Original Article

Ultrasound-guided Procedures for Postoperative Pain Management in Paediatric Patients Undergoing Thoracic Surgeries: A Systematic Review

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Abstract

Background: This systematic review seeks to assess and compare various ultrasound-guided procedures for delivering analgesia through peripheral nerve blockade, aiming to ascertain the most effective approach for paediatric thoracic surgeries. The primary goal is to evaluate the efficiency of these ultrasound_guided procedures in managing postoperative pain among children undergoing thoracic surgeries. **Materials and Methods:** A systematic literature search was performed in PubMed, SCOPUS, Central Cochrane Registry of Controlled Trials (The Cochrane Library) and Science Direct databases for paediatric thoracic surgeries conducted with ultrasound-guided procedures for administering analgesia. We included studies involving randomised controlled trials (RCTs) only. Quasi-randomised controlled studies, prospective, retrospective observational studies, case series, case reports, letters, editorials, comments, animal studies and studies from non-English literature were excluded. **Results:** After screening 29 articles with our search strategy and removing duplicates, a total of 4 articles met our criteria. Analysing 225 patients from RCTs, TTPB (29.78%) was the most used block. Opioid consumption varied, but overall trends aligned with pain scores. Time to the first analgesia ranged from 5 to 7 h, with PIPB at 5 h. Complications included pneumothorax and hematoma with TTPB and hematoma with PIPB (n = 3). **Conclusions:** While the existing body of literature is limited, this study underscores the crucial need for additional RCTs to thoroughly investigate the optimal procedures for various types of thoracic surgeries. The scarcity of studies emphasises the importance of further research to glean meaningful conclusions and enhance our understanding of the most suitable approaches in this field.

Keywords: Bilateral intercostal nerve block, bilateral thoracic paravertebral block, pecto-intercostal fascial plane block, transversus thoracis muscle plane block, ultrasound-guided procedures

Introduction

Postoperative pain tends to be more severe following thoracic surgeries, potentially compromising lung expansion due to the pain associated with chest movements. In such cases, opioids are commonly prescribed as the initial line of treatment for postoperative pain.[1] However, the use of opioids in these situations may adversely affect respiratory drive, particularly in paediatric patients.[2] To mitigate the risk of excessive opioid consumption, ultrasound-guided procedures/blocks emerge as a pivotal strategy for postoperative pain relief and enhanced recovery. Despite the recognised benefits, there is a lack of comprehensive studies comparing various ultrasound-guided procedures or blocks specifically tailored for postoperative pain management in children undergoing thoracic surgeries, whether open or thoracoscopic. This systematic review was conducted to discern the most suitable procedure for optimising postoperative pain management in children undergoing thoracic surgeries.

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Materials and Methods

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting the present review.[3] This systematic review has been registered with PROSPERO (CRD42023493703), the international registry for systematic reviews.

PICO question

We examined articles featuring paediatric patients <21 years of age who underwent thoracic surgeries involving ultrasound-guided procedures for analgesia administration. Our objective was to compare various blocks used for postoperative analgesia, assessing their efficiency and identifying potential complications.

Search strategy

A systematic literature search was conducted across PubMed, SCOPUS, Central Cochrane Registry of Controlled Trials and Science Direct databases, using the search terms outlined in Table 1.

