

Pain management in pediatrics presented for thoracotomy is especially tricky. Uncontrolled pain induces a rapid shallow pattern of breathing, predisposing the patient to atelectasis. On the other hand, Opioid use may contribute to respiratory complications. For instance, respiratory depression necessitates non-invasive positive-pressure ventilation or reintubation which can place undue strain on delicate suture lines (17). While opioid-free regional anesthesia is the ideal solution, it is frequently contraindicated in these patients due to comorbid prematurity conditions. With continuous ESP block, patients experienced minimal postoperative pain and

required no supplemental opioids (7). significantly reduced pain scores from zero hours to six

Table 4: Patients' FLACC scores at various time intervals of both groups.

	control (Group C)	ESP (Group B)			
	median (min-max)	median (min-max)	Mann Whitney U	Z	P-value
FLACC 1hr	3 (2 -4)	2 (1 - 3)	294	2.844	**<.001***
FLACC 2hr	3 (2 - 4)	3 (1 - 3)	326.5	3.63	**<.001***
FLACC 4hr	4 (2 - 5)	3 (1 - 4)	310	3.109	**<0.05***
FLACC 6hr	4.5 (3 - 6)	3.5 (2 - 5)	331.5	3.796	**<.001***
FLACC 8hr	5 (3 - 6)	4 (2 - 5)	310	3.109	**<0.05***
FLACC 12hr	4 (3 - 6)	3 (2 - 5)	324	3.553	**<.001***
FLACC 18hr	5 (3 - 6)	4 (2 - 5)	309.5	3.094	**<0.05***
FLACC 24hr	5 (4 - 6)	4 (3 - 5)	334	3.877	**<.001***

Shows statistically significant differences between both groups with P-value <0.05 utilizing the Mann-Whitney test for FLACC pain score at different time intervals during the first 24 hours.

Following a review of the literature, only a few studies discuss the current issue, the majority of which are sporadic case reports or studies on surgeries other than thoracotomy, LUO et al. conducted a meta-analysis on seven randomized controlled trials involving 379 patients and found only five studies had compared the ESPB with control and found ESP hours postoperatively at rest and significantly reduced the need for rescue analgesics compared to the absence of a block (18).

Our study suggests that ESPB is superior to standard intravenous analgesics alone in pediatric patients undergoing left posterior thoracotomy approach for aortic coarctation repair, as evidenced by

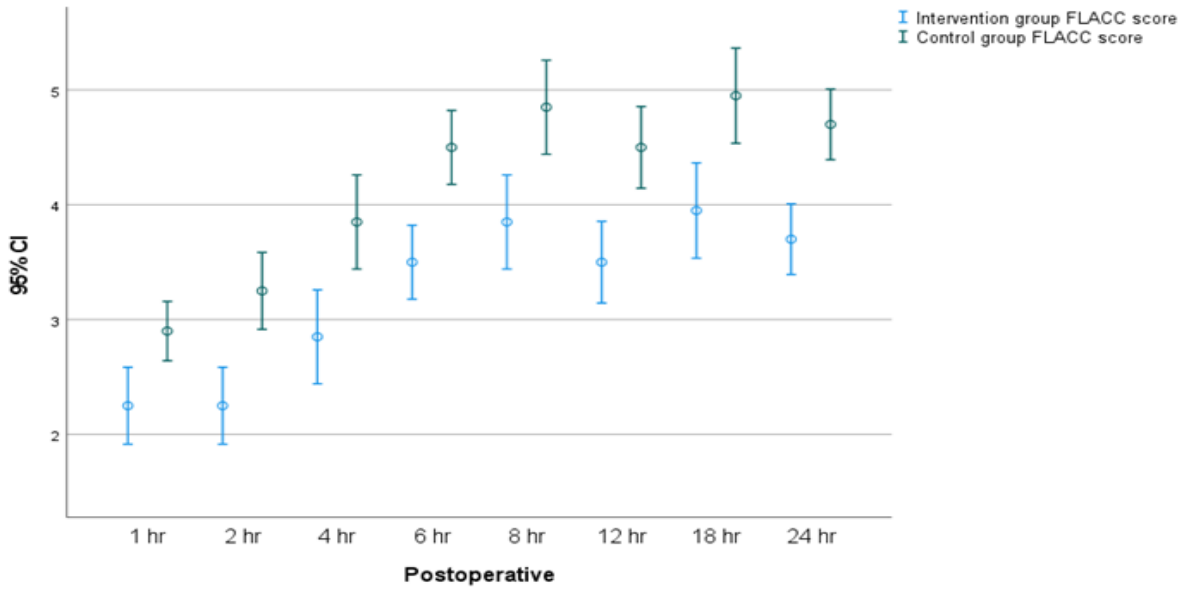

Figure 2. FLACC scores at different time intervals during the first 24 hours.

significantly lower intraoperative and postoperative fentanyl consumption and significantly lower FLACC score across time intervals during the first day postoperatively.

