

Original Research Article

COMPARISON OF ANALGESIC EFFICACY OF ULTRASOUND-GUIDED CAUDAL BLOCK VERSUS POSTERIOR QUADRATUS LUMBORUM BLOCK IN PAEDIATRIC LOWER ABDOMINAL SURGERIES: A RANDOMISED CONTROLLED TRIAL

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Received : 10/08/2026
Received in revised form : 12/09/2026
Accepted : 26/09/2026

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DOI: 10.70034/ijmedph.2026.4.116

Source of Support: Nil,

Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (4); 770-775

ABSTRACT

Background: Caudal epidural block is the standard regional technique for paediatric infra-umbilical surgery but provides limited analgesia duration. Posterior quadratus lumborum block (QLB) offers prolonged somatic and visceral analgesia via paravertebral spread and may be a superior alternative. The objective is to compare analgesic efficacy of ultrasound-guided posterior QLB versus caudal block in children aged 6 months–8 years undergoing elective infra-umbilical surgery.

Materials and Methods: In this prospective RCT, 24 children (ASA I–II) were randomised to caudal block (0.125% bupivacaine 1 mL/kg + dexmedetomidine 0.5 µg/kg) or posterior QLB (0.125% bupivacaine 0.5 mL/kg + dexmedetomidine 0.5 µg/kg). Primary outcome was time to first rescue analgesia; secondary outcomes included FLACC pain scores, rescue analgesia requirement, and complications.

Results: One block failure per group left 11 participants per group for analysis. Time to first rescue analgesia was significantly longer in the QLB group (12.00 ± 2.00 h vs 7.73 ± 1.10 h; $p < 0.001$). FLACC scores differed significantly at 12 h (1.45 ± 0.69 vs 2.73 ± 0.79 ; $p = 0.002$). Rescue analgesia was required in fewer QLB children (18.2% vs 72.7%; $p = 0.03$). No block-related complications occurred.

Conclusion: Posterior QLB was associated with longer postoperative analgesia and reduced rescue analgesia requirement compared with caudal block in children undergoing lower abdominal surgery. Larger multicentre studies are warranted to confirm these findings.

Keywords: paediatric anaesthesia; quadratus lumborum block; caudal epidural block; postoperative pain; FLACC scale; regional anaesthesia; ultrasound guidance.

INTRODUCTION

Postoperative pain management in children undergoing lower abdominal surgery is a cornerstone of perioperative care. Inadequately controlled pain is associated with neuroendocrine stress responses, sleep disturbances, behavioural regression, and long-term adverse sequelae including heightened pain sensitivity and anxiety disorders.^[1,2] Undertreated acute postoperative pain in childhood is an independent predictor of chronic pain and psychological morbidity in later life.^[3]

Regional anaesthesia within multimodal analgesic strategies reduces perioperative opioid consumption and its adverse effects such as respiratory depression, nausea, vomiting, and delayed mobilisation while facilitating enhanced recovery.^[4,5] For infra-umbilical procedures such as inguinal herniorrhaphy, open appendectomy, and ileostomy closure, caudal epidural block has been the most commonly used regional technique in paediatric practice for over four decades, owing to the accessibility of the caudal epidural space in young children and its well-established safety record.^[6,7] However, its principal

limitation is a narrow analgesic window: plain bupivacaine provides analgesia for only four to six hours, requiring supplementary systemic analgesia thereafter.^[8,9] Although adjuvants such as dexmedetomidine extend block duration, concerns about sedation, haemodynamic perturbation, and urinary retention limit their use, particularly in ambulatory patients.^[10,11]

The quadratus lumborum block (QLB), first described by Blanco, deposits local anaesthetic in the thoracolumbar fascial plane adjacent to the quadratus lumborum (QL) muscle.^[12] The posterior approach is of particular interest: cadaveric and MRI studies demonstrate spread of injectate into the paravertebral space, enabling blockade of thoracolumbar spinal nerves (T10–L1) and sympathetic visceral afferents via the splanchnic nerves.^[13,14] This dual somatic-visceral coverage may confer an analgesic advantage over caudal block for procedures involving visceral manipulation. Emerging paediatric data suggest QLB is feasible, safe, and superior in analgesic duration,^[15,16] but published randomised controlled trials (RCTs) are few.