Table 1: Details of search strategy

PUBMED	Search
	(‘pain, postoperative’[MeSH Terms] OR(‘pain’[All Fields] AND ‘postoperative’[All Fields]) OR ‘postoperative pain’[All Fields] OR (‘postoperative’[All Fields] AND ‘pain’[All Fields])) AND (‘analgesic s’[All Fields] OR ‘analgesically’[All Fields] OR ‘analgesics’[Pharmacological Action] OR ‘analgesics’[MeSH Terms] OR ‘analgesics’[All Fields] OR ‘analgesic’[All Fields]) AND (‘pediatrics’[All Fields] OR ‘pediatrics’[MeSH Terms] OR pediatrics’[All Fields] OR ‘pediatric’[All Fields] OR ‘pediatric’[All Fields]) AND (‘diagnostic imaging’[MeSH Subheading] OR (‘diagnostic’[All Fields] AND ‘imaging’[All Fields]) OR ‘diagnostic imaging’[All Fields] OR ‘ultrasound’[All Fields] OR ‘ultrasonography’[MeSH Terms] OR ‘ultrasonography’[All Fields] OR ‘ultrasonics’[MeSH Terms] OR ‘ultrasonics’[All Fields] OR ‘ultrasounds’[All Fields] OR ‘ultrasound s’[All Fields]) AND (‘chested’[All Fields] OR ‘thorax’[MeSH Terms] OR ‘thorax’[All Fields] OR ‘chest’[All Fields] OR ‘chests’[All Fields])
COCHRANE	12 Trials matching postoperative pain analgesics, pediatric ultrasound chest in Title, Abstract
SCOPUS	KeywordTITLE-ABS-KEY (postoperative AND pain ANDanalgesicsAND pediatric AND ultrasound AND chest)
SCIENCE DIRECT	ScienceDirect Title, abstract, keywords: postoperative pain analgesics, pediatric ultrasound chest

In addition, the reference lists of included studies were reviewed for potentially relevant studies. Four investigators independently screened abstracts, with selected articles undergoing full-text evaluation. Conflicts were resolved through consensus, resulting in a final list of studies.

Eligibility criteria

Randomised controlled trials (RCTs) meeting the inclusion criteria, which focused on ultrasound-guided procedures for analgesia in paediatric thoracic surgeries, were included. Quasi-randomised controlled studies, prospective and retrospective observational studies, case series, case reports, letters, editorials, comments, animal studies and non-English literature studies were excluded.

Data extraction

Four investigators independently assessed studies and extracted data using a pre-designed pro forma based on inclusion criteria. Extracted details included study author, publication year, country, sample size, type of block, type of surgery, reported outcomes and any complications. Authors were contacted for missing data, and discrepancies were resolved through consensus. The PRISMA flow chart illustrating the study selection process is presented in Figure 1.

Results

Utilising the search criteria outlined in Table 1, we initially identified a total of 29 articles. After removing 7 duplicates, the remaining 22 articles underwent a title search, resulting in the selection of 11 articles. Subsequent detailed examination led to the inclusion of four RCTs.[2,4-6] We employed the revised JBI critical appraisal tool to assess the risk of bias in RCTs[7] [Table 2].

Seven articles were excluded from the study,[8-14] the reasons for exclusion are detailed in Table 3.

The total number of patients included in the analysed RCTs was 225, with an age range spanning from 2 to 16 years. Among these patients, 57.78% were male, and 42.22% were female. The two main surgical procedures performed using the studied blocks were open-heart surgery requiring sternotomy (59.11%) and the Nuss procedure for pectus excavatum (40.89%).[2,4-6] Specifically, the transversus thoracis muscle plane block (TTPB) was utilised in 29.78% of cases, making it the most common procedure in our review, mainly used for sternotomies.[4-6] The pecto-intercostal fascial plane block (PIPB) was used in 13.33%, bilateral intercostal nerve block (ICNB) in 15.11%, thoracic paravertebral block in 6.67% and the remaining 35.11% involved controls.[2,4]

The pain scores used by the studies in our review included Modified Objective Pain Score (MOPS), Faces Pain Scale - Revised (FPS-R), Face, Legs, Activity, Cry, Consolability (FLACC) and visual analogue scale (VAS). MOPS was used in both studies with open-heart surgeries, while FLACC, VAS and FPS-R scores were used for theNuss procedure.[2,4-6] The main outcomes measured in these studies were pain score at a definite time period post_surgery, opioid

