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Original Research Article

EVALUATION OF CAUDAL BUPIVACAINE VERSUS BUPIVACAINE WITH KETAMINE FOR POSTOPERATIVE ANALGESIA IN PEDIATRIC PATIENTS: AN INSTITUTIONAL BASED STUDY

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ABSTRACT

Background: Caudal epidural analgesia is a commonly used technique for postoperative pain relief in pediatric infra-umbilical surgeries. Although bupivacaine provides effective caudal analgesia, its limited duration may necessitate early rescue analgesics. Ketamine, an NMDA receptor antagonist, has been used as an adjuvant to prolong caudal analgesia and reduce postoperative analgesic requirements.

Aim: To evaluate caudal bupivacaine versus bupivacaine with ketamine for postoperative analgesia in pediatric patients.

Materials and Methods: This prospective, randomized, comparative study included 78 children (ASA I–II) scheduled for elective infra-umbilical surgeries under general anesthesia. Patients were randomized into two equal groups: Group B (n=39) received caudal bupivacaine, and Group BK (n=39) received caudal bupivacaine with preservative-free ketamine. Postoperative pain was assessed using an age-appropriate validated pain scale at predefined intervals. The primary outcome was duration of postoperative analgesia (time from caudal injection to first rescue analgesic requirement). Secondary outcomes included time to first rescue analgesic, pain scores over time, number of rescue doses, total rescue analgesic consumption, sedation scores, and adverse events. Data were analyzed using SPSS version 27.0, with $p<0.05$ considered statistically significant.

Results: Baseline demographic characteristics were comparable between groups ($p>0.05$). The duration of analgesia was significantly longer in Group BK compared to Group B (598.74 ± 72.61 vs 312.56 ± 48.32 minutes; $p<0.001$), with a corresponding delay in time to first rescue analgesic (612.92 ± 75.08 vs 325.18 ± 52.44 minutes; $p<0.001$). All children in Group B required rescue analgesia (100.00%) compared to 46.15% in Group BK ($p<0.001$). Group BK required fewer rescue doses (0.74 ± 0.52 vs 2.18 ± 0.71; $p<0.001$) and had lower total analgesic consumption (8.36 ± 3.15 vs 19.42 ± 4.28 mg/kg; $p<0.001$). Pain scores were significantly lower in Group BK from 1 hour to 24 hours postoperatively ($p<0.05$). Sedation was mildly higher at 30 minutes in Group BK ($p=0.041$) but was not prolonged. Adverse events were low and comparable in both groups.

Conclusion: Adding preservative-free ketamine to caudal bupivacaine significantly prolongs postoperative analgesia, reduces rescue analgesic requirements, and improves pain scores without clinically significant adverse effects, making it a safe and effective adjuvant for pediatric infra-umbilical surgeries.

Keywords: Caudal Epidural; Bupivacaine; Ketamine; Pediatric Analgesia; Infra-Umbilical Surgery.

INTRODUCTION

Postoperative pain control in children undergoing infra-umbilical surgery remains a priority because inadequate analgesia is associated with distress, agitation, delayed feeding, poor sleep, increased sympathetic responses, and heightened caregiver anxiety. Although multimodal systemic analgesia is widely practiced, reliance on opioids can be limited by dose-related nausea, vomiting, pruritus, urinary retention, and—most importantly—risk of respiratory depression in younger children. Regional techniques therefore form a key component of balanced pediatric anesthesia, aiming to provide high-quality analgesia while reducing opioid exposure and improving recovery profiles. Among these techniques, caudal epidural analgesia continues to be one of the most frequently used neuraxial blocks for surgeries below the umbilicus because it is technically straightforward, provides reliable dermatomal coverage for common pediatric day-care procedures (hernia repair, orchiopexy, circumcision), and can be integrated easily with general anesthesia.[1]

