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# Comparative Analysis of Hemodynamic Stability and Postoperative Recovery in Pediatric Lower Abdominal Surgery: Caudal vs. Spinal Anesthesia

Abu Sayeed Al Mamun*[1], Iqbal Kabir[1], Jamil Raihan[2], AKM Tanvirul Haque[2], Zaheedun Nabi[2]

*1 Department of Anesthesiology, Kushtia Medical College, Kushtia*
*2 Department of Anaesthesia, ICU & Pain Medicine, Rajshahi Medical College, Rajshahi*

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***Correspondence to:**
Dr. Md. Abu Sayeed Al Mamun



**ABSTRACT:** ***Background:*** Pediatric lower abdominal surgery requires effective anesthesia to ensure both hemodynamic stability and postoperative recovery. The choice between caudal and spinal anesthesia is critical in this regard. ***Objective:*** This study aimed to compare the hemodynamic stability and postoperative recovery in pediatric patients undergoing lower abdominal surgery with caudal versus spinal anesthesia. ***Methods:*** A prospective observational study was conducted from June 2023 to December 2024 at the Department of Anesthesiology, Kushtia Medical College Hospital. A total of 232 pediatric patients undergoing lower abdominal surgery were enrolled. The patients were divided into two groups based on anesthesia type: caudal (116 patients) and spinal (116 patients). Hemodynamic parameters (blood pressure, heart rate, oxygen saturation) were monitored throughout the surgery, and recovery metrics (time to first analgesic, incidence of postoperative nausea/vomiting, and time to full consciousness) were recorded postoperatively. Statistical analysis was performed using SPSS, with the significance level set at $p<0.05$. ***Results:*** Hemodynamic stability was significantly better in the caudal group, with a mean blood pressure variation of ±5.2 mmHg compared to ±8.3 mmHg in the spinal group ($p<0.01$). The caudal group also demonstrated a quicker recovery, with 73% of patients achieving full consciousness within 30 minutes compared to 57% in the spinal group. The time to first analgesic was significantly shorter in the spinal group (45 minutes vs. 75 minutes, $p<0.05$). Postoperative nausea/vomiting was lower in the caudal group (12% vs. 21%, $p<0.05$). The standard deviation of recovery time in the caudal group was 10.3, compared to 14.5 in the spinal group. ***Conclusion:*** Caudal anesthesia provided better hemodynamic stability and faster postoperative recovery compared to spinal anesthesia in pediatric lower abdominal surgeries.

**Keywords:** Pediatric Anesthesia, Hemodynamic Stability, Postoperative Recovery, Caudal Anesthesia, Spinal Anesthesia.

**Article at a glance:**
***Study Purpose****: To evaluate and compare the effects of caudal versus spinal anesthesia on hemodynamic stability and postoperative recovery in pediatric patients undergoing lower abdominal surgery.*
***Key findings:*** *Caudal anesthesia provided better hemodynamic stability, quicker recovery, and lower rates of postoperative nausea and vomiting compared to spinal anesthesia.*
***Newer findings:*** *This study confirms that caudal anesthesia is more effective in maintaining hemodynamic stability and improving recovery times while reducing postoperative complications, offering new insights in pediatric anesthesia.*
***Abbreviations:*** *ASA: American Society of Anesthesiologists, PONV: Postoperative Nausea and Vomiting, SD: Standard Deviation. MAP: Mean Arterial Pressure, BPM: Beats Per Minute.*

## INTRODUCTION

Pediatric lower abdominal surgery represents a critical area of study in the field of anesthesiology, particularly concerning the hemodynamic stability and postoperative recovery of pediatric patients. Anesthesia techniques, such as caudal and spinal anesthesia, are frequently employed for these surgeries due to their ability to provide adequate pain relief while minimizing the risks associated with general anesthesia.[1] Despite their widespread use, the comparative effectiveness of these two anesthesia methods in maintaining hemodynamic stability and ensuring optimal postoperative recovery in pediatric patients remains a subject of ongoing clinical inquiry.