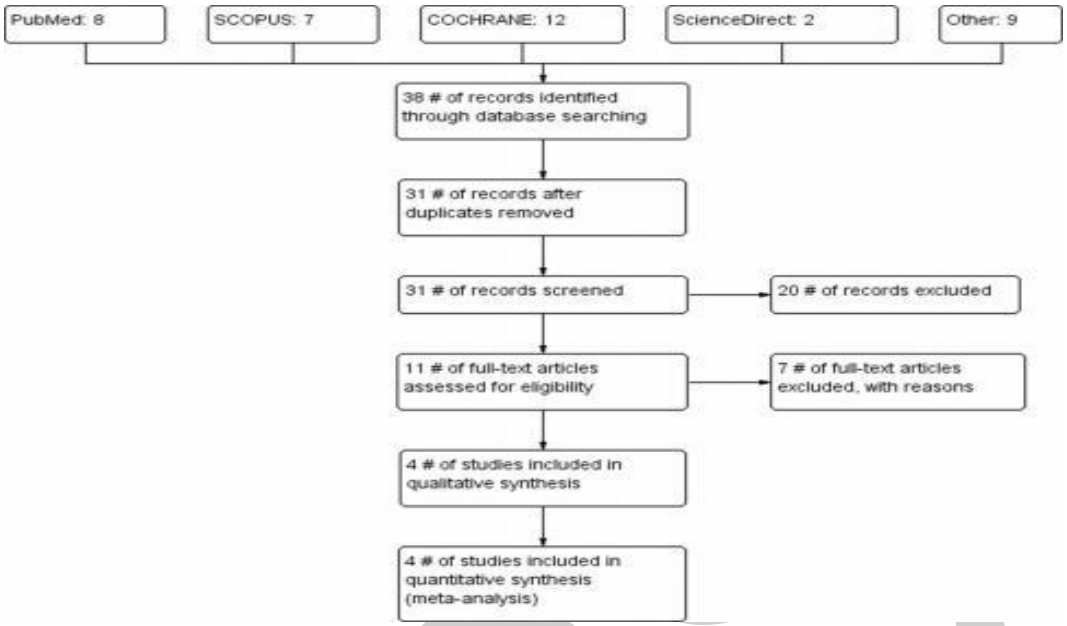


Figure 1: Preferred Reporting Items for Systematic Reviews and Meta_Analyses flow diagram

Table 2: Joanna Briggs Institute critical appraisal checklist for randomised controlled trial studies

Study ID	PI	P2	P3	P4	P5	P6	P7	P8	P9	PI0	PI1	PI2	PI3
Luo *et al*., 2017[2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Elbardan *et al*., 2023[4]	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Abdelbaser and Mageed, 2020[5]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Qi *et al*., 2014[6]	Unclear	Unclear	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

1. Was true randomisation used for assignment of participants to treatment groups?

2. Was allocation to treatment groups concealed?

3. Were treatment groups similar at the baseline?

Bias related to administration of intervention/exposure

4. Were participants blind to treatment assignment?

5. Were those delivering the treatment blind to treatment assignment?

6. Were treatment groups treated identically other than the intervention of interest?

Bias related to assessment, detection and measurement of the outcome

7. Were outcome assessors blind to treatment assignment?

8. Were outcomes measured in the same way for treatment groups?

9. Were outcomes measured in a reliable way?

Bias related to participant retention

9. Was follow_up complete, and if not, were differences between groups in terms of their follow_up adequately described and analysed? Statistical Conclusion Validity

10. Were participants analysed in the groups to which they were randomised?

11. Was appropriate statistical analysis used?

12. Was the trial design appropriate and any deviations from the standard RCT design (individual randomisation, parallel groups) accounted for in the conduct and analysis of the trial?

RCT: Randomised controlled trial

consumption and time to first rescue analgesia. Different pain scores were used by various studies, making direct comparison challenging. However, TTPB showed better pain scores compared to PIPB; ICNB and bilateral thoracic paravertebral block (BTPV) demonstrated better pain scores compared to controls.[2,4-6] Opioid consumption was not comparable among these studies due to variations in opioid types and reporting methods. However, overall results were similar to the pain scores mentioned above. The time to the first analgesia was not explicitly mentioned in two studies, with the remaining studies reporting a range of 5–7 h.[2,4-6] PIPB had the shortest time to analgesia at 5 h, with other blocks performing better than controls. There were two cases of pneumothorax and one case of hematoma documented with TTPB and one case of hematoma documented with PIPB[4] [Table 4].