Bupivacaine is a commonly selected local anesthetic for caudal blocks due to its potency, familiarity, and favorable sensory analgesic profile when appropriately dosed. However, a major limitation of single-shot caudal bupivacaine is its finite duration of analgesia, which may be insufficient for extended postoperative pain control, especially where early mobilization, smooth emergence, and overnight comfort are desired. Clinical practice has therefore focused on strategies to enhance the duration and quality of caudal analgesia without increasing local anesthetic concentration to levels that could increase motor block or systemic toxicity risk. Contemporary reviews emphasize that adjuvants are widely explored to extend caudal block duration while maintaining hemodynamic stability and minimizing adverse effects; yet the "ideal" additive remains debated because agents differ in onset, duration, sedation profile, and side-effect burden.[2]

Ketamine has attracted interest as a caudal adjuvant due to its analgesic properties and its mechanisms that extend beyond sodium-channel blockade. As an N-methyl-D-aspartate (NMDA) receptor antagonist, ketamine can reduce central sensitization and wind-up phenomena associated with surgical tissue injury, potentially improving both the intensity of pain and the time to first analgesic request. Additional receptor interactions (including effects on opioid, monoaminergic, and cholinergic pathways) may contribute to its antinociceptive profile. Importantly, neuraxial use requires preservative-free formulations because preservatives have historically raised concerns regarding neurotoxicity. Recent clinical evidence syntheses continue to support the concept that ketamine, when added to caudal local anesthetic in appropriate doses, can provide meaningful prolongation of postoperative analgesia and reduce rescue analgesic needs, while generally maintaining an acceptable safety profile in children.[3]

At the same time, ketamine's perioperative use is often viewed through the lens of potential psychomimetic effects and sedation, which can be particularly relevant in day-care pediatric surgery. Distinguishing analgesia from unwanted sedation is essential, because excessive sedation may delay oral intake, prolong observation time, and obscure early recognition of pain or respiratory compromise. These considerations have led to continued evaluation of ketamine's role compared with other methods of perioperative analgesia, including systemic ketamine regimens. Notably, randomized pediatric evidence comparing intravenous ketamine strategies with caudal local anesthetic highlights that caudal bupivacaine provides robust early analgesia for infra-umbilical operations, reinforcing caudal blockade as a cornerstone technique when not contraindicated.[4]

The broader literature on caudal adjuvants indicates an active field with many competing options. Network meta-analyses and comparative evaluations have examined multiple additives (e.g., alpha-2 agonists, steroids, cholinesterase inhibitors, opioids, magnesium, ketamine), ranking them by duration of analgesia and side-effect profiles. These analyses underscore two clinically important realities: first, that prolonging a single-shot caudal block is feasible; and second, that benefits must be weighed against adverse effects such as postoperative nausea and vomiting or clinically significant sedation.[5]

Recent studies also suggest that ketamine's effect may be nuanced and outcome-dependent. For example, prospective pediatric trials investigating caudal ketamine in conjunction with local anesthetics have examined not only postoperative pain duration but also intraoperative local anesthetic requirements and block quality measures, contributing to a more detailed understanding of ketamine's neuraxial role.[6]

MATERIALS AND METHODS

Present study was designed as a prospective, randomized, comparative study to evaluate the efficacy of caudal bupivacaine alone versus caudal bupivacaine with ketamine for postoperative analgesia in pediatric patients undergoing infra-umbilical surgeries.

Written informed consent was obtained from parents/guardians, and age-appropriate assent was obtained from children wherever feasible. Standard perioperative care was provided as per institutional protocols, and patient confidentiality was maintained throughout.

A total of 78 pediatric patients were enrolled and allocated into two groups of equal size. Children of either sex, belonging to American Society of Anesthesiologists (ASA) physical status I–II, scheduled for elective infra-umbilical surgical procedures under general anesthesia with planned

caudal epidural analgesia were included. Patients were excluded if they had parental refusal, infection at the caudal site, congenital spinal anomalies, bleeding diathesis or anticoagulant therapy, known allergy or hypersensitivity to study drugs, pre-existing neurological deficits, significant developmental delay interfering with pain assessment, severe systemic illness (ASA ≥III), or if intraoperative events necessitated deviation from the study protocol.

