Section: Anaesthesia

Original Research Article

ANALGESIC BENEFITS OF CAUDAL DEXMEDETOMIDINE WITH BUPIVACAINE IN CHILDREN UNDERGOING INFRA-UMBILICAL PROCEDURES

Anil Kumar LN[1], Aroma Raghav[2], Shikha Chahar[3]

[1]Department of Anaesthesia, Seth GS Medical College and KEM Hospital, Mumbai, India.
[2]Associate Consultant, Fortis Hospital, Manesar, Haryana, India.
[3]Assistant Professor, Department of Anaesthesia, NDMC Medical College and Hindu Rao Hospital, Delhi, India.

Received : 29/10/2025
Received in revised form : 12/12/2025
Accepted : 31/12/2025

Keywords:
Dexmedetomidine; Bupivacaine; Caudal block; Infra-umbilical surgery; Emergence agitation.

Corresponding Author:
Dr. Anil Kumar LN,
Email: anilkumarln92@gmail.com

DOI: 10.47009/jamp.2026.8.1.6

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (1); 27-33

ABSTRACT

Background: Optimal postoperative analgesia is essential in pediatric infra-umbilical surgeries, and caudal epidural block with bupivacaine is widely used but limited by relatively short analgesic duration. Dexmedetomidine, a highly selective α2-agonist, has emerged as a promising adjuvant to enhance and prolong caudal analgesia in children. This study aimed to evaluate the efficacy and safety of dexmedetomidine added to caudal bupivacaine in children undergoing elective infra-umbilical surgeries. **Materials and Methods:** This prospective, randomized, double-blind study included 137 children aged 1–8 years (ASA I–II) scheduled for elective infra-umbilical surgeries. Participants were randomized into two groups: Group B (n = 68) received 0.25% bupivacaine (1 mL/kg), and Group BD (n = 69) received bupivacaine with dexmedetomidine 1 µg/kg via the caudal route. Standardized anesthesia was administered, and postoperative outcomes were assessed using the FLACC pain scale. Primary outcome was duration of analgesia. Secondary outcomes included postoperative pain scores, rescue analgesic requirements, intraoperative stability, sedation, adverse events, and recovery characteristics. **Result:** Baseline demographic and surgical characteristics were comparable between groups. The mean duration of analgesia was significantly longer in Group BD (9.2 ± 2.8 hours) compared with Group B (3.9 ± 1.1 hours; $p < 0.001$). Time to first rescue analgesic was significantly prolonged (median 9 vs. 4 hours; $p < 0.001$), and rescue paracetamol requirements were markedly reduced in Group BD (median 0 vs. 2 doses; $p < 0.001$). Postoperative FLACC pain scores were consistently lower from 2 to 12 hours in the dexmedetomidine group ($p < 0.001$). While the incidence of excessive sedation was higher in Group BD (11.6% vs. 2.9%; $p = 0.046$), no respiratory depression occurred. Emergence agitation was significantly reduced with dexmedetomidine (2.9% vs. 13.2%; $p = 0.018$), and recovery profiles remained comparable. **Conclusion:** Dexmedetomidine significantly enhances caudal bupivacaine analgesia by prolonging postoperative pain relief, reducing analgesic requirements, lowering pain scores, and minimizing emergence agitation, with only a modest increase in clinically manageable sedation. It represents an effective and safe adjuvant for caudal anesthesia in pediatric infra-umbilical surgeries.

INTRODUCTION

Effective perioperative analgesia is a critical component of pediatric anesthesia, particularly for infra-umbilical surgeries such as herniotomy, orchidopexy, hypospadias repair, and lower limb procedures. Inadequately managed postoperative pain in children is associated with adverse physiological responses including tachycardia, hypertension, poor oral intake, and delayed mobilization as well as long-term behavioural consequences such as anxiety and needle fear.[1,2] Regional anesthesia, especially caudal epidural block, remains one of the most widely practiced techniques for providing intra- and postoperative analgesia in children due to its simplicity, reliability, and favourable safety profile.[3]

Caudal epidural anesthesia using local anesthetics such as bupivacaine has been used for decades. A standard caudal dose of bupivacaine (0.125–0.25%)

provides 3–4 hours of postoperative analgesia in most pediatric patients.[4] However, its duration is often insufficient for modern day-care and short-stay pediatric surgeries, prompting the search for safe adjuvants that can prolong analgesia without increasing complications such as motor block, urinary retention, or respiratory depression.[5] Various adjuvants including opioids (morphine, fentanyl), ketamine, midazolam, clonidine, and α2-agonists have been studied with mixed efficacy and varying safety concerns.[6] Notably, opioids, while effective, may cause nausea, vomiting, pruritus, and respiratory depression, limiting their use in the pediatric population.[7] Thus, the need persists for an ideal adjuvant that prolongs analgesia with minimal adverse effects.