We conducted this prospective RCT to test the hypothesis that ultrasound-guided posterior QLB provides superior postoperative analgesia quantified by time to first rescue analgesia, FLACC pain scores, and rescue analgesia requirement compared with ultrasound-guided caudal block in children aged 6 months–8 years undergoing elective infra-umbilical surgery.

MATERIALS AND METHODS

Study Design and Ethics: This prospective RCT was conducted at the Department of Paediatric Anaesthesia, Post Graduate Institute of Child Health, Noida, India. Ethics approval was obtained (IEC no. 2024-13-IM-27) and the trial was prospectively registered (CTRI/2024/10/075676). The trial was conducted per the Declaration of Helsinki and reported according to CONSORT 2010.⁽¹⁷⁾ Written informed consent was obtained from parents or legal guardians prior to enrolment.

Participants: Children aged 6 months–8 years, ASA (American Society of Anaesthesiologists) physical status I or II, scheduled for elective infra-umbilical surgery under general anaesthesia were eligible. Exclusion criteria were: parental refusal; skin or soft-tissue infection at the injection site; coagulopathy or thrombocytopenia (platelets < 80 × 10⁹/L); hypersensitivity to amide local anaesthetics; congenital vertebral or sacral anomalies; and pre-existing neurological or neuromuscular disorders.

Randomisation and Blinding: Eligible participants were randomly allocated 1:1 to posterior QLB (Group Q) or caudal block (Group C) using a computer-generated sequence. Allocation was concealed via sequentially numbered sealed opaque envelopes opened after induction. Postoperative pain

assessments were performed by a blinded investigator.

Anaesthetic and Regional Technique: All children received standardised general anaesthesia. Pre-induction medications included IV midazolam 0.05 mg/kg, glycopyrrolate 4 µg/kg, and ketamine 1 mg/kg. Anaesthesia was induced with IV fentanyl 1 µg/kg and propofol 2–3 mg/kg, and neuromuscular blockade achieved with atracurium 0.5 mg/kg. Anaesthesia was maintained with sevoflurane in 50:50 O₂/Air with intermittent dose of atracurium. The airway was secured with an appropriately sized airway device, and standard ASA monitoring was applied throughout.

Group C-Ultrasound guided Caudal Block: With the child in the left lateral decubitus position, a high frequency linear ultrasound probe (SonoSite HFL 38X/13-6MHz, Fujifilm SonoSite) was held longitudinally over the lower sacrum. The sacrococcygeal ligament and caudal epidural space were identified under real-time ultrasound guidance, and a 22–24 G short-bevel needle was advanced in-plane into the caudal epidural space (Figure 1). The injectate consisted of 0.125% bupivacaine 1 mL/kg with dexmedetomidine 0.5 µg/kg (maximum volume 20 mL).

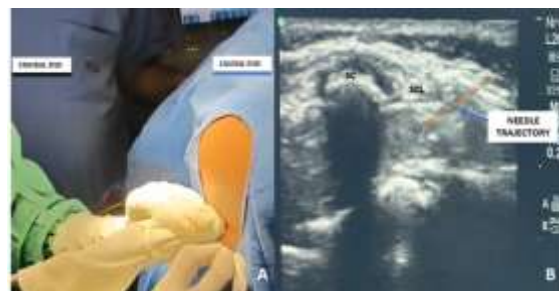


Figure 1: Ultrasound guided caudal block; 1A: Probe and needle orientation showing cranial and caudal end on the patient; 1B: Ultrasound image showing needle trajectory (orange line). Abbreviations-SC, sacral cornua; SCL, sacrococcygeal ligament.