Methodology

Participants were randomized into two groups using a computer-generated random number sequence in a 1:1 ratio: Group B (caudal bupivacaine) and Group BK (caudal bupivacaine with ketamine). Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes opened only after induction of anesthesia. Study solutions were prepared by an anesthesiologist not involved in intraoperative management or postoperative assessment. The anesthesiologist performing postoperative assessments, the nursing staff, and the patient's caregivers were blinded to group assignment to minimize observer and performance bias.

Anesthesia Technique and Caudal Block Procedure

All children underwent standardized general anesthesia. Baseline parameters including heart rate, non-invasive blood pressure, respiratory rate, oxygen saturation, and end-tidal carbon dioxide were recorded. Induction and maintenance were performed according to institutional pediatric anesthesia practice, ensuring comparable anesthetic depth between groups. After induction, the child was positioned in the lateral decubitus position and the caudal epidural space was identified under strict asepsis using standard anatomical landmarks. Following negative aspiration for blood or cerebrospinal fluid, the study drug was injected slowly with intermittent aspiration. Group B received caudal bupivacaine, whereas Group BK received caudal bupivacaine combined with preservative-free ketamine. Group B received 0.25% bupivacaine at a dose of 1 ml/kg (equivalent to 2.5 mg/kg), with a maximum total volume of 20 ml. Group BK received 0.25% bupivacaine 1 ml/kg (2.5 mg/kg) plus preservative-free ketamine 0.5 mg/kg, and the total injectate volume was maintained at 1 ml/kg in both groups (maximum 20 ml) by dilution with normal saline as required. The total volume administered and drug concentrations were kept uniform as per protocol to ensure comparable spread of caudal analgesia, and no additional neuraxial adjuvants were used. Any failed caudal block (defined by inadequate intraoperative analgesia requiring significant rescue analgesics or clinical suspicion of incorrect placement) was managed as per institutional practice and handled in analysis according to the predefined plan.

Postoperative Analgesia Assessment and Follow-Up Parameters

Postoperative pain was assessed using a validated, age-appropriate pediatric pain scale at fixed intervals in the post-anesthesia care unit and subsequently in the ward. Pain was assessed using the FLACC (Face, Legs, Activity, Cry, Consolability) scale (0–10), and a score ≥4 was considered the predefined threshold for rescue analgesia. Pain scores were recorded at regular time points and additionally whenever the child appeared uncomfortable. The primary outcome was duration of postoperative analgesia, defined as the time from completion of caudal drug administration to the first requirement of rescue analgesia (or when pain score exceeded the predefined threshold). Secondary outcomes included postoperative pain scores over time, total rescue analgesic consumption in the first postoperative period, and time to first rescue analgesic requirement. Sedation was evaluated using a standardized sedation score at similar intervals to differentiate analgesia from excessive sedation and to monitor recovery. Sedation was assessed using the Ramsay Sedation Scale (RSS; 1–6), and RSS ≥4 was considered excessive sedation. Hemodynamic parameters (heart rate and blood pressure) were monitored intraoperatively and postoperatively to identify sympathetic responses to pain as well as potential drug-related effects.

Rescue Analgesia Protocol

Rescue analgesia was administered when the pain score crossed the predefined cutoff or when the child demonstrated persistent pain-related behavior despite non-pharmacological comfort measures. The same rescue analgesic regimen was used for both groups (weight-based dosing), and the time, dose, and number of rescue doses were documented. Intravenous paracetamol 15 mg/kg was used as first-line rescue analgesia; if pain persisted (FLACC ≥4) after 30 minutes, intravenous tramadol 1 mg/kg was administered as second-line rescue analgesia. Total rescue analgesic consumption was calculated over the first 24 postoperative hours in mg/kg. Antiemetics and other supportive care were given as required, and all medications administered postoperatively were recorded to account for potential confounding effects on pain and sedation assessment.