In line with our study, Bliss DP and his colleagues evaluated ESPB in 30 pediatric patients undergoing the Nuss procedure and found it safe and effective, furthermore they suggested it as an alternative to thoracic epidural in such patients [19]. (19).

Another study by Fang et al. was conducted on 94 adult patients scheduled for thoracotomy for lung surgery and assigned randomly to receive either ESPB or TPVB, with both groups receiving intravenous patient-controlled analgesia (PCA) sufentanil. there was no statistically significant difference between both groups regarding postoperative pain scores in the first 48 hours following surgery or postoperative sufentanil consumption. Additionally, the ESPB group experienced significantly less hypotension. They concluded that preoperative single-injection ESP block plus postoperative sufentanil PCA provided comparable pain relief to TPVB in patients undergoing thoracotomy. ESPB, on the other hand, had the advantage of being simpler and having a lower incidence of complications as reported by the study (20).

Indeed, postoperative pain increases the incidence of pulmonary atelectasis, and retention of secretions, with subsequent hypoxemia and hypoventilation (2, 21, 22). We hypothesized that adequate pain control would allow early weaning from oxygen therapy by mitigating these effects. However, we failed to show a significant difference between both study groups (P = 0.49). We think that pain in our group of patients is not the only determinant of weaning from oxygen; the procedure itself entails ipsilateral mechanical lung trauma, collapse, and bleeding, in addition, the contralateral lung suffers from gravity-dependent plethora and spillage of secretions all of which certainly affects pulmonary recovery (23).

In contrast to our study, ESPB successfully resulted in preserved lung volumes and lung capacities evaluated postoperatively by spirometry when compared with intercostal nerve block in adult patients undergoing video-assisted thoracoscopic surgeries (24), ESPB was also associated with statistically significant earlier discharge from PACU. Apparently due to ameliorating the negative impact of pain on lung recovery. However, upon further looking at the results we noticed that no significant difference between both study groups in terms of the number of patients requiring postoperative supplemental oxygen (p= 0.605), agreeing with the multifactorial theory of post-repair pulmonary compromise.

Future studies are warranted to evaluate postoperative pulmonary complications following thoracic surgeries in ESPB receivers versus non-receivers but with a larger sample size. Sympathetic block in ESPB occurs secondary to the ventral spread of local anesthetic to paravertebral space where it blocks ventral and dorsal rami as well as grey and white rami communicate which holds sympathetic preganglionic and postganglionic fibers (25)**.** Pınar P and his colleagues suggested that ESPB would increase regional intraabdominal oxygen saturation (rSO_2) secondary to sympathetic block and subsequent vasodilatation in pediatric patients undergoing abdominal surgeries when they receive ESPB, but they could not confirm a significant difference between ESPB receivers and non-receivers ($p > 0.05$). However, they mentioned that there was a consistent rise of rSO_2 following ESPB compared to preblock, in addition, they stopped recording rSO_2 after only 50 minutes of the block (26) a longer period of observation may have shown more relevant results.

Repair of coarctation of the aorta in particular may be associated with paradoxical hypertension which may occur as early as within the first 24 hrs or be delayed for days postoperative early hypertension may be due to sympathetic stimulation and may result in postoperative bleeding or even rupture of the anastomosis (11), we assumed that adequate postoperative analgesia through reducing sympathetic stimulation would ameliorate hypertension. We found a modestly less incidence of hypertension necessitating vasodilators in the ESPB group, yet differences were not statistically significant (P value= 0.054). We think this may owe to the multifactorial pathogenesis of paradoxical hypertension which includes the reduced stretch of baroreceptors and activation of the renin-angiotensin-aldosterone system (27), all of which are not affected by our block. Another factor may be that

we performed the block unilaterally, a bilateral block may be more efficient and worth investigating in future trials. On the other hand, Epidural block successfully reduced the postoperative vasodilator infusion requirements in pediatrics undergoing repair of aortic coarctation when compared with non-receivers (p value= 0.021) in a retrospective cohort by Matthew and his colleagues (28). They explained their finding through the pain relief and sympathetic block provided by epidural block. A future comparative study between both techniques is worth trying.

Our study gains its strength from being the first study to explore the influence of ESPB on the incidence of postoperative paradoxical hypertension, we are also the first to explore the beneficial effect of ESPB on postoperative pulmonary recovery through the duration of oxygen therapy in this particular group of patients, we think further studies with larger sample size can be built upon our findings in the future.

The study's findings had some limitations. To begin with, the sample size was small and there was no blinding for participants. Second, despite the favorable pain scores, we were unable to accurately assess the dermatomal distribution of blockade due to the subject's age and the use of single-injection ESPB. Third, we recorded the only number of patients requiring postoperative vasodilator therapy, a more detailed evaluation of dosage and duration of vasodilator infusion would have added to the value of the study.

Conclusion

ESPB may be efficient in lowering postoperative pain in pediatric patients undergoing cardiac surgery via the thoracotomy approach and enhancing postoperative recovery, but additional research is necessary to implement this technique in fast-track cardiac surgery.

Acknowledgment

None.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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