Dexmedetomidine, a highly selective α2-adrenergic receptor agonist with an α2:α1 selectivity ratio of 1620:1, has gained attention as a promising adjuvant in regional anesthesia owing to its sedative, analgesic, and sympatholytic properties without significant respiratory depression.[8] Its mechanism of action includes suppression of nociceptive neurotransmission at the dorsal horn, enhancement of descending inhibitory pain pathways, and reduction of sympathetic outflow.[9] When used in neuraxial blocks, dexmedetomidine has shown to prolong sensory blockade, improve postoperative analgesia, and provide smoother recovery profiles.[10]

Emerging evidence suggests that caudal dexmedetomidine, in doses ranging from 1–2 µg/kg, added to bupivacaine significantly extends analgesia duration from a typical 3–4 hours with bupivacaine alone to 6–10 hours in several pediatric trials—without major hemodynamic instability or excessive sedation.[11,12] A meta-analysis reported that dexmedetomidine improved postoperative pain scores, decreased rescue analgesic requirements by nearly 40%, and reduced emergence agitation, while maintaining an acceptable safety profile.[13] However, concerns remain regarding bradycardia, hypotension, and prolonged sedation, particularly at doses >2 µg/kg, highlighting the need for further well-designed studies to define the optimal dose–response profile.[14]

Despite an increasing number of studies, heterogeneity persists regarding patient age groups, surgical procedures, dosing regimens, and pain assessment methods. Additionally, existing literature from Indian pediatric populations is limited, despite the widespread use of caudal epidural anesthesia in routine practice. Therefore, further research is warranted to evaluate the efficacy, duration of analgesia, hemodynamic profile, and safety of dexmedetomidine as an adjuvant to bupivacaine in children undergoing infra-umbilical surgeries.

The present study aims to address these gaps by systematically assessing the analgesic efficacy and safety outcomes of dexmedetomidine–bupivacaine combination administered via the caudal route in pediatric patients undergoing elective infra-umbilical surgeries.

MATERIALS AND METHODS

Study Design and Setting

This prospective study was conducted in the Department of Anaesthesiology at a tertiary care teaching institution, over a period of 12 months from July 2021 to June 2022 . Approval was obtained from the Institutional Ethics Committee prior to study initiation. Written informed consent was obtained from parents or legal guardians of all participating children.

Study Population

Children aged 1 to 8 years, belonging to the American Society of Anesthesiologists (ASA) physical status I–II and scheduled for elective infra-umbilical surgical procedures such as herniotomy, orchidopexy, circumcision, hypospadias repair, and lower limb orthopedic procedures, were eligible for inclusion. Children with known hypersensitivity to study drugs, congenital spinal deformities, coagulopathy, local infection at caudal region, neurological disorders, developmental delay, pre-existing cardiac conduction abnormalities, or those receiving α2-agonists, opioids, or anticonvulsants were excluded. Children in whom caudal block could not be successfully administered were also excluded from analysis.

Sample Size Calculation

The sample size was calculated based on the expected prolongation of postoperative analgesia with caudal dexmedetomidine. Assuming a mean difference of at least 2 hours in duration of analgesia between groups, a standard deviation of 3 hours, a power of 80%, and an alpha error of 0.05, the minimum required sample size was estimated as 62 participants per group. To account for possible dropouts or block failures, a total of 137 children were recruited and randomized.

Randomization and Blinding

Participants were randomly allocated into two groups using a computer-generated randomization sequence placed in sealed, opaque envelopes. Group B received caudal bupivacaine alone, while Group BD received bupivacaine with dexmedetomidine. An independent anesthesiologist, not involved in patient care or postoperative assessment, prepared all study drug solutions in identical syringes to ensure blinding. Both the anesthesiologist performing the block and the observer collecting intraoperative and postoperative data were blinded to group allocation.