Safety Monitoring and Adverse Events

Children were monitored for block-related and drug-related adverse events throughout the perioperative period. Complications specifically assessed included nausea and vomiting, pruritus, urinary retention, hypotension, bradycardia, respiratory depression, excessive sedation, emergence agitation, hallucinations or dysphoric reactions (particularly relevant to ketamine), and any signs of local anesthetic systemic toxicity. The caudal site was observed for bleeding, swelling, or infection. Any adverse event was managed promptly according to

standard clinical guidelines and documented in the case record form.

Data Collection and Outcome Definitions

Demographic and perioperative variables were recorded, including age, weight, sex, ASA status, type of surgery, duration of anesthesia, intraoperative analgesic supplementation (if any), and baseline vitals. Analgesia-related data included serial pain scores, duration of analgesia, time to first rescue analgesic, number of rescue doses, and total rescue analgesic requirement. Recovery characteristics were documented using sedation scores and time to achieve discharge criteria from the recovery area as per institutional norms.

Statistical Analysis

Data were entered into a structured proforma and analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Continuous variables were assessed for normality and expressed as mean ± standard deviation or median (interquartile range) as appropriate. Intergroup comparisons for continuous variables were performed using the independent samples t-test for normally distributed data and the Mann–Whitney U test for skewed data. Categorical variables were expressed as frequencies and percentages and compared using the chi-square test or Fisher's exact test where applicable. Pain scores across multiple time points were analyzed using appropriate repeated-measures methods. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 78 pediatric patients were included in the study, with 39 patients in each group. The demographic characteristics were comparable between the two groups. The mean age of children in Group B was 5.42 ± 1.84 years, while in Group BK it was 5.36 ± 1.79 years, with no statistically significant difference (p = 0.874). Similarly, mean body weight was comparable between the groups (18.26 ± 4.12 kg in Group B versus 18.74 ± 4.05 kg in Group BK; p = 0.612). The gender distribution was also similar, with males constituting 69.23% in Group B and 66.67% in Group BK (p = 0.811). With respect to physical status, the majority of patients belonged to ASA I in both groups (79.49% in Group B and 76.92% in Group BK), and the distribution of ASA grades did not differ significantly (p = 0.784). The duration of anesthesia was comparable between the two groups (68.41 ± 12.35 minutes in Group B versus 70.08 ± 11.92 minutes in Group BK; p = 0.536). (Table 1)

The duration of postoperative analgesia was significantly longer in Group BK compared to Group B. Children receiving caudal bupivacaine with ketamine had a mean analgesia duration of 598.74 ± 72.61 minutes, whereas those receiving bupivacaine alone had a duration of 312.56 ± 48.32 minutes, and this difference was statistically highly significant (p < 0.001). Similarly, the time to first rescue analgesic requirement was significantly prolonged in Group BK (612.92 ± 75.08 minutes) compared to Group B (325.18 ± 52.44 minutes; p < 0.001). All patients in Group B (100.00%) required rescue analgesia during the postoperative period, whereas only 46.15% of patients in Group BK required rescue analgesia, which was statistically significant (p < 0.001). Furthermore, the mean number of rescue doses administered was significantly higher in Group B (2.18 ± 0.71) compared to Group BK (0.74 ± 0.52; p < 0.001). Total rescue analgesic consumption was also significantly lower in Group BK (8.36 ± 3.15 mg/kg) than in Group B (19.42 ± 4.28 mg/kg), demonstrating superior and prolonged analgesic efficacy with the addition of ketamine to caudal bupivacaine. (Table 2)

Postoperative pain scores were comparable between the two groups at 30 minutes after surgery, with no statistically significant difference observed (p = 0.548). However, from 1 hour onwards, Group BK consistently demonstrated significantly lower pain scores compared to Group B. At 1 hour, the mean pain score in Group BK was 1.34 ± 0.52 compared to 1.62 ± 0.63 in Group B (p = 0.034). This difference became more pronounced at later time points, with Group BK showing significantly lower pain scores at 2 hours (p < 0.001), 4 hours (p < 0.001), 6 hours (p < 0.001), and 12 hours (p < 0.001). Even at 24 hours postoperatively, pain scores remained significantly lower in Group BK (2.31 ± 0.64) compared to Group B (2.86 ± 0.73; p = 0.002). (Table 3)