Group Q-Posterior Quadratus Lumborum Block (QLB):

With the child in the lateral decubitus position (operative side uppermost), a high frequency linear ultrasound probe (SonoSite HFL 38X/13-6MHz, Fujifilm SonoSite) was placed in the mid-axillary line cranial to the iliac crest and moved posteriorly until the shamrock sign was identified.^[13] A 22 G cannula-over-needle was advanced to the plane between the posterior quadratus lumborum muscle and the middle layer of the thoracolumbar fascia. [Figure 2] The injectate consisted of 0.125% bupivacaine 0.5 mL/kg with dexmedetomidine 0.5 µg/kg (maximum volume 10 mL).



Figure 2: Posterior Quadratus Lumborum block; 2A: Probe position showing cranial and caudal orientation on the patient; 2B: Ultrasound image showing needle trajectory (blue line). Abbreviations- ESM, erector spinae muscle; QLM, quadratus lumborum muscle; MTLF, middle thoracolumbar fascia.

Intraoperative Monitoring: Haemodynamic parameters were recorded at predefined intervals: baseline, at time of block, at surgical incision, at 5, 10, 15, 30, and 45 minutes after incision.

Block failure was defined as a haemodynamic response (heart rate or mean arterial pressure >20% above baseline) persisting for more than one minute following surgical incision. These patients received supplemental IV fentanyl 1 µg/kg and were excluded from the efficacy analysis.

IV paracetamol 15 mg/kg and ondansetron 0.1 mg/kg were administered to all patients just before skin closure. All children were reversed with neostigmine (50µg/kg), glycopyrrolate (10µg/kg) and extubated at the end of surgery.

Outcome Measures and Pain Assessment: The primary outcome was time to first rescue analgesia. Secondary outcomes included FLACC pain scores at PACU arrival, 15 and 30 minutes in PACU, and at 6, 12, 18, and 24 hours postoperatively; proportion requiring rescue analgesia; total rescue doses; perioperative haemodynamics; and block-related complications. A FLACC score ≥4 prompted rescue analgesia: IV fentanyl 0.5–1 µg/kg in PACU, intravenous paracetamol 15 mg/kg in the ward.^[18]

Sample Size and Statistical Analysis: Sample size was estimated using data from the paediatric RCT by Öksüz et al. ⁽¹⁵⁾, which reported mean time to first rescue analgesia of 16.1 ± 4.47 h (QLB) and 6.7 ± 2.03 h (caudal block) in children undergoing infra-umbilical surgery. Based on a two-sided α of 0.05 and

90% power, a minimum of 5 participants per group was required. To account for block failure and protocol deviations, and to improve precision of secondary outcome estimates, 12 participants were enrolled per group (total n = 24).

Continuous variables were tested for normality using the Shapiro–Wilk test and expressed as mean ± SD or median (IQR) as appropriate. Between-group comparisons were made using the independent-samples t-test or Mann–Whitney U test. Categorical variables were expressed as frequency (percentage) and compared using Fisher's exact test or Chi-square test. Repeated postoperative FLACC pain scores were analysed using repeated-measures ANOVA with Bonferroni correction. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Twenty-four children were enrolled and randomised (12 per group). (Figure 3) One child in each group met the haemodynamic criterion for block failure and was excluded from efficacy analysis, leaving 11 participants per group.

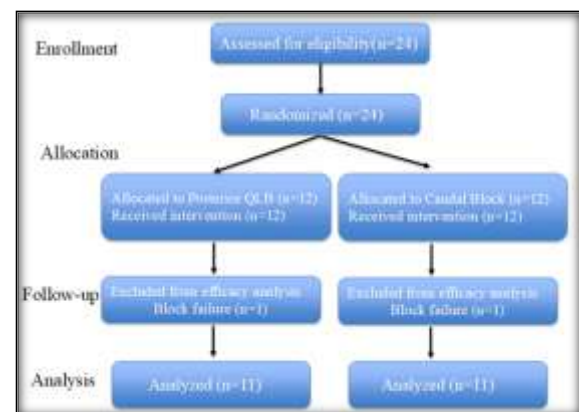


Figure 3: CONSORT 2010 flow diagram of participant enrolment, randomization, allocation, follow-up, and analysis. QLB = quadratus lumborum block. Block failure was defined as a haemodynamic response to surgical incision (>20% increase in heart rate or mean arterial pressure from baseline for >1 minute).