Anesthesia Technique

All children were kept fasting as per standard pediatric fasting guidelines. In the operating theatre, baseline heart rate, oxygen saturation, and non-invasive blood pressure were recorded. General anesthesia was induced using intravenous propofol (2–3 mg/kg) or inhalational sevoflurane through a facemask, followed by securing an appropriately sized laryngeal mask airway or endotracheal tube based on institutional protocols. After induction and positioning in the left lateral decubitus posture, the

ISSN (O): 2687-5365; ISSN (P): 2753-6556

caudal block was performed under strict aseptic precautions using a 22-gauge short-bevel needle introduced through the sacral hiatus.

Children in Group B received 0.25% bupivacaine at a dose of 1 mL/kg, whereas those in Group BD received 0.25% bupivacaine 1 mL/kg combined with dexmedetomidine 1 µg/kg. The total volume remained constant in both groups. Correct needle placement was confirmed by the characteristic loss of resistance and absence of blood or cerebrospinal fluid aspiration before drug injection. No additional analgesic or sedative was administered caudally.

Intraoperative Monitoring and Management

Standard monitoring including ECG, pulse oximetry, capnography, and non-invasive blood pressure was maintained throughout surgery. Hemodynamic parameters were noted at baseline, after induction, after caudal block, and subsequently at 5-minute intervals for the first 15 minutes and every 10 minutes thereafter. A decrease in heart rate or mean arterial pressure by >20% of baseline was treated as bradycardia (managed with atropine 0.02 mg/kg) or hypotension (managed with intravenous fluids or ephedrine as needed). Intraoperative analgesia was considered inadequate if heart rate or blood pressure increased by >20% from baseline, and fentanyl 1 µg/kg was administered as rescue analgesia. Total anesthesia duration and intraoperative complications were recorded.

Postoperative Assessment

Children were shifted to the post-anesthesia care unit (PACU) for continuous monitoring. Postoperative pain was assessed using an age-appropriate validated scale such as the FLACC (Face–Legs–Activity–Cry–Consolability) score at 30-minute intervals for the first 2 hours and hourly thereafter until 12 hours or until pain required intervention. The duration of analgesia, the primary outcome, was defined as the time from caudal drug administration to the first FLACC score ≥4, at which point paracetamol (15 mg/kg IV/oral) was given as rescue analgesic. Sedation was evaluated using the Ramsay Sedation Scale at similar intervals. Hemodynamic parameters, emergence agitation, nausea, vomiting, urinary retention, pruritus, and any episodes of bradycardia or hypotension were documented. Total rescue analgesic consumption in the first 12 or 24 hours was calculated.

Outcome Measures

The primary outcome measure was the duration of postoperative analgesia. Secondary outcomes included intraoperative hemodynamic stability, need for intraoperative rescue analgesia, postoperative pain scores at predefined intervals, sedation scores, number of rescue analgesic doses, time to first rescue analgesic, and incidence of adverse effects such as bradycardia, hypotension, vomiting, urinary retention, respiratory events, and delayed recovery.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on normality assessed by the Kolmogorov–Smirnov test. Comparisons between the two groups were performed using the independent t-test or Mann–Whitney U-test as appropriate. Categorical variables were analyzed using the Chi-square test or Fisher's exact test. A p-value <0.05 was considered statistically significant.

RESULTS

The two groups were comparable with respect to demographic and preoperative clinical characteristics. The mean age (4.2 ± 1.8 vs. 4.0 ± 1.7 years; p = 0.448) and mean weight (14.5 ± 3.2 vs. 14.2 ± 3.1 kg; p = 0.512) did not differ significantly between Group B and Group BD. The distribution of gender was similar, with males comprising 72.1% and 69.6% respectively (p = 0.788). ASA physical status (I/II) was also comparable between the groups (p = 0.702). The types of infra-umbilical surgeries (herniotomy, orchidopexy, circumcision, hypospadias/penile procedures, and lower limb/other surgeries) were evenly distributed (p = 0.951), confirming that both groups were well matched at baseline without any statistically significant differences. [Table 1]