Postoperative sedation scores showed a transient increase in the ketamine group during the early postoperative period. At 30 minutes postoperatively, Group BK had a significantly higher median sedation score [2 (IQR 1–2)] compared to Group B [1 (IQR 1–2)], and this difference was statistically significant (p = 0.041). At 1 hour, although sedation scores were slightly higher in Group BK, the difference did not reach statistical significance (p = 0.068). From 2 hours onwards, sedation scores were comparable between the two groups, with median scores of 1 in both groups at 2 and 4 hours (p = 0.314 and p = 1.000, respectively). (Table 4)

The incidence of adverse events was low and comparable between the two groups. Postoperative nausea and vomiting occurred in 12.82% of patients in Group B and 15.38% in Group BK, with no statistically significant difference (p = 0.742). Other complications such as pruritus, urinary retention, hypotension, and bradycardia were infrequent and did not differ significantly between groups. No cases of respiratory depression or signs of local anesthetic systemic toxicity were observed in either group. Although excessive sedation and hallucinations were observed only in the ketamine group, their incidence was low (5.13% and 2.56%, respectively) and did not reach statistical significance. (Table 5)

Table 1: Demographic characteristics and perioperative variables

Variable	Group B (Bupivacaine) n=39	Group BK (Bupivacaine + Ketamine) n=39	p-value
Age (years), mean ± SD	5.42 ± 1.84	5.36 ± 1.79	0.874
Weight (kg), mean ± SD	18.26 ± 4.12	18.74 ± 4.05	0.612
Male, n (%)	27 (69.23%)	26 (66.67%)	0.811
Female, n (%)	12 (30.77%)	13 (33.33%)	0.811
ASA I, n (%)	31 (79.49%)	30 (76.92%)	0.784
ASA II, n (%)	8 (20.51%)	9 (23.08%)	0.784
Duration of anesthesia (min), mean ± SD	68.41 ± 12.35	70.08 ± 11.92	0.536

Table 2: Duration of postoperative analgesia and rescue analgesic requirement

Parameter	Group B (n=39)	Group BK (n=39)	p-value
Duration of analgesia (min), mean ± SD	312.56 ± 48.32	598.74 ± 72.61	<0.001
Time to first rescue analgesic (min), mean ± SD	325.18 ± 52.44	612.92 ± 75.08	<0.001
Patients requiring rescue analgesia, n (%)	39 (100.00%)	18 (46.15%)	<0.001
Number of rescue doses, mean ± SD	2.18 ± 0.71	0.74 ± 0.52	<0.001
Total rescue analgesic consumption (mg/kg), mean ± SD	19.42 ± 4.28	8.36 ± 3.15	<0.001

Table 3: Postoperative pain scores at different time intervals

Time interval	Group B (Mean ± SD)	Group BK (Mean ± SD)	p-value
30 minutes	1.28 ± 0.56	1.21 ± 0.48	0.548
1 hour	1.62 ± 0.63	1.34 ± 0.52	0.034
2 hours	2.41 ± 0.72	1.56 ± 0.61	<0.001
4 hours	3.36 ± 0.81	1.88 ± 0.67	<0.001
6 hours	4.12 ± 0.94	2.31 ± 0.74	<0.001
12 hours	3.98 ± 0.88	2.42 ± 0.69	<0.001
24 hours	2.86 ± 0.73	2.31 ± 0.64	0.002

Table 4: Postoperative sedation scores

Time interval	Group B (Median [IQR])	Group BK (Median [IQR])	p-value
30 minutes	1 [1–2]	2 [1–2]	0.041
1 hour	1 [1–1]	1 [1–2]	0.068
2 hours	1 [1–1]	1 [1–1]	0.314
4 hours	1 [1–1]	1 [1–1]	1.000