Baseline characteristics were comparable between groups [Table 1].

Table 1: Baseline demographic and operative characteristics

Variable	QLB Group (n=11)	Caudal Group (n=11)	Statistical Test	p Value
Age (years), mean ± SD*	5.1 ± 1.8	3.5 ± 2.5	Mann-Whitney U	0.62
Weight (kg), mean ± SD	18.4 ± 5.2	14.9 ± 6.1	Mann-Whitney U	0.41
Male sex, n (%)	8 (72.7)	7 (63.6)	Fisher exact	0.67
ASA# I / II, n^	7 / 4	8 / 3	Fisher exact	>0.99
Type of surgery				
Inguinal herniorrhaphy	5 (45.5)	4 (36.4)		
Open appendectomy	3 (27.3)	4 (36.4)		
Stoma closure	2 (18.2)	2 (18.2)		
Open orchidopexy	1 (9.1)	1 (9.1)		

*SD, standard deviation; #American Society of Anaesthesiologists; ^Type of surgery expressed as n (%).

Haemodynamic Parameters: No significant differences in heart rate or mean arterial pressure were identified at baseline or at intraoperative time

points between both groups (all p > 0.05). A borderline difference in heart rate was noted at PACU 15 minutes (QLB: 90.9 ± 11.1 vs Caudal: 107.3 ±

18.0 bpm; $p = 0.038$), which was not considered clinically significant as all values remained within 20% of individual baselines and no intervention was required.

Primary Outcome: Time to First Rescue Analgesia: Time to first rescue analgesia was significantly longer in the QLB group (12.00 ± 2.00 h) compared with the caudal group (7.73 ± 1.10 h; $p < 0.001$), representing an approximately 4.3-hour prolongation of analgesia. FLACC scores are presented in Table 2. Mean scores did not differ significantly at PACU arrival or at 15 and 30 minutes in PACU (all $p > 0.05$). At 6 hours, a numerical trend towards lower scores in the QLB group (1.27 ± 0.47 vs 1.55 ± 1.13) did not reach significance ($p = 0.38$). A statistically significant between-group difference was identified at 12 hours (QLB 1.45 ± 0.69 vs Caudal 2.73 ± 0.79 ; $p = 0.002$). At 18 hours, scores were numerically lower in the QLB group (2.27 ± 0.79 vs 2.73 ± 0.65) but did not differ significantly ($p = 0.12$). At 24 hours, data were available for both groups; mean scores were 2.27 ± 0.47 (QLB) and 2.55 ± 0.52 (Caudal), with no significant difference

($p = 0.22$). Within-group analysis showed a significant increase in FLACC scores over 24 hours in both groups ($p < 0.001$ for both), consistent with waning of local anaesthetic effect; the trajectory of increase was attenuated in the QLB group [Figure 4].

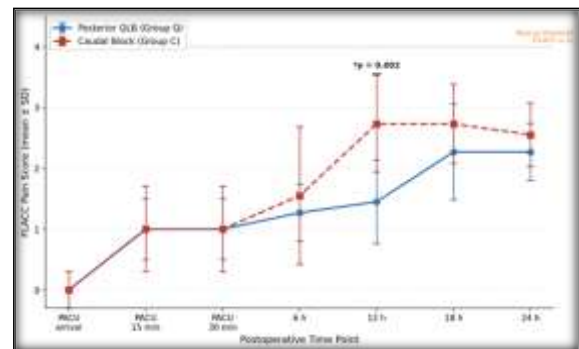


Figure 4: Postoperative FLACC pain scores (mean $\pm$ SD) over 24 hours in the posterior QLB (Group Q) and caudal block (Group C) groups. The orange dotted line indicates the rescue analgesia threshold (FLACC ≥ 4). *Statistically significant between-group difference at 12 h ($p = 0.002$). Error bars represent SD.