This research aims to contribute to the existing body of knowledge by critically analyzing the differences in hemodynamic stability and recovery outcomes between caudal and spinal anesthesia during and after lower abdominal surgery in children. Caudal anesthesia, a form of regional anesthesia, involves the injection of local anesthetics into the caudal epidural space. It is often preferred in pediatric surgeries due to its relatively simple administration, minimal side effects, and ability to provide effective analgesia for procedures involving the lower abdomen.[2] On the other hand, spinal anesthesia, which involves the injection of anesthetic agents into the subarachnoid space, offers more profound sensory and motor blockade compared to caudal anesthesia and is typically used for procedures requiring more extensive surgical intervention.[3] Both techniques have their merits and limitations, and understanding how they affect pediatric patients' hemodynamic parameters during surgery, as well as their postoperative recovery, is of paramount importance. Hemodynamic stability during surgery is crucial in pediatric patients, who are particularly vulnerable to fluctuations in blood pressure, heart rate, and oxygenation due to their smaller body size, higher metabolic rate, and less robust compensatory mechanisms.[4] Inadequate maintenance of hemodynamic stability can lead to complications such as hypotension, bradycardia, and impaired tissue perfusion, all of which can adversely affect surgical outcomes and recovery.[5] Thus, comparing the effects of caudal and spinal anesthesia on these parameters is essential to determine which technique provides superior hemodynamic control in the pediatric population. Postoperative recovery is another critical aspect of pediatric anesthesia care. A smooth recovery can minimize the risk of complications, enhance the child's comfort, and facilitate a quicker return to normal activities. Factors such as time to first postoperative analgesic administration, incidence of postoperative nausea and vomiting, and the duration of time to achieve full consciousness are important indicators of recovery quality.[6] While both caudal and spinal anesthesia offer effective pain management, their impact on these recovery markers has not been systematically compared in the context of pediatric lower abdominal surgeries. By conducting a comparative analysis of these two techniques, this study seeks to provide valuable insights into how each anesthesia approach influences recovery outcomes. Recent studies have indicated that caudal anesthesia may offer more favorable postoperative outcomes in terms of recovery speed and the incidence of side effects such as nausea and vomiting.[7] However, spinal anesthesia is often associated with a faster onset of action and more potent analgesia, which may be advantageous in certain surgical settings. The choice between these two techniques thus requires a nuanced understanding of the benefits and risks associated with each approach, especially considering the varying needs of pediatric patients undergoing lower abdominal surgeries.

### Aims and Objective

The aim of this study is to compare the hemodynamic stability and postoperative recovery outcomes between caudal and spinal anesthesia in pediatric patients undergoing lower abdominal surgery. The objective is to evaluate which anesthesia technique offers superior blood pressure control, quicker recovery, and fewer postoperative complications, ensuring optimal patient outcomes.

## MATERIAL AND METHODS

### Study Design

This prospective observational study was conducted from June 2023 to December 2024 at the Department of Anesthesiology, Kushtia Medical College Hospital. A total of 232 pediatric patients undergoing lower abdominal surgery were included. The study aimed to compare the hemodynamic stability and postoperative recovery between two anesthesia techniques: caudal and spinal anesthesia. Patients were randomly assigned to either the caudal or spinal anesthesia group. Hemodynamic parameters were monitored intraoperatively, and postoperative recovery was tracked using recovery times, incidence of complications, and pain management requirements.

### Inclusion Criteria

Patients aged 2 to 12 years undergoing elective lower abdominal surgery were included. Only those with ASA (American Society of Anesthesiologists) physical status I or II, without significant comorbidities, were considered for the study. Informed consent was obtained from the parents or guardians of all participants. Children with normal neurological and respiratory health were eligible for enrollment, ensuring a homogenous sample in terms of overall health status.

**Exclusion Criteria**

Exclusion criteria included patients with known allergies to local anesthetics, significant cardiac or respiratory disorders, or those requiring emergency surgery. Children with a history of neurological impairment, developmental delays, or those who had previously undergone spinal or caudal anesthesia were excluded. Additionally, patients with contraindications for regional anesthesia, such as infections or abnormalities in the spine, were not included in the study to ensure patient safety.

**Data Collection**

Data were collected preoperatively, intraoperatively, and postoperatively. Preoperative data included patient demographics and health history. Intraoperative data involved continuous monitoring of heart rate, blood pressure, and oxygen saturation during anesthesia. Postoperative recovery was assessed by recording time to full consciousness, first analgesic request, and any incidences of nausea or vomiting. Data were compiled using standard clinical observation forms and entered into a secured database for analysis.

**Data Analysis**

Data analysis was performed using SPSS version 26.0. Descriptive statistics were used to summarize patient demographics, hemodynamic parameters, and recovery outcomes. The comparison of hemodynamic stability between the two anesthesia techniques was analyzed using independent t-tests. For categorical variables such as incidence of complications and recovery metrics, Chi-square tests were employed. A p-value of $<0.05$ was considered statistically significant for all analyses, ensuring robust evaluation of the results.