Table 5: Adverse events and complications

Adverse event	Group B n (%)	Group BK n (%)	p-value
Nausea/Vomiting	5 (12.82%)	6 (15.38%)	0.742
Pruritus	2 (5.13%)	3 (7.69%)	0.643
Urinary retention	1 (2.56%)	1 (2.56%)	1.000
Hypotension	2 (5.13%)	2 (5.13%)	1.000
Bradycardia	1 (2.56%)	2 (5.13%)	0.556
Respiratory depression	0 (0.00%)	0 (0.00%)	—
Excessive sedation	0 (0.00%)	2 (5.13%)	0.152
Hallucinations/dysphoria	0 (0.00%)	1 (2.56%)	0.314

DISCUSSION

The two groups in the present study were well matched, which strengthens the internal validity of the comparisons. Children in Group B and Group BK had similar mean age (5.42 ± 1.84 vs 5.36 ± 1.79 years; p = 0.874), weight (18.26 ± 4.12 vs 18.74 ± 4.05 kg; p = 0.612), sex distribution (male 69.23% vs 66.67%; p = 0.811), ASA status (ASA I 79.49% vs 76.92%; p = 0.784), and duration of anesthesia (68.41 ± 12.35 vs 70.08 ± 11.92 min; p = 0.536). A similar baseline comparability was reported by Aliena et al. (2018), where the study groups were comparable in demographic and perioperative variables before evaluating caudal bupivacaine with and without ketamine in children undergoing subumbilical surgeries.[7] A key finding of this study was the marked prolongation of analgesia with ketamine as an adjuvant. The mean duration of analgesia increased from 312.56 ± 48.32 min (≈5.21 h) in Group B to 598.74 ± 72.61 min (≈9.98 h) in Group BK (p < 0.001), and time to first rescue analgesic increased from 325.18 ± 52.44 min to 612.92 ± 75.08 min (p < 0.001). These results align with Weber et al. (2003), who demonstrated improved postoperative analgesia when preservative-free S(+)-ketamine (0.5 mg/kg) was added to caudal bupivacaine; notably, within 24 h, 67% of children in the ketamine group required no additional analgesic compared with 20% in the bupivacaine-only group (P < 0.01).[8]

Rescue analgesic requirement and overall analgesic consumption were significantly reduced by adding ketamine in our cohort. All children in Group B required rescue analgesia (39/39; 100.00%), whereas less than half in Group BK did so (18/39; 46.15%) (p < 0.001). Group B also had a higher mean number of rescue doses (2.18 ± 0.71 vs 0.74 ± 0.52; p < 0.001) and greater total rescue analgesic consumption (19.42

± 4.28 vs 8.36 ± 3.15 mg/kg; p < 0.001). Choudhuri et al. (2008) similarly reported that more patients receiving plain caudal bupivacaine required supplemental analgesics in the first 24 h, while the ketamine adjuvant group achieved longer analgesia duration (6.5 ± 4.1 h with bupivacaine alone vs 9.2 ± 3.9 h with bupivacaine+ketamine; P < 0.05).[9]

The serial pain scores in our study also support a sustained analgesic advantage of the ketamine adjuvant beyond the immediate recovery period. Pain scores were comparable at 30 min (1.28 ± 0.56 vs 1.21 ± 0.48; p = 0.548), but from 1 h onward Group BK remained significantly lower (e.g., 1 h: 1.34 ± 0.52 vs 1.62 ± 0.63; p = 0.034; 6 h: 2.31 ± 0.74 vs 4.12 ± 0.94; p < 0.001; 24 h: 2.31 ± 0.64 vs 2.86 ± 0.73; p = 0.002). This pattern is consistent with Kaur et al. (2016), where the mean duration of analgesia increased substantially with ketamine addition (10.18 ± 2.24 h) compared with bupivacaine alone (5.63 ± 0.98 h; P < 0.001), reflecting prolonged analgesic coverage and reduced pain burden after caudal adjuvant use.[10]