Table 2: Postoperative FLACC pain scores (mean $\pm$ SD) by time point and group

Time Point	QLB Mean	QLB SD	Caudal Mean	Caudal SD	p Value†
PACU arrival	0	0–1	0	0–1	>0.99
PACU 15 min	1	0–1	1	0–2	0.41
PACU 30 min	1	0–1	1	0–2	0.33
6 h	1.27	0.47	1.55	1.13	0.38
12 h	1.45	0.69	2.73	0.79	0.002*
18 h	2.27	0.79	2.73	0.65	0.12
24 h	2.27	0.47	2.55	0.52	0.22

SD, standard deviation. †Independent-samples t-test or Mann–Whitney U test. *Statistically significant ($p < 0.05$ after Bonferroni correction).

Secondary Outcomes: Rescue Analgesia: Rescue analgesia was required by 2/11 (18.2%) children in the QLB group compared with 8/11 (72.7%) in the caudal group ($p = 0.03$). Mean rescue doses were

lower in the QLB group (0.18 ± 0.40 vs 1.09 ± 0.94 ; $p = 0.009$). No child experienced FLACC scores ≥ 7 . Data are presented in [Table 3].

Table 3: Rescue analgesia requirement during the 24-hour postoperative period

Parameter	QLB Group (n=11)	Caudal Group (n=11)	p Value‡
Rescue analgesia required, n (%)	2 (18.2)	8 (72.7)	0.03
Rescue fentanyl in PACU, n (%)	1 (9.1)	4 (36.4)	0.17
Rescue paracetamol in ward, n (%)	1 (9.1)	7 (63.6)	0.01
Time to first rescue analgesia (h), mean $\pm$ SD	12.00 $\pm$ 2.00	7.73 $\pm$ 1.10	<0.001
Total rescue doses, mean $\pm$ SD	0.18 $\pm$ 0.40	1.09 $\pm$ 0.94	0.009

SD, standard deviation. ‡Fisher's exact test (categorical) or Mann–Whitney U / t-test (continuous). PACU, post-anaesthesia care unit.

Block Failure and Complications: Block failure occurred in one child per group (8.3% each). No procedural complications including local anaesthetic systemic toxicity, haematoma, neurological deficit, or inadvertent vascular puncture were observed in either group.

DISCUSSION

This RCT demonstrates that ultrasound-guided posterior QLB provides significantly more prolonged

postoperative analgesia than caudal block in children aged 6months–8 years undergoing infra-umbilical surgery. The primary outcome, time to first rescue analgesia was approximately^[4,3] hours longer with QLB (12.00 ± 2.00 h vs 7.73 ± 1.10 h; $p < 0.001$), and rescue analgesia was required in only 18.2% vs 72.7% of children. The between-group difference in FLACC scores was most pronounced at 12 hours; by 18 and 24 hours, scores converged without statistically significant differences, reflecting waning of both blocks. Early analgesia and perioperative

haemodynamics were equivalent. No block-related complications occurred in either group.

Caudal block achieves analgesia by depositing local anaesthetic in the epidural space, where it diffuses cephalad to block sacral and lumbar spinal nerve roots.^[6] However, systemic absorption, CSF dilution, and redistribution curtail effective analgesia to four to eight hours for plain bupivacaine.^[8,9] Even with dexmedetomidine as adjuvant—which prolongs block duration by three to four hours via neuronal hyperpolarisation.^[10,11] The mean time to first rescue analgesia in the caudal group of 7.73 hours confirms that block recession was well underway within the first eight to ten hours.

Posterior QLB targets the thoracolumbar fascial plane posterior to the QL muscle. Cadaveric and MRI studies consistently demonstrate that injectate spreads medially into the paravertebral space, contacting the dorsal and ventral rami of thoracolumbar spinal nerves (T10–L1) and grey rami communicantes carrying sympathetic visceral afferents.^[13,14] This dual somatic-visceral coverage, combined with the limited vascularity of the thoracolumbar fascia that retards systemic absorption, likely accounts for the extended analgesic duration observed in our QLB group.