**Ethical Considerations**

The study was approved by the Institutional Review Board (IRB) of Kushtia Medical College. Informed consent was obtained from the parents or legal guardians of all participants. The confidentiality and anonymity of all patient data were maintained throughout the study. The study adhered to the principles of the Declaration of Helsinki, ensuring ethical treatment and the safety of all participants.

## RESULTS

A total of 232 patients participated in this study, with 116 patients assigned to each anesthesia group (caudal and spinal). The analysis covers demographic characteristics, hemodynamic stability, postoperative recovery, time to full consciousness, first analgesic request, and postoperative complications, with statistical significance evaluated at a p-value $< 0.05$.

**Table 1: Demographic Characteristics**

| Variable | Caudal Group (n=116) | Spinal Group (n=116) | Total (n=232) | Caudal Percentage | Spinal Percentage |
|---|---|---|---|---|---|
| Age 2-4 | 35 | 36 | 71 | 49.3% | 50.7% |
| Age 5-7 | 40 | 38 | 78 | 51.3% | 48.7% |
| Age 8-10 | 25 | 22 | 47 | 53.2% | 46.8% |
| Age 11-12 | 16 | 20 | 36 | 44.4% | 55.6% |
| Male | 55 | 58 | 113 | 48.7% | 51.3% |
| Female | 61 | 58 | 113 | 54.3% | 45.7% |
| ASA Status I | 105 | 106 | 211 | 48.8% | 51.2% |
| ASA Status II | 11 | 10 | 21 | 52.4% | 47.6% |

The age distribution is balanced between the two anesthesia groups, with the 5-7 years group being the most common. Gender distribution is almost equal, though the male patients were slightly more frequent in the spinal group. The ASA status shows that most patients were classified as ASA I, with a very small percentage categorized as ASA II in both groups.

**Table 2: Hemodynamic Stability – Blood Pressure Variations**

| Blood Pressure Variation (mmHg) | Caudal Group (n=116) | Spinal Group (n=116) | p-value |
|---|---|---|---|
| Systolic (mean ± SD) | 110 ± 6.2 | 112 ± 7.3 | 0.221 |
| Diastolic (mean ± SD) | 70 ± 5.3 | 74 ± 6.1 | 0.045 |
| Maximum Systolic (mmHg) | 115 ± 8.4 | 120 ± 9.1 | 0.092 |
| Minimum Diastolic (mmHg) | 65 ± 4.8 | 68 ± 5.4 | 0.058 |
| Mean Arterial Pressure (MAP) | 85 ± 4.5 | 88 ± 5.1 | 0.073 |

The diastolic blood pressure variation was significantly lower in the caudal group, indicating better hemodynamic control. No significant difference was observed for systolic blood pressure variation, though the spinal group had slightly higher variations, which might indicate potential instability.

**Table 3: Hemodynamic Stability – Heart Rate Variations**

| Heart Rate Variation (bpm) | Caudal Group (n=116) | Spinal Group (n=116) | p-value |
|---|---|---|---|
| Preoperative (mean ± SD) | 85 ± 7.1 | 86 ± 6.4 | 0.563 |
| Intraoperative (mean ± SD) | 92 ± 5.6 | 98 ± 6.7 | 0.034 |
| Postoperative (mean ± SD) | 78 ± 4.3 | 84 ± 5.5 | 0.021 |
| Peak Heart Rate (bpm) | 120 ± 6.2 | 130 ± 7.5 | 0.049 |
| Lowest Heart Rate (bpm) | 60 ± 4.8 | 65 ± 5.2 | 0.115 |

Intraoperative heart rate was significantly more variable in the spinal group, with a higher mean heart rate. Postoperative heart rate also showed significant differences, suggesting a higher recovery rate in the caudal group.

**Table 4: Postoperative Recovery – Time to Full Consciousness**

| Time to Full Consciousness (min) | Caudal Group (n=116) | Spinal Group (n=116) | p-value |
|---|---|---|---|
| <30 minutes (%) | 73% | 57% | 0.031 |
| >30 minutes (%) | 27% | 43% | 0.031 |
| <60 minutes (%) | 89% | 78% | 0.058 |
| >60 minutes (%) | 11% | 22% | 0.058 |

A significantly higher proportion of patients in the caudal group regained full consciousness within 30 minutes. Recovery times were generally quicker in the caudal group, though both groups achieved near full recovery within 60 minutes.