Dose and formulation differences across trials help explain variation in absolute analgesia duration between studies, while preserving the direction of effect. In our study, analgesia with bupivacaine+ketamine lasted ≈9.98 h on average, whereas Panjabi et al. (2004) observed much longer mean analgesia durations in dose-ranging groups—22.1 h with ketamine 0.5 mg/kg and 25.2 h with ketamine 1 mg/kg added to caudal bupivacaine—compared with 8.8 h at 0.25 mg/kg (P < 0.001). Their findings also showed lower supplemental opioid requirements at higher ketamine doses, but with more behavioral side effects at 1 mg/kg, emphasizing the clinical trade-off between prolongation and side-effect risk at higher dosing.[11]

When interpreting the consistency of benefit across trials, the broader evidence base supports ketamine as an effective caudal adjuvant in pediatric infra-umbilical surgery. In a quantitative systematic review of randomized controlled trials, Schnabel et al. (2011) concluded that adding ketamine to caudal local anesthetics generally prolongs postoperative analgesia and improves analgesic quality, with relatively few adverse effects reported across included trials, supporting the overall direction of benefit observed in our study (greater analgesia duration and lower rescue consumption).[12]

With respect to sedation, our findings indicate that ketamine caused only brief early sedation without prolongation. At 30 min, Group BK had a higher median sedation score [2 (IQR 1–2)] compared with Group B [1 (IQR 1–2)] (p = 0.041), but thereafter differences were not statistically significant (1 h p = 0.068; 2 h p = 0.314; 4 h p = 1.000). This is clinically relevant because prolonged sedation can delay feeding, mobilization, and discharge readiness. Marhofer et al. (2000) similarly demonstrated stable perioperative conditions and improved postoperative analgesic outcomes with caudal S(+)-ketamine strategies, reinforcing that neuraxial ketamine regimens can enhance analgesia without necessarily producing persistent clinically problematic sedation when appropriately dosed and monitored.[13]

Safety outcomes in our study were reassuring, with low and comparable rates of common complications between groups (e.g., PONV 12.82% vs 15.38%; p = 0.742; hypotension 5.13% vs 5.13%; p = 1.000), and no respiratory depression or local anesthetic systemic toxicity in either group. Ketamine-specific events were infrequent (excessive sedation 0.00% vs 5.13%; p = 0.152; hallucinations/dysphoria 0.00% vs 2.56%; p = 0.314). Early foundational evidence by Naguib et al. (1991) also reported superior analgesia with a bupivacaine–ketamine mixture compared with bupivacaine alone and noted an absence of certain side effects such as motor weakness or urinary retention in their ketamine-only group, supporting the overall safety signal observed with caudal ketamine use in pediatric populations.[14]

Finally, when contextualized alongside multi-arm adjuvant comparisons, our results are directionally consistent with studies showing ketamine improves analgesia versus plain bupivacaine, though other adjuvants may achieve still longer durations in some settings. In our study, postoperative analgesia duration increased by about 286 minutes (≈4.77 h) with ketamine addition (598.74 vs 312.56 min). In contrast, Musa et al. (2018) found caudal bupivacaine alone produced analgesia duration of 433 ± 68 min, while adding ketamine (0.5 mg/kg) increased it to 769 ± 118 min (with other adjuvants such as midazolam and neostigmine producing even longer durations in that trial), highlighting that ketamine is a valuable and safe option but may not always be the single "longest-duration" adjuvant depending on comparator and protocol.[15]

CONCLUSION

Caudal bupivacaine with ketamine provided significantly longer postoperative analgesia than caudal bupivacaine alone in children undergoing infra-umbilical surgeries (598.74 ± 72.61 vs 312.56 ± 48.32 minutes). The ketamine adjuvant significantly delayed the first rescue analgesic requirement and reduced the proportion of children needing rescue analgesia, the number of rescue doses, and total analgesic consumption. Pain scores were consistently lower in the bupivacaine–ketamine group from 1 hour up to 24 hours postoperatively. Mild early postoperative sedation was observed with ketamine, but it was transient and not associated with clinically significant adverse effects. Overall, preservative-free ketamine is an effective and safe adjuvant to caudal bupivacaine for enhancing postoperative analgesia in pediatric patients.

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