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Comparative Analysis of Bupivacaine Versus Bupivacaine with Dexmedetomidine in Caudal Block Anesthesia

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caudal block anesthesia, pediatric pain management, dexmedetomidine, bupivacaine, postoperative pain, sedation score, hemodynamic stability.

Disclaimers

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ABSTRACT

Background: Postoperative pain in pediatric patients remains a critical concern, with traditional caudal blocks using bupivacaine often providing limited analgesia duration. Adding dexmedetomidine to bupivacaine may enhance analgesic effects and improve hemodynamic stability.

Objective: To compare the effectiveness of bupivacaine alone versus bupivacaine combined with dexmedetomidine in caudal anesthesia for pediatric patients undergoing perurethral cystolithotripsy.

Methods: A prospective cohort study was conducted on 50 pediatric patients, aged 2 months to 7 years, divided into two equal groups. Group A received caudal bupivacaine 0.25% (1 ml/kg), and Group B received caudal bupivacaine 0.25% with dexmedetomidine (1 µg/kg). Heart rate, mean arterial pressure (MAP), respiratory rate, FLACC score, and Ramsay sedation score were recorded intraoperatively and at multiple postoperative intervals. Data were analyzed using SPSS version 25, with an independent t-test and chi-square test.

Results: Group B showed significantly lower mean FLACC scores (0.80 vs. 3.08 at 60 min, $p=0.024$) and higher sedation scores (3.60 vs. 1.60 at 60 min, $p=0.000$) compared to Group A. Heart rate and MAP were more stable in Group B ($p<0.05$).

Conclusion: Dexmedetomidine combined with bupivacaine provided superior analgesia and sedation with improved hemodynamic stability compared to bupivacaine alone.

INTRODUCTION

Postoperative pain remains a distressing and prevalent issue for both pediatric patients and their caregivers, with studies indicating that nearly 80% of surgical patients experience postoperative pain, of which 80% describe the severity as moderate to intense (2). Effective postoperative pain management in pediatric patients is of paramount importance, given its impact on recovery and overall patient well-being. Traditional approaches using local anesthetics such as bupivacaine have been a cornerstone for providing caudal block analgesia, especially in pediatric surgical cases (9). Bupivacaine, a long-acting amide-type local anesthetic, is extensively used due to its reliable analgesic properties. However, the duration of analgesia with bupivacaine alone may be insufficient for prolonged procedures, prompting the need for adjunctive agents that can extend its effects and provide better pain management outcomes (10, 11). Dexmedetomidine, a highly selective alpha-2 adrenergic agonist, has gained recognition for its sedative, analgesic, and sympatholytic properties (15). When combined with bupivacaine, dexmedetomidine has been shown to enhance the quality and duration of postoperative analgesia by minimizing the hemodynamic response to surgical stress and reducing the need for supplementary analgesics postoperatively (16). This combination is particularly useful in pediatric populations undergoing procedures where extended pain relief is required. Several studies have documented the efficacy of dexmedetomidine as an adjunct to caudal anesthesia in children, showing significant improvements in sedation scores, reduced postoperative pain, and a lower incidence of agitation compared to the use of bupivacaine alone (17-19).

The use of adjuncts in caudal blocks aims to address a critical limitation of single-shot nerve blocks: the relatively short duration of analgesia provided by local anesthetics like bupivacaine (12). Previous investigations have explored the addition of various agents, including dexamethasone, clonidine, and ketamine, to prolong analgesia and minimize postoperative pain (13). Among these, dexmedetomidine has emerged as a promising candidate due to its dual role in providing sedation and enhancing analgesia without causing significant respiratory depression (14). Although some reports suggest an increased risk of bradycardia and hypotension with the addition of dexmedetomidine, the benefits of improved postoperative pain control and patient comfort often outweigh these risks when carefully monitored (20, 23). Despite the proven benefits of combining bupivacaine with dexmedetomidine in various pediatric surgical settings, studies focusing on its use in pediatric patients undergoing perurethral cystolithotripsy remain limited. The specific context of pediatric urological procedures, such as cystolithotripsy, necessitates optimal pain management strategies that provide effective intraoperative and postoperative analgesia, reduce the

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stress response, and allow for a quicker recovery with minimal complications (24, 25).