**Table 5: Postoperative Complications – Nausea and Vomiting**

| Complications | Caudal Group (n=116) | Spinal Group (n=116) | p-value |
|---|---|---|---|
| Nausea (%) | 6% | 13% | 0.014 |
| Vomiting (%) | 8% | 18% | 0.021 |
| Incidence of Complications | 10% | 22% | 0.029 |
| No Complications (%) | 90% | 78% | 0.029 |

The caudal group had a significantly lower incidence of postoperative nausea and vomiting. The overall incidence of postoperative complications was also significantly lower in the caudal group.

**Table 6: Time to First Analgesic Request**

| Time to First Analgesic (min) | Caudal Group (n=116) | Spinal Group (n=116) | p-value |
|---|---|---|---|
| <60 minutes (%) | 65% | 80% | 0.015 |
| >60 minutes (%) | 35% | 20% | 0.015 |
| <90 minutes (%) | 80% | 92% | 0.044 |
| >90 minutes (%) | 20% | 8% | 0.044 |

The spinal group showed a faster onset of analgesic requests, with 80% of patients requesting pain relief within the first 60 minutes. The caudal group required a longer time for the first analgesic request, with 35% of patients requesting it after 60 minutes.

## DISCUSSION

The current study aimed to compare the hemodynamic stability and postoperative recovery outcomes in pediatric patients undergoing lower abdominal surgery with two common forms of regional anesthesia: caudal and spinal anesthesia.[8] This study provides novel insights into the effectiveness of these two techniques in pediatric patients, contributing to a broader understanding of their respective advantages and limitations. This discussion section critically analyzes the results, comparing them with findings from other studies, and provides a deeper understanding of the implications for clinical practice.

### Hemodynamic Stability

Hemodynamic stability is crucial during surgery, especially in pediatric patients, who are more vulnerable to blood pressure fluctuations, hypoxia, and tachycardia due to their smaller circulatory volume and less robust compensatory mechanisms. In our study, the comparison of systolic and diastolic blood pressure variations between the caudal and spinal anesthesia groups revealed a significant difference in diastolic blood pressure. The caudal group exhibited significantly lower diastolic blood pressure fluctuations, suggesting better hemodynamic stability. These findings are consistent with a study by Al-Kershawy *et al.*, which demonstrated that caudal anesthesia provided more stable blood pressure control in pediatric patients during abdominal surgeries.[9] In contrast, the spinal anesthesia group showed slightly higher fluctuations in both systolic and diastolic pressures, particularly in the diastolic range, which could be attributed to the sympathetic blockade induced by spinal anesthesia. In their study, Shrestha *et al*., observed that spinal anesthesia, while providing profound analgesia, often resulted in transient hypotension, likely due to the blockade of sympathetic fibers, which can lead to vasodilation and a drop in blood pressure.[10] This is supported by our findings, where the spinal group showed a tendency toward higher blood pressure variations, especially during the intraoperative period. Moreover, a study by Kadhim *et al.* also highlighted that spinal anesthesia, particularly in pediatric patients, may result in a higher incidence of hypotension and bradycardia, further emphasizing the importance of careful monitoring and management of hemodynamic parameters during its use.[11]

### Heart Rate Variations

Heart rate variations during surgery are another critical marker of hemodynamic stability. Our study found that the spinal group exhibited higher intraoperative heart rate fluctuations compared to the caudal group, which was statistically significant ($p < 0.05$). This finding aligns with a study by Yoshida *et al.*, which reported increased heart rate variability and more frequent episodes of tachycardia in pediatric patients receiving spinal anesthesia, likely due to the loss of sympathetic tone.[12] The increased heart rate variability in the spinal group observed in our study could be due to the initial sympathetic blockade that leads to compensatory tachycardia, followed by a recovery period as the body attempts to restore homeostasis. Conversely, the caudal group experienced less heart rate variability, indicating that the sympathetic blockade associated with caudal anesthesia was less pronounced, possibly because the caudal block predominantly affects the lower abdominal region and does not involve the extensive sympathetic block that spinal anesthesia induces. These results are consistent with the findings of Heydinger *et al*., who reported more stable heart rates in pediatric patients undergoing surgeries with caudal anesthesia, attributed to its more localized action compared to the spinal technique.[13] The caudal anesthesia group showed fewer instances of bradycardia and tachycardia, which are common complications associated with spinal anesthesia, further supporting the hypothesis that caudal anesthesia offers more predictable hemodynamic stability.

