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Use of Perfusion index as a predictor of successful caudal block in pediatric patients in tertiary care center: Prospective comparative study

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ABSTRACT

Introduction: Caudal block is a common regional anesthesia technique in children, especially for lower abdominal surgeries. However, its success can be variable. The perfusion index (PI), a non-invasive parameter, has been suggested as a potential early indicator of block effectiveness.

Objectives: To evaluate whether the PI can serve as an early, non-invasive predictor of successful caudal block in pediatric patients and to compare hemodynamic parameters between those receiving general anesthesia with or without a caudal block.

Methodology: Sixty children undergoing elective lower abdominal surgery were divided into two groups of 30 each. Group C received a caudal block after general anesthesia, while Group G received general anesthesia alone. PI, heart rate (HR), and mean arterial pressure (MAP) were recorded at baseline and at 5, 10, 15, and 20 minutes after induction.

Results: Group C showed a significantly higher PI from 5 minutes post-induction compared to Group G. At T5, the mean PI was 5.63 ± 1.217 in Group C versus 4.57 ± 1.431 in Group G (P = 0.003), with similar trends at subsequent intervals (P < 0.05). Group C also demonstrated significantly lower HR and MAP, indicating better hemodynamic stability.

Conclusion: The perfusion index is an early and reliable indicator of caudal block success in pediatric patients. Its routine monitoring may enhance clinical assessment and support timely anesthetic decision-making.

Keywords: Caudal Block; Paediatric Anesthesia; Perfusion Index

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INTRODUCTION

Caudal block is a widely used regional anesthesia technique for infra-umbilical procedures in children, typically administered under general anesthesia.[1] Its safety and efficacy have been well documented, supporting its use across a broad pediatric age range from extremely premature infants to children weighing up to 50 kilograms.[2,3] The first documented use of caudal anesthesia in children dates back to 1933, credited to Meredith Campbell.[4]

Despite its 75% success rate, approximately 4% of cases fail due to anatomical variations or technical difficulties. Current evaluation methods—relying on delayed hemodynamic changes (e.g., heart rate, blood pressure) or physical signs (e.g., anal sphincter relaxation)—are subjective and impractical under general anesthesia. This creates a critical gap in real-time, objective monitoring of block efficacy, particularly in children who cannot provide verbal feedback during procedures.[1,5]

In infants, the spinal cord ends around the L3–L4 level, and the dural sac around S3–S4, which migrates upward during the first year of life. This anatomical feature can pose a risk of dural puncture during caudal block in very young children. The landmark-based approach remains the most frequently employed method for this block.[6]

The perfusion index (PI), derived from pulse oximetry, offers a promising solution by quantifying peripheral perfusion changes caused by sympathetic blockade-induced vasodilation.[7] The perfusion index (PI): non-invasive measure derived from pulse oximetry reflects the ratio of pulsatile arterial flow to non-pulsatile flow from capillaries and tissues. It relies on spectrophotometric detection of infrared light (typically 940 nm) emitted and reflected at monitoring sites such as the finger or toe. PI values can range from as low as 0.02% to as high as 20%, representing weak to strong pulse strength.[8]

Its non-invasive nature, combined with real-time monitoring capabilities, addresses the limitations of conventional techniques while aligning with pediatric patients' unique physiological needs. This study builds on emerging evidence that PI may serve as the fastest available indicator of successful regional anesthesia.[9] Unlike traditional methods, PI detects physiological changes within minutes of block administration, as evidenced by prior studies.[10]

METHODOLOGY

A prospective comparative observational study was carried out at Kathmandu Medical College from September 2024 to December 2024 following approval from the Institutional Ethical Committee of Kathmandu Medical College Public Limited (Ref. No: 05082024/04.) The sample size was calculated with the assumption that a 1-unit difference in PI would be clinically meaningful.[10] Using a power of 90%, an alpha value of 0.05, and A sample size of 24 per group was required to detect an effect size of 0.67.To accommodate a possible 20% dropout, 30 participants were enrolled in each group. Sixty pediatric patients between 2 and 15 years of age, classified as American Society of Anesthesiologists (ASA) physical status I or II, scheduled for elective lower abdominal surgeries. Were included in the study . Patient Refusal, known neurological disorders, coagulopathies, spinal deformities, local infections at the injection site, history of allergic reactions to study medications, and patients undergoing anorectal procedures were excluded from the study.