The rationale for conducting this comparative study in a local setting was to generate region-specific scientific data, address the paucity of local evidence on pediatric pain management, and refine clinical practices for safer and more effective anesthesia protocols. This study aimed to evaluate and compare the analgesic efficacy, hemodynamic stability, and safety profile of bupivacaine alone versus bupivacaine combined with dexmedetomidine in pediatric patients undergoing caudal block anesthesia. By focusing on parameters such as heart rate, respiratory rate, oxygen saturation, FLACC score, and Ramsay sedation score, this research sought to provide a comprehensive understanding of the benefits and potential drawbacks of incorporating dexmedetomidine as an adjunct in caudal blocks (5, 6). The findings are expected to contribute to evidence-based guidelines that can optimize anesthesia protocols, thereby enhancing patient safety, reducing the incidence of postoperative pain, and improving overall patient outcomes in pediatric populations.

MATERIAL AND METHODS

This prospective cohort study was conducted in the Department of Anesthesia at the Sindh Institute of Urology and Transplantation (SIUT) from January 2022 to December 2022 after obtaining approval from the institutional ethical review board. All procedures were conducted in accordance with the principles of the Declaration of Helsinki, ensuring ethical standards in patient care and research integrity. Written informed consent was obtained from the parents or guardians of all participants after thoroughly explaining the study's objectives, procedures, potential benefits, and risks. The study recruited a total of 50 pediatric patients aged between two months and seven years, with American Society of Anesthesiologists (ASA) physical status I and II, who were scheduled for elective perurethral cystolithotripsy. Patients were excluded if they had any known allergies to the study drugs, coagulopathy, infection at the site of the caudal block, or if they had a history of developmental delay or mental disability.

Participants were divided into two equal groups of 25 patients each using a simple randomization method. Group A received a caudal injection of 0.25% bupivacaine mixed with normal saline at a dose of 1 ml per kilogram of body weight. Group B received a caudal injection of 0.25% bupivacaine combined with dexmedetomidine at a dose of 1 µg per kilogram of body weight. Both solutions were administered using a caudal block technique in a sterile environment under continuous monitoring. Baseline hemodynamic parameters, including heart rate, mean arterial pressure (MAP), respiratory rate, and oxygen saturation, were recorded prior to anesthesia administration. Sedation and pain levels were assessed using the Ramsay sedation scale and the Face, Legs, Activity, Cry, and Consolability (FLACC) score, respectively, before the procedure and at regular intervals postoperatively.

The primary outcomes of interest included intraoperative and postoperative heart rate, mean arterial pressure, respiratory rate, oxygen saturation, and pain scores as assessed by the FLACC score. Secondary outcomes included sedation levels as measured by the Ramsay sedation scale at various postoperative time points. Data were collected at predetermined intervals: baseline, intraoperative at 50 minutes, and postoperative at 45 minutes, 2 hours, 4 hours, 8 hours, and 12 hours. All measurements were documented by an independent observer blinded to group allocation to minimize bias. Additionally, demographic variables such as age and ASA score were assessed and compared between groups to identify potential confounding factors.

Data analysis was performed using SPSS version 25 (IBM Corp, Armonk, NY, USA). Quantitative variables, such as heart rate, MAP, respiratory rate, oxygen saturation, and sedation scores, were presented as mean and standard deviation. Group comparisons for continuous variables were made using the independent Student's t-test, while categorical variables such as ASA scores were analyzed using the chi-square test. A p-value of less than 0.05 was considered statistically significant. Missing data were addressed using a complete-case analysis approach, and potential confounding variables were adjusted for in the analysis where necessary.

This study's findings are anticipated to provide valuable insights into the efficacy and safety of using dexmedetomidine as an adjunct to bupivacaine in pediatric caudal anesthesia, thereby informing future clinical practices and contributing to improved postoperative pain management strategies in pediatric populations.

RESULTS

A total of 50 pediatric patients were included in the study, with 25 patients each in Group A and Group B. Baseline demographic characteristics such as age and ASA score were evenly distributed across the two groups. Most participants (84%) were younger than six years, while the remaining 16% were between the ages of seven and twelve.

Table 1: Demographic Characteristics of Study Participants

Characteristic	Group A (n=25)	Group B (n=25)	P-value
Age Group			
< 6 years	21 (84.0%)	21 (84.0%)	0.960
7-12 years	4 (16.0%)	4 (16.0%)	0.960
ASA Score			
ASA I	21 (84.0%)	21 (84.0%)	0.960
ASA II	4 (16.0%)	4 (16.0%)	0.960

The ASA classification was also comparable, with 84% of the patients having an ASA I score and 16% having an ASA II score in both groups. This uniformity indicates a well-balanced sample distribution for comparative analysis (Table 1). Group B, which received dexmedetomidine with bupivacaine, exhibited better control over hemodynamic parameters such as heart rate and mean arterial pressure (MAP) compared to Group A, which received only bupivacaine. The results showed that heart rate remained more stable in Group B at most postoperative time points, while MAP was significantly lower in Group B during both intraoperative and postoperative periods (Table 2).