Table 3: Reason for exclusion of studies

Study author (year)	Reason for exclusion
Breglio *et al*., 2023[8]	Retrospective study
Heo *et al*., 2021[9]	Systematic review and meta-analysis
Muller *et al*., 2018[10]	The study is on thoracoscopy versus open for PDA
Roy *et al*., 2021[11]	Prospective cohort study
Velayos *et al*., 2022[12]	Preliminary retrospective review
Velayos *et al*., 2023[13]	Prospective Pilot study, Details of randomisation not available
Yamamoto *et al*., 2020[14]	Case report

PDA: Patent Ductus Arteriosus

Table 4: Characteristics of randomised controlled trials included for the systematic review

Study author (year)	Sample size	Age (year)	Sex male/ female	USG guided procedure used	Surgery	Pain scores used	Results			Complications	Conclusion
							Pain scores comparison	Opioid consumption	Time to first rescue analgesia (h)		
Luo *et al*., 2017[2]	62	4–16	34/28	ICNB (34)	Nuss	FPS-R	Lower in ICNB	Lower in ICNB	Lower in ICNB	Nil	ICNB might be more effective than PCIA for post-operative analgesia in children who undergo Nuss procedure
Elbardan *et al*., 2023[4]	60	2-12	31/29	TTPB (30) PIFB (30)	Open Heart	MOPS	Lower in TTPB	Lower in TTPB	7.2 5	Pneumothorax 2 Hematoma 1	TTPB provides better and longer-lasting post-operative analgesia with less incidence of non-sternal wound pain than PIFB
Abdelbaser and Mageed, 2020[5]	73	2-12	38/35	TTPB (37)	Open Heart	MOPS	Lower in TTPB	Lower in TTPB	6	Nil	The use ofTTP block decreased perioperative fentanyl consumption and reduced post-operative pain intensity
Qi *et al*., 2014[6]	30	2-15	27/03	BTPV (15)	Nuss	FLACC-VAS	Lower in BTPV	Lower in BTPV	Not clear	Nil	BTPV block provides improved post-operative analgesia for children undergoing the Nuss procedure as compared with intravenous PCA

TTPB: Transversus Thoracis Muscle Plane Block, PIPB: Pecto-IntercostalFascial Plane Block, BTPV: Bilateral Thoracic Paravertebral Block, ICNB: Bilateral intercostal Nerve block, MOPS: Modified objective pain score, FPS_R: Faces Pain Scale_ Revised, FLACC: Face, Legs, Activity, Cry, Consolability,VAS: Visual Analogue Scale, PCIA: Patient-Controlled Intravenous Analgesia, USG: Ultrasound sonography, PCA: Patient-controlled analgesia

AJPS

Discussion

Thoracotomies present a distinct challenge in terms of postoperative pain management. While older children may comprehend and cooperate with postoperative breathing exercises, managing smaller and special-needs children poses significant difficulties. In these cases, the compromised lung function resulting from surgery is exacerbated by the child's inadequate breathing efforts due to pain, leading to potential issues such as insufficient coughing, pooling of secretions and an increased risk of post-operative pulmonary complications.[4] While opioids remain the standard management for post-thoracotomy pain across all age groups, their restricted use in many underdeveloped and developing countries poses challenges, particularly in paediatric cases. Even when available, the escalating opioid dosages can lead to various side effects such as respiratory depression and constipation. Non steroidal anti-inflammatory drugs , though considered an alternative, may provide inadequate pain relief and pose significant risks, including bleeding, especially in children undergoing anticoagulation therapy.[4] Epidural analgesia is recognised as a superior pain relief modality for thoracic surgeries. However, this approach carries inherent risks and contraindications, notably in cases involving anticoagulation. Anticipated complications associated with epidural analgesia include neuropraxia and lower limb weakness, some of which are documented with children undergoing Nuss repair.[2]