Table 1: Baseline demographic and clinical characteristics

Variable	Group B (n = 68)	Group BD (n = 69)	p-value
	Frequency (%)/mean ± SD		
Age (years)	4.2 ± 1.8	4.0 ± 1.7	0.448
Weight (kg)	14.5 ± 3.2	14.2 ± 3.1	0.512
Gender			
Female	19 (27.9%)	21 (30.1%)	0.788
Male	49 (72.1%)	48 (69.6%)	
ASA			
I	58 (85.3%)	57 (82.6%)	0.702
II	10 (14.7%)	12 (17.4%)	
Type of surgery			
Herniotomy	27 (39.7%)	29 (42.0%)	0.951
Orchidopexy	17 (25.0%)	16 (23.2%)	
Circumcision	10 (14.7%)	9 (13.0%)	
Hypospadias / penile	3 (4.4%)	4 (5.8%)	
Lower limb ortho / others	11 (16.2%)	11 (15.9%)	

ASA – American Society of Anesthesiologists.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Intraoperative parameters and block characteristics were comparable between the groups. The duration of surgery (45.8 ± 15.4 vs. 47.4 ± 14.3 minutes; p = 0.367) and duration of anesthesia (62.9 ± 18.1 vs. 64.8 ± 17.4 minutes; p = 0.446) showed no significant difference. Single-attempt caudal block success was high and almost identical (92.6% vs. 92.8%; p = 0.983). Although intraoperative rescue fentanyl requirements were lower in Group BD (8.7% vs. 14.7%), the difference was not statistically significant (p = 0.271). The incidence of intraoperative bradycardia and hypotension remained very low in both groups, with no significant differences (p > 0.05). [Table 2]

Table 2: Intraoperative variables and immediate block performance

Variable	Group B (n = 68)	Group BD (n = 69)	p-value
	Frequency (%)/mean ± SD		
Duration of surgery (min)	45.8 ± 15.4	47.4 ± 14.3	0.367
Duration of anesthesia (min)	62.9 ± 18.1	64.8 ± 17.4	0.446
Successful single-attempt caudal	63 (92.6%)	64 (92.8%)	0.983
Intraop rescue fentanyl required (≥1 dose)	10 (14.7%)	6 (8.7%)	0.271
Intraop bradycardia (requiring treatment)	1 (1.5%)	2 (2.9%)	0.625
Intraop hypotension (requiring treatment)	0 (0.0%)	1 (1.4%)	0.322

Intraop – Intraoperative.

Group BD demonstrated a markedly superior analgesic profile compared to Group B. The mean duration of analgesia was more than doubled with dexmedetomidine (9.2 ± 2.8 vs. 3.9 ± 1.1 hours; p < 0.001). The time to first rescue analgesic was significantly prolonged (median 9 [7–12] vs. 4 [3–5] hours; p < 0.001). Children in Group BD required substantially fewer rescue paracetamol doses within 24 hours (median 0 [0–1] vs. 2 [1–3]; p < 0.001), and the overall proportion requiring any rescue analgesia was dramatically lower (30.4% vs. 82.4%; p < 0.001). Total paracetamol consumption was correspondingly reduced (12.6 ± 10.6 vs. 45.7 ± 18.4 mg/kg; p < 0.001). [Table 3]

Table 3: Primary and key secondary analgesic outcomes

Outcome	Group B (n = 68)	Group BD (n = 69)	p-value
	Frequency (%)/mean ± SD/median (IQR)		
Duration of analgesia (hours)	3.9 ± 1.1	9.2 ± 2.8	<0.001
Time to first rescue analgesic (hours)	4 (3–5)	9 (7–12)	<0.001
Number of rescue paracetamol doses in 24 h	2 (1–3)	0 (0–1)	<0.001
Proportion needing any rescue analgesic in 24 h	56 (82.4%)	21 (30.4%)	<0.001
Total paracetamol consumption in 24 h (mg/kg)	45.7 ± 18.4	12.6 ± 10.6	<0.001

IQR – Interquartile range.

Postoperative pain scores were consistently and significantly lower in Group BD after the first hour of recovery. While FLACC scores at 1 hour were similar in both groups (p = 0.625), pain scores diverged thereafter, with Group BD showing lower median scores at 2 hours (p = 0.003), 4 hours, 6 hours, 8 hours, and 12 hours (all p < 0.001). Notably, pain scores in Group B rose steadily from 4 to 8 hours, whereas Group BD maintained minimal pain throughout this period. [Table 4]

Table 4: Postoperative FLACC pain scores at prespecified times

Time after caudal	Group B (n = 68)	Group BD (n = 69)	p-value
	median (IQR)		
1 hour	0 (0–1)	0 (0–1)	0.625
2 hours	1 (0–2)	0 (0–1)	0.003
4 hours	3 (2–4)	1 (0–2)	<0.001
6 hours	4 (3–5)	1 (0–2)	<0.001
8 hours	4 (3–5)	2 (1–3)	<0.001
12 hours	3 (2–4)	1 (0–2)	<0.001

FLACC – Face–Legs–Activity–Cry–Consolability; IQR – Interquartile range.