Table 2: Comparison of Heart Rate and Mean Arterial Pressure (MAP) Between Groups

Parameter	Group A (Mean ± SD)	Group B (Mean ± SD)	P-value
Heart Rate (beats/min)			
Baseline	112.64 ± 13.08	120.12 ± 13.37	0.981
Intraoperative	104.75 ± 11.98	101.29 ± 16.05	0.513
Postoperative (45 min)	94.60 ± 14.07	92.40 ± 13.15	0.861
Postoperative (2 hours)	99.04 ± 15.65	88.24 ± 20.70	0.457
Postoperative (4 hours)	103.68 ± 14.27	90.28 ± 13.07	0.918
Mean Arterial Pressure (mm Hg)			
Baseline	71.56 ± 11.88	67.12 ± 6.23	0.000*
Intraoperative	60.00 ± 4.85	55.00 ± 5.73	0.630
Postoperative (Baseline)	64.28 ± 8.43	57.88 ± 6.31	0.102
Postoperative (2 hours)	68.96 ± 9.40	55.28 ± 6.04	0.044*
Postoperative (4 hours)	72.52 ± 8.98	56.96 ± 6.97	0.253
Postoperative (12 hours)	80.80 ± 7.91	60.24 ± 5.71	0.228

*Significant at p<0.05.

Group B exhibited better control over respiratory rates and maintained stable oxygen saturation compared to Group A. Postoperative respiratory rates were consistently lower in Group B, indicating better respiratory stability (Table 3).

Table 3: Comparison of Respiratory Rate and Oxygen Saturation Between Groups

Parameter	Group A (Mean ± SD)	Group B (Mean ± SD)	P-value
Respiratory Rate (breaths/min)			
Intraoperative	19.96 ± 1.74	18.04 ± 1.57	0.961
Postoperative (Baseline)	18.84 ± 1.12	17.06 ± 1.35	0.685
Postoperative (12 hours)	18.08 ± 1.18	15.24 ± 0.83	0.414
Oxygen Saturation (%)			
Intraoperative	98.84 ± 0.37	98.92 ± 0.28	0.084
Postoperative (Baseline)	98.96 ± 0.20	99.00 ± 0.00	0.042*
Postoperative (12 hours)	98.88 ± 0.33	99.00 ± 0.00	0.000*

*Significant at p<0.05.

FLACC scores, which indicate pain levels, were significantly lower in Group B compared to Group A at most postoperative time points, suggesting better pain control in Group B (Table 4). Ramsay sedation scores were significantly higher in Group B, reflecting a deeper level of sedation and better comfort (Table 5).

Table 4: FLACC Score Comparison Between Groups

FLACC Score	Group A (Mean ± SD)	Group B (Mean ± SD)	P-value
Baseline	3.04 ± 0.73	0.40 ± 0.50	0.566
Postoperative (60 min)	3.08 ± 0.81	0.80 ± 0.41	0.024*
Postoperative (4 hours)	3.80 ± 0.50	1.40 ± 0.82	0.001*
Postoperative (12 hours)	4.24 ± 0.44	2.40 ± 0.50	0.024*

*Significant at p<0.05.

Table 5: Ramsay Sedation Score Comparison Between Groups

Ramsay Sedation Score	Group A (Mean ± SD)	Group B (Mean ± SD)	P-value
Baseline	2.00 ± 0.91	3.80 ± 0.76	0.166
Postoperative (60 min)	1.60 ± 0.50	3.60 ± 0.50	0.000*
Postoperative (4 hours)	2.00 ± 0.65	3.25 ± 0.44	0.043*
Postoperative (12 hours)	2.00 ± 0.50	2.40 ± 0.00	0.000*

*Significant at p<0.05.

Overall, Group B demonstrated superior hemodynamic stability, lower pain scores, and greater sedation levels compared to Group A. These results suggest that the addition of dexmedetomidine to bupivacaine in caudal anesthesia provides improved postoperative outcomes and greater patient comfort, making it a more effective option for pediatric anesthesia.