Öksüz et al. conducted the first paediatric RCT directly comparing QLB with caudal block in children undergoing inguinal hernia repair and orchiopexy and reported significantly lower postoperative analgesic requirement over 24 hours in the QLB group, with a rescue analgesia rate of 20% vs 73.3%—proportions strikingly concordant with our 18.2% and 72.7%.^[15] Similarly, Aksu et al. reported significantly lower pain scores and analgesic consumption over 24 hours with posterior QLB versus caudal block in 60 children undergoing inguinal herniorrhaphy, with no difference in haemodynamic parameters or complications.^[16] In the paediatric literature, a meta-analysis encompassing^[16] RCTs confirmed that QLB significantly reduced the need for rescue analgesia at both 12 and 24 hours postoperatively, and lowered FLACC pain scores compared with conventional analgesic techniques.^[20] The convergence of adult and paediatric evidence supports a genuine pharmacological advantage of the posterior approach.

Dexmedetomidine was standardised across both groups to ensure any between-group analgesic difference reflected technique rather than pharmacological confounding. The sustained superiority of QLB despite adjuvant use in the caudal group reinforces the mechanistic hypothesis of paravertebral spread.

QLB reduces rescue analgesia, lowering opioid use and related side effects, especially important in paediatric day-surgery settings.^[4,5] The similar safety profiles of both techniques confirm that QLB is safe and feasible in young children when done by a trained anaesthesiologist using ultrasound guidance.

Posterior QLB avoids complications of caudal block such as dural puncture, epidural haematoma, and urinary retention. However, it requires familiarity with the shamrock sign. The 8.3% block failure rate in each group aligns with reported paediatric success rates of 90–97%.^[15,16]

A novel aspect of this study is using low-dose bupivacaine (0.125%) with a reduced dexmedetomidine dose (0.5 µg/kg) in both groups. Most studies use higher bupivacaine concentrations (0.2–0.25%), risking systemic toxicity and motor block, and higher dexmedetomidine doses (1–2 µg/kg), associated with sedation and haemodynamic instability.^[11,21,22]

Analgesic superiority of QLB at these low doses highlights the efficiency of the thoracolumbar fascial plane as a drug depot, suggesting that correct block placement matters more than high drug concentrations.

To our knowledge, this is the first RCT comparing caudal block and posterior QLB in children using 0.125% bupivacaine with dexmedetomidine 0.5 µg/kg, confirming effective analgesia at this minimal dose combination.

This study used a prospective randomised design with allocation concealment, blinded outcome assessment, a standardised anaesthetic protocol, a validated pain scale, and comprehensive haemodynamic monitoring. However, we observed certain limitations; The small sample size ($n = 11$ per group) limits statistical power for secondary outcomes and prevents subgroup analyses by age, weight, or procedure type. Being a single-centre study, selection bias and limited generalisability are acknowledged. Sensory dermatomal mapping was not performed, and outcomes beyond 24 hours were not assessed. Blinding of the performing anaesthesiologist was not feasible, though outcome assessors remained blinded.

Larger multicentre RCTs, dose-optimisation studies, and health economic analyses are needed to confirm these findings and guide clinical practice.

CONCLUSION

Ultrasound-guided posterior quadratus lumborum block provides superior and significantly more prolonged postoperative analgesia compared with ultrasound-guided caudal epidural block in children undergoing elective lower abdominal surgery. Time to first rescue analgesia was approximately 4.3 hours longer with posterior QLB (12.00 ± 2.00 h vs 7.73 ± 1.10 h; $p < 0.001$), and the rescue analgesia requirement was markedly lower (18.2% vs 72.7%). Both techniques demonstrated equivalent haemodynamic stability and a favourable safety profile. These findings support consideration of posterior QLB as a potentially effective alternative to caudal block in paediatric infra-umbilical surgery, particularly within enhanced recovery and

ambulatory programmes, subject to appropriate operator training and ultrasound expertise.

Acknowledgements: The authors thank the nursing and technical staff of the Department of Paediatric Anaesthesia and the Post-Anaesthesia Care Unit for their support during data collection. No external funding was received for this study.

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