The incidence of adverse events was low in both groups. Bradycardia occurred more frequently in Group BD (7.2% vs. 1.5%), though the difference did not reach statistical significance (p = 0.094). Hypotension was rare and comparable across groups (p = 0.247). Excessive sedation (Ramsay Sedation Score >3) was significantly higher in the dexmedetomidine group (11.6% vs. 2.9%; p = 0.046), although all cases were transient and clinically manageable. Rates of postoperative nausea/vomiting were similar (p = 0.499), and no child in either group developed urinary retention or respiratory depression (RR <10/min or SpO_2 <92%). [Table 5]

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Table 5: Adverse events and sedation

Event	Group B (n = 68)	Group BD (n = 69)	p-value
	Frequency (%)		
Bradycardia (HR drop requiring atropine)	1 (1.5%)	5 (7.2%)	0.094
Hypotension (treated)	0 (0.0%)	2 (2.9%)	0.247
Excessive sedation (Ramsay >3)	2 (2.9%)	8 (11.6%)	0.046
Nausea / vomiting	6 (8.8%)	4 (5.8%)	0.499
Urinary retention	0 (0.0%)	0 (0.0%)	—
Respiratory depression (RR <10 or desat <92%)	0 (0.0%)	0 (0.0%)	—

HR – Heart rate; RR – Respiratory rate.

The incidence of adverse events was low in both groups. Bradycardia occurred more frequently in Group BD (7.2% vs. 1.5%), though the difference did not reach statistical significance ($p = 0.094$). Hypotension was rare and comparable across groups ($p = 0.247$). Excessive sedation (Ramsay Sedation Score >3) was significantly higher in the dexmedetomidine group (11.6% vs. 2.9%; $p = 0.046$), although all cases were transient and clinically manageable. Rates of postoperative nausea/vomiting were similar ($p = 0.499$), and no child in either group developed urinary retention or respiratory depression (RR <10/min or SpO_2 <92%). [Table 6]

Table 6: Recovery and discharge parameters

Outcome	Group B (n = 68)	Group BD (n = 69)	p-value
	Frequency (%)/mean ± SD		
Emergence agitation	9 (13.2%)	2 (2.9%)	0.018
Time in PACU (hours)	2.1 ± 0.8	2.4 ± 1.0	0.078
Readmission / unexpected overnight stay	3 (4.4%)	2 (2.9%)	0.663
Parental satisfaction (satisfied/very satisfied)	52 (76.5%)	60 (87.0%)	0.101

PACU – Post-Anesthesia Care Unit.

DISCUSSION

In this randomized controlled study evaluating the efficacy of dexmedetomidine as an adjuvant to caudal bupivacaine in children undergoing elective infra-umbilical surgeries, we observed a significant enhancement in postoperative analgesia, reduced analgesic requirement, superior pain scores, and a favourable recovery profile, with only a modest increase in sedation. Both groups were comparable at baseline, as demonstrated by the absence of statistically significant differences in demographic variables, ASA classification, and distribution of surgical procedures. This homogeneity ensured that the analgesic and recovery outcomes could be attributed primarily to the pharmacological intervention rather than confounding factors.

Dexmedetomidine significantly prolonged the duration of postoperative analgesia compared to bupivacaine alone, with the mean duration increasing from 3.9 ± 1.1 hours to 9.2 ± 2.8 hours ($p < 0.001$). This nearly 2.5-fold extension aligns with previous studies demonstrating the analgesic potentiation of dexmedetomidine when used caudally. Oruobu-Nwogu et al., reported a similar prolongation from 5 to 10 hours with 2 µg/kg dexmedetomidine added to bupivacaine,[15] while Goyal et al., documented prolonged analgesia extending to 8–10 hours in Indian pediatric populations.[16] The mechanism is likely due to the high α2-adrenergic selectivity of dexmedetomidine, which inhibits nociceptive transmission at the dorsal horn, enhances hyperpolarization of interneurons, and reduces sympathetic outflow, thereby modulating both central and peripheral pain pathways.[16,17,18]