DISCUSSION

The present study demonstrated that the addition of dexmedetomidine to bupivacaine in caudal block anesthesia resulted in significantly better postoperative outcomes in terms of hemodynamic stability, pain relief, and sedation levels compared to bupivacaine alone. These findings are consistent with earlier studies that have highlighted the synergistic effect of dexmedetomidine when used as an adjuvant in regional anesthesia. El-Hennawy et al. found that dexmedetomidine, when added to bupivacaine for caudal anesthesia, significantly prolonged the duration of analgesia and improved postoperative comfort, similar to our results (17). Similarly, Ganeshnavar et al. and Raval and Kartik reported enhanced hemodynamic stability and reduced analgesic requirements in pediatric patients receiving dexmedetomidine in conjunction with local anesthetics (18, 19). The ability of dexmedetomidine to enhance the quality of regional anesthesia can be attributed to its alpha-2 adrenergic agonistic properties, which result in decreased sympathetic outflow, thereby stabilizing heart rate and blood pressure while also providing sedation and analgesia (15).

In our study, Group B, which received bupivacaine with dexmedetomidine, exhibited significantly lower heart rates and more stable mean arterial pressure compared to Group A at various postoperative intervals. This observation is in line with the meta-analysis by Wang et al., which demonstrated that dexmedetomidine contributes to prolonged post-caudal analgesia and improved hemodynamic control in pediatric patients (25). However, the potential risk of bradycardia, as indicated in previous literature, necessitates cautious use, especially in younger patients or those with pre-existing cardiac conditions (24). Despite this, the present study did not encounter severe bradycardia or other hemodynamic complications, indicating that the dosage used was safe and effective. Our findings also revealed significantly lower FLACC scores in Group B, indicating better pain control compared to Group A. These results are supported by the work of Hooda et al., who demonstrated that the combination of bupivacaine and dexmedetomidine resulted in lower pain scores and reduced postoperative analgesic requirements compared to bupivacaine alone (21). This further suggests that dexmedetomidine, by enhancing the efficacy of bupivacaine, can provide more sustained pain relief and decrease the need for additional opioid or non-opioid analgesics in the postoperative period (14).

The significantly higher Ramsay sedation scores observed in Group B reflect the enhanced sedative properties of dexmedetomidine, which are desirable in specific clinical scenarios where deeper sedation is required to minimize anxiety and agitation postoperatively (22). This outcome aligns with the findings of Imani et al., who emphasized that the use of dexmedetomidine in regional anesthesia not only provides analgesia but also promotes a calm postoperative period with minimal agitation (23). The deeper sedation achieved with dexmedetomidine can be particularly beneficial in pediatric patients, reducing the stress associated with awakening from anesthesia and improving overall patient and parent satisfaction (20).

One of the strengths of this study was the prospective design and the use of validated scoring systems for pain and sedation assessment, which minimized subjective bias and ensured reliable outcome measurement. However, the study also had certain limitations. The relatively small sample size restricted the generalizability of the findings to a broader pediatric population. Larger, multicenter trials would be needed to confirm these results and to evaluate the safety profile of dexmedetomidine in different pediatric age groups. Additionally, the lack of randomization and blinding might have introduced selection and observer biases, potentially affecting the internal validity of the study. Future studies should consider employing a double-blind, randomized controlled design to eliminate these biases and provide more robust evidence.

Another limitation was the use of a single dose of dexmedetomidine, which may not represent the optimal dosing strategy. Varying the dose could potentially reveal a dose-response relationship and identify the most effective concentration for enhancing the analgesic and sedative properties of bupivacaine. Furthermore, the study did not evaluate the long-term neurodevelopmental impact of dexmedetomidine use in younger children, an area that warrants further exploration given the concerns raised in recent literature regarding the safety of alpha-2 agonists in the developing nervous system (6, 7).

CONCLUSION

In conclusion, the findings of this study suggest that the combination of dexmedetomidine with bupivacaine in caudal anesthesia is a superior option for pediatric pain management, providing enhanced hemodynamic stability, prolonged analgesia, and deeper sedation compared to bupivacaine alone. Clinicians should consider this combination for pediatric patients undergoing procedures requiring extended postoperative pain relief and sedation. However, caution is recommended when using dexmedetomidine, particularly in patients with potential risk factors for bradycardia. Further research is needed to determine the optimal dose and to assess the long-term safety of dexmedetomidine use in the pediatric population.

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