Regional anaesthesia blocks emerge as a promising alternative to address the aforementioned challenges. The application of ultrasound has significantly enhanced the precision of block administration, minimising complications. While various procedures are well-established for adult patients, the utilisation and corresponding literature are relatively limited for paediatric populations across different surgical scenarios. The most commonly used regional anaesthesia blocks for thoracotomies in adults are ICNBs, pectoral nerve blocks (PECS I, II), serratus plane block, paravertebral block and erector spinae block.

In our review, the most commonly used regional anaesthesia block was TTPB, similar to the abdominal version of the transversus abdominis block, injecting bilaterally between the 4th and 5th rib space close to the sternum. This block offers advantages, such as delivering local anaesthetic close to the sternum for effective analgesia over the surgical site without changing the patient's position. However, the need for a substantial amount of local anaesthetic for proper distribution across the fascial planes is a consideration.[5]

Transversus Thoracis Muscle Plane Block is designed to block the 2nd–6th intercostal nerves, and while complications such as pneumothorax and chest wall haematoma are expected to be less due to its superficial nature and ultrasound guidance, reported cases indicate a potential for such complications. Another option, PIPB, involves injecting the local anaesthetic close to the sternum between the pectoralis major and internal intercostal muscle between the 5th and 6th ribs. Despite the reduced risk of pneumothorax compared to TTPB, its efficacy is reported to be lower.[4] ICNB, as utilised by Luo *etal*. in theNuss procedure, involves administration in the supine position at the midaxillary line, targeting three intercostal spaces, including the space of interest with one above and below, a process repeated on the opposite side. It is important to note that this procedure may not be suitable for sternotomy incisions, in contrast to other techniques like TTPB and PIPB. Luo *et al*. were the first in conduction an RCT using ICNB for the Nuss procedure in children. Anticipated complications are akin to other blocks, such as pneumothorax. However, it is noteworthy that ICNB is not dose-dependent, although systemic absorption may be higher due to the proximity of intercostal vessels to the nerve.[2]

Qi *et al*. employed the BTPV technique, where a single injection of 0.5 ml/kg is anticipated to cover a minimum of four dermatomal segments. The injection site is at the costotransverse ligament at the level of T5. Expected risks associated with this procedure include pneumothorax, vascular complications and neural injury, all of which can be mitigated using ultrasound guidance. Typically, the patient's position needs to be changed, usually to the lateral decubitus position, for the administration of this procedure. In addition to providing a sensory block, BTPV has the capability to block the thoracic sympathetic chain as well. Qi *et al*. reported a 20% decrease in blood pressure without significant bradycardia in their study, which was effectively managed. This suggests the need for careful monitoring and consideration of potential hemodynamic changes associated with the BTPV technique.[6] Common limitations in these studies include patient age considerations for those younger than 2 years, the absence of confirmed doses and volumes required for safe fascial blocks and unexplored options such as the erector spinae block, known for effectiveness but associated with significant complication risks, like paravertebral blocks. This review underscores the need for further RCTs to explore different options in children, even those younger than 2 years old. Homogeneity in reporting pain scores at defined intervals, evaluating the dose and dilution of local anaesthetic for proper effect while avoiding toxicity and uniformity in reporting opioid consumption scores are essential for advancing our understanding of effective and safe pain management strategies in this specialised domain.

Conclusions

Each approach exhibits its specific strengths and drawbacks, underscoring the intricacy of customising pain relief strategies for the distinct needs of paediatric patients. This comprehensive examination sheds light on the

advancements achieved in post-operative analgesia using ultrasound guidance for paediatric patients undergoing thoracic surgeries. This review reveals numerous untapped possibilities for regional blocks and unexplored surgical procedures. Nonetheless, it also underscores the opportunities for forthcoming RCTs to assess effectiveness, establish standardised practices and improve patient outcomes within this specialised field.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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