The time to first rescue analgesia in our study was significantly delayed in the dexmedetomidine group (median 9 vs. 4 hours; $p < 0.001$), consistent with findings by Salama et al., and Xu et al., they observed delayed analgesic demand and reduced postoperative analgesic consumption with 1–2 µg/kg caudal dexmedetomidine.[18,19] In our study, the proportion of children requiring any rescue analgesic in the first 24 hours decreased dramatically from 82.4% in Group B to 30.4% in Group BD ($p < 0.001$). This robust reduction in analgesic requirement is clinically relevant in pediatric practice as it minimizes opioid and paracetamol exposure, reduces nursing interventions, and improves overall patient comfort.[20] Total paracetamol consumption, reduced by nearly 70% in the dexmedetomidine group (12.6 ± 10.6 vs. 45.7 ± 18.4 mg/kg; $p < 0.001$), further corroborates the superior analgesic efficacy observed in studies by Elfawal et al., and Shah et al.[20,21]

Postoperative pain scores assessed using the FLACC scale also demonstrated consistently lower values in the dexmedetomidine group from 2 to 12 hours postoperatively. The difference became significant as early as 2 hours ($p = 0.003$) and was highly significant thereafter ($p < 0.001$). These results mirror studies by Singh et al., and Al-Zaben et al., who reported significantly lower FLACC scores up to 8–10 hours postoperatively with caudal dexmedetomidine.[22,23] The sustained analgesic effect observed in our study supports the hypothesis that dexmedetomidine prolongs both sensory blockade and central analgesic modulation.[23]

Importantly, dexmedetomidine did not compromise intraoperative hemodynamic stability. Intraoperative bradycardia and hypotension were infrequent and

ISSN (O): 2687-5365; ISSN (P): 2753-6556

comparable between groups, consistent with literature indicating that low-dose caudal dexmedetomidine maintains cardiovascular stability.[24] Although intraoperative fentanyl rescue was less frequently required in the dexmedetomidine group (8.7% vs. 14.7%), this difference did not reach statistical significance, possibly due to limited sample size or the modest nociceptive stimulus of the included surgical procedures.[25]

In terms of adverse effects, excessive sedation (Ramsay >3) was significantly higher in the dexmedetomidine group (11.6% vs. 2.9%; p = 0.046). However, all episodes were transient and clinically manageable. This finding aligns with reports from Senthamizh et al., and Sneha et al., who observed mild-to-moderate sedation with similar dosing but without respiratory compromise.[26,27] The absence of respiratory depression in any child in our study further reinforces the respiratory safety of dexmedetomidine, which is a well-known advantage of α2-agonists compared to opioids.[28]

A notable finding was the significantly lower incidence of emergence agitation in Group BD (2.9% vs. 13.2%; p = 0.018). Dexmedetomidine is recognised for producing smoother emergence by modulating central sympathetic activity and reducing anesthetic excitatory responses. Previous pediatric studies, including those by Yadav et al., and Singh et al., have similarly reported reduced emergence agitation and improved recovery profiles with dexmedetomidine.[22,28] Although the PACU stay was slightly longer in the dexmedetomidine group (2.4 ± 1.0 hours vs. 2.1 ± 0.8 hours; p = 0.078), this difference was not clinically significant and did not affect discharge or unplanned admissions. Parental satisfaction scores, though not statistically different, were higher in the dexmedetomidine group (87.0% vs. 76.5%), likely reflecting improved postoperative comfort and calmer recovery.[29]

Physiologically, the augmentation of caudal analgesia by dexmedetomidine may be attributed to several mechanisms inhibition of C-fiber neurotransmitter release, potentiation of local anesthetic effects via hyperpolarization of dorsal horn neurons, central sympatholysis reducing stress responses, and anti-inflammatory effects contributing to prolonged analgesia.[30,31] The consistency of our results with these known pharmacodynamic properties strengthens their validity.

Limitations

This study has some limitations. The use of a single dose of dexmedetomidine precludes evaluation of dose–response relationships, and the optimal dose for balancing analgesia and sedation could not be determined. Despite blinding, observer bias in sedation and behavioral assessments cannot be fully excluded. The follow-up period was limited to the first 24 postoperative hours; long-term behavioral outcomes, late adverse effects, or delayed analgesic needs were not assessed. Additionally, although the overall sample size was adequate, the study may have been underpowered to detect rare adverse events such as significant bradycardia or hypotension. Finally, being a single-center study may limit the external validity across diverse healthcare settings with varying anesthetic practices.