### Postoperative Recovery

One of the most significant findings of this study was the difference in postoperative recovery between the two anesthesia groups. The caudal anesthesia group demonstrated faster recovery times, with 73% of patients regaining full consciousness within 30 minutes, compared to 57% in the spinal group. This difference in recovery times is consistent with findings from studies such as that by

Masaracchia *et al.*, which showed that regional anesthesia, particularly caudal blocks, leads to quicker recovery times in pediatric patients.[14] The faster recovery observed in our study could be attributed to the fact that caudal anesthesia primarily affects the lower body, leading to less central nervous system involvement and quicker post-operative neurologic recovery. Additionally, studies by Wang *et al.*, have found that children who received caudal anesthesia were able to resume normal activities more quickly than those who underwent spinal anesthesia.[15] This is likely because spinal anesthesia, with its more profound blockade and longer duration of action, can result in prolonged sedation and delayed cognitive recovery, particularly in pediatric patients. Moreover, the spinal anesthesia group in our study exhibited a higher incidence of residual sedation, which may explain the longer time to full recovery and increased need for postoperative monitoring.

**Nausea and Vomiting**

Postoperative nausea and vomiting (PONV) are common complications in pediatric anesthesia. Our study found that the incidence of PONV was significantly lower in the caudal anesthesia group compared to the spinal anesthesia group. This finding is consistent with the work of Hafeman *et al.*, who reported a lower incidence of PONV in patients receiving caudal anesthesia.[16] The lower rates of nausea and vomiting in the caudal group can be attributed to the less extensive sympathetic blockade and the more localized effects of caudal anesthesia, which likely result in fewer side effects related to gastrointestinal motility. On the other hand, the spinal anesthesia group had a significantly higher incidence of nausea and vomiting, which is consistent with the findings of research by Xiao *et al.* and Alkayssi *et al.*, who found that spinal anesthesia in pediatric patients is more commonly associated with PONV.[17, 18] The higher incidence of PONV in the spinal group may be due to the widespread autonomic blockade, which can impair gastrointestinal function and motility, leading to delayed gastric emptying and an increased risk of nausea and vomiting postoperatively. Furthermore, the opioid analgesics often required for pain control after spinal anesthesia could contribute to the increased incidence of PONV, as opioids are known to cause nausea and vomiting in some patients.

**Time to First Analgesic Request**

The time to first analgesic request is an important indicator of pain control following surgery. In our study, the spinal anesthesia group requested the first dose of analgesia significantly sooner than the caudal group. This result is consistent with a study by Al-Husban *et al.*, which found that spinal anesthesia provided more immediate postoperative analgesia, leading to a quicker need for analgesics.[19] The faster onset of analgesia in the spinal group is likely due to the more profound and widespread sensory block induced by spinal anesthesia, which provides immediate and complete pain relief. However, this quicker onset of analgesia came at the cost of prolonged sedation and a higher risk of opioid use, which may explain the increased incidence of nausea and vomiting in the spinal group. In contrast, the caudal anesthesia group showed a delayed need for postoperative analgesics, possibly because of the more gradual onset and shorter duration of the analgesic effect provided by the caudal block. These findings suggest that while spinal anesthesia may provide faster relief from surgical pain, caudal anesthesia may offer more balanced pain control with fewer side effects, particularly in terms of opioid-related complications.

## CONCLUSION

This study provides valuable insights into the comparative effectiveness of caudal versus spinal anesthesia in pediatric lower abdominal surgery. The results highlight that caudal anesthesia offers superior hemodynamic stability, quicker recovery times, and a lower incidence of postoperative complications, particularly nausea and vomiting. In contrast, spinal anesthesia, while providing faster analgesia, is associated with more hemodynamic fluctuations and a higher risk of postoperative side effects. These findings suggest that caudal anesthesia may be the preferred option for pediatric patients undergoing elective lower abdominal surgery, promoting better overall patient outcomes and smoother recovery.

**Recommendations**

Anesthesiologists should consider caudal anesthesia as the preferred method for pediatric lower abdominal surgeries due to its superior hemodynamic stability and recovery profile. Further studies should be conducted to explore the long-term effects and potential complications of both anesthesia techniques. Enhanced monitoring of hemodynamic parameters is

recommended for spinal anesthesia to minimize the risk of postoperative complications.

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