CONCLUSION

The addition of dexmedetomidine to caudal bupivacaine in children undergoing elective infra-umbilical surgeries significantly improves the quality and duration of postoperative analgesia compared to bupivacaine alone. Dexmedetomidine prolonged analgesia by more than twofold, reduced postoperative pain scores, markedly decreased rescue analgesic requirements, and lowered the incidence of emergence agitation without compromising intraoperative hemodynamic stability or respiratory function. Although a slightly higher incidence of transient sedation was observed, it remained clinically manageable and did not affect discharge readiness or overall recovery. These findings support the safe and effective use of dexmedetomidine as an adjuvant in pediatric caudal anesthesia and highlight its potential to enhance postoperative comfort and parental satisfaction in day-care and short-stay pediatric surgical settings.

REFERENCES

1. Ponde V. Recent trends in paediatric regional anaesthesia. Indian J Anaesth. 2019;63(9):746-753.
2. Kendall MC, Alves LJC, Suh EI, McCormick ZL, De Oliveira GS. Regional anesthesia to ameliorate postoperative analgesia outcomes in pediatric surgical patients: an updated systematic review of randomized controlled trials. Local Reg Anesth. 2018;11:91-109.
3. Wiegele M, Marhofer P, Lönnqvist PA. Caudal epidural blocks in paediatric patients: a review and practical considerations. Br J Anaesth. 2019;122(4):509-517.
4. Parameswari A, Dhev AM, Vakamudi M. Efficacy of clonidine as an adjuvant to bupivacaine for caudal analgesia in children undergoing sub-umbilical surgery. Indian J Anaesth. 2010;54(5):458-463.
5. Cettler M, Zielińska M, Rosada-Kurasińska J, et al. Guidelines for treatment of acute pain in children - the consensus statement of the Section of Paediatric Anaesthesiology and Intensive Therapy of the Polish Society of Anaesthesiology and Intensive Therapy. Anaesthesiol Intensive Ther. 2022;54(3):197-218.
6. Swain A, Nag DS, Sahu S, Samaddar DP. Adjuvants to local anesthetics: Current understanding and future trends. World J Clin Cases. 2017;5(8):307-323.
7. Lima LS, Costa NSD, Galiciolli MEA, et al. Harmful Effects of Prescribed Opioids in Children and Adults: A Systematic Review. Pharmaceuticals (Basel). 2025;18(10):1429.
8. Halaszynski TM. Dexmedetomidine: A look at a promising new avenue of use. Saudi J Anaesth. 2012;6(2):104-106.
9. Zhao Y, He J, Yu N, Jia C, Wang S. Mechanisms of Dexmedetomidine in Neuropathic Pain. Front Neurosci. 2020;14:330.
10. Grewal A. Dexmedetomidine: New avenues. J Anaesthesiol Clin Pharmacol. 2011;27(3):297-302.
11. Tu Z, Tan X, Li S, Cui J. The Efficacy and Safety of Dexmedetomidine Combined with Bupivacaine on Caudal Epidural Block in Children: A Meta-Analysis. Med Sci Monit. 2019;25:165-173.
12. Azemati S, Pourali A, Aghazadeh S. Effects of adding dexmedetomidine to local infiltration of bupivacaine on

ISSN (O): 2687-5365; ISSN (P): 2753-6556

postoperative pain in pediatric herniorrhaphy: a randomized clinical trial. Korean J Anesthesiol. 2020;73(3):212-218.
13. Zhu M, Wang H, Zhu A, Niu K, Wang G. Meta-analysis of dexmedetomidine on emergence agitation and recovery profiles in children after sevoflurane anesthesia: different administration and different dosage. PLoS One. 2015;10(4):e0123728.
14. Chan KJ, Bolisetty S. Dexmedetomidine: Shifting Paradigms in Neonatal Sedation and Pain Control. Children (Basel). 2025;12(4):444.
15. Oruobu-Nwogu A, Aggo AT, Johnson UU. Analgesic effects of caudal dexmedetomidine versus midazolam combined with bupivacaine on postoperative pain following paediatric infraumbilical surgeries. Int J Res Med Sci. 2022;10(9):1865-1871.
16. Goyal V, Kubre J, Radhakrishnan K. Dexmedetomidine as an adjuvant to bupivacaine in caudal analgesia in children. Anaesth Essays Res. 2016;10:227-32.
17. Brouwer BA, Merkies IS, Gerrits MM, Waxman SG, Hoeijmakers JG, Faber CG. Painful neuropathies: the emerging role of sodium channelopathies. J Peripher Nerv Syst. 2014;19(2):53-65.
18. Salama AK, Galente D, Abdallah NM. Comparison between caudal dexmedetomidine and nalbuphine in children undergoing hypospadias surgery: a prospective randomized double blind controlled study. Pediatr Anesth Crit Care J. 2016;4(1):48-54.
19. Xu D, Xiu M, Zhang X, et al. Effect of dexmedetomidine added to ropivacaine for caudal anaesthesia in patients undergoing hemorrhoidectomy. Medicine. 2018;97(34):e11731.
20. Elfawal SM, Abdelaal WA, Hosny MR. A comparative study of dexmedetomidine and fentanyl as adjuvants to levobupivacaine for caudal analgesia in children undergoing lower limb orthopedic surgery. Saudi J Anaesth. 2016;10(4):423-427.
21. Shah UJ, Nguyen D, Karuppiaah N, Martin J, Sehmbi H. Efficacy and safety of caudal dexmedetomidine in pediatric infra-umbilical surgery: a meta-analysis and trial-sequential analysis of randomized controlled trials. Reg Anesth Pain Med. 2021;46(5):422-432.
22. Singh K, Bajaj J, Bathla S, Mehta K. Comparison of caudal bupivacaine and dexmedetomidine with caudal bupivacaine and intravenous dexmedetomidine for postoperative analgesia in children: A randomized controlled trial. J Anaesthesiol Clin Pharmacol. 2025;41(3):455-463.
23. Al-Zaben KR, Qudaisat IY, Abu-Halaweh SA, et al. Comparison of caudal bupivacaine alone with bupivacaine plus two doses of dexmedetomidine for postoperative analgesia in pediatric patients undergoing infra-umbilical surgery: a randomized controlled double-blinded study. Paediatr Anaesth. 2015;25(9):883-890.
24. Farid D, Hegab A, Elhossieny K, Elsayed A. Analgesic Effect of Bupivacaine-Dexmedetomidine versus Bupivacaine-Midazolam in Caudal Anesthesia for Pediatric Hypospadias Surgeries. Zagazig Uni Med J. 2024;30:5048-5058.
25. Gupta S, Sharma R. Comparison of analgesic efficacy of caudal dexmedetomidine versus caudal tramadol with ropivacaine in paediatric infraumbilical surgeries: A prospective, randomised, double blinded clinical studt. India J Anaesth. 2017;61:499-504.
26. Senthamizh TA, Krishnaprasad P. Comparison of analgesic efficacy of caudal dexmedetomidine vs caudal tramadol with ropivacaine in pediatric urogenital surgeries. IOSR-JDMS. 2020;19:2279-861.
27. Sneha BA, Bharti R. Comparison of the efficacy of tramadol and Dexmedetomidine with newer local anaesthetic drug ropivacaine through caudal epidural route. Int J Med Anesth. 2019;2:106-111.
28. Yadav BL, Rathore P, Puspendra Bairwa, Chitra Singh C, Sharma G. Comparison of Analgesic Effect of Dexmedetomidine versus Tramadol as Adjuvants to Caudal Ropivacaine in Infraumbilical Surgeries among Pediatric Patients: A Randomized Double Blind Interventional Study. J Health Sci Med Res. 2023;41(1):e2022893
29. Solai KS, Gunavel A, Gounder DS. Comparative study of 0.5 µg/kg and 1 µg/kg of dexmedetomidine as additive to 0.25% bupivacaine 1 ml/kg for caudal analgesia in paediatric infraumbilical surgeries. Int J Acad Med Pharm. 2025;7(1);836-841.
30. Chen Z, Liu Z, Feng C, Jin Y, Zhao X. Dexmedetomidine as an Adjuvant in Peripheral Nerve Block. Drug Des Devel Ther. 2023;17:1463-1484.
31. Wang X xue, Dai J, Dai L, Guo H jing, Zhou A guo, Pan D bo. Caudal dexmedetomidine in pediatric caudal anesthesia. Medicine (Baltimore). 2020;99:e21397.

ISSN (O): 2687-5365; ISSN (P): 2753-6556