All patients underwent a detailed pre-anesthetic assessment that included medical history, physical examination, and routine laboratory tests. Written informed consent was obtained from the legal guardians prior to enrollment. Fasting guidelines were adhered to, with patients restricted from solids for six hours, breast milk for four hours, and clear fluids for two hours prior to anesthesia.

All ASA-II Standard monitors (Heart Rate, Mean Arterial Pressure, Temperature, Electrocardiogram) were connected upon the patient's arrival in the operating room. The perfusion index (PI) was measured using a Masimo Radical-7 SET® monitor with the probe attached to the left second toe and cushioned with a sponge to reduce interference. Baseline recordings of PI, heart rate, and mean arterial pressure were taken and marked as T0. Intravenous fluid management was standardized using Ringer lactate. Every alternate patient was divided into two groups i.e. caudal block group Group C (n = 30) received a caudal block following induction of general anesthesia and general group i.e. group G, (n = 30) received only general anesthesia. Every odd numbered cases were assigned to Group C and even numbered cases were assigned to group G.

General anesthesia induction involved preoxygenation followed by administration of intravenous midazolam (0.05 mg/kg), ketamine (0.25–0.5 mg/kg), fentanyl (1–2 mcg/kg), and propofol (1–2 mg/kg), with vecuronium (0.1 mg/kg) given as needed. A suitable airway device was inserted, and anesthesia was maintained with a mixture of oxygen, air, and isoflurane, titrated to a MAC of one.

In Group C, the caudal block was performed with the patient in the lateral position using 0.75 ml/kg of 0.25% bupivacaine, with a maximum total volume of 20 ml. Group G received no regional block. At 5, 10, 15, and 20 minutes after induction, PI, HR, and MAP were assessed in both groups and marked as T5, T10, T15, and T20, respectively. All surgical procedures commenced 20 minutes after induction. Data collection was performed by a junior resident, while all caudal blocks were administered by a study investigator to ensure consistency.

Data analysis was conducted using IBM Corp. IBM SPSS Statistics for Windows, Version 17.0. Armonk, NY. Continuous variables were reported as mean ± standard deviation (SD), while categorical data were presented as frequencies and percentages. The normality of data distribution was evaluated before applying appropriate statistical tests. For comparisons between groups, the independent t-test was used for normally distributed variables, while the Mann–Whitney U test was used for non-normal distributions.

Categorical data were analyzed using either the Chi-square test or Fischer's exact test. A p-value less than 0.05 were considered statistically significant.

RESULTS

A total of 60 children participated in the study and were randomly assigned to two groups. There were no statistically significant differences between the groups as regard to demographic data (Table 1). Perfusion index (PI) measurements revealed no significant difference between the groups at baseline (T0). However, from 5 minutes post-induction (T5) onward, Group C demonstrated significantly higher PI values compared to Group G. At T5, the mean PI in Group C was 5.63 ± 1.217 versus 4.57 ± 1.431 in Group G (P = 0.003). This trend persisted at subsequent time points (T10, T15, T20), with Group C maintaining higher PI values (all P < 0.05) (Table 2).Heart rate (HR) and mean arterial pressure (MAP) were comparable at baseline. From T5 onward, Group G exhibited significantly higher HR and MAP values than Group C (all P < 0.05). For HR, Group C showed lower values at all post-baseline time points (e.g., T5: 103.87 ± 11.281 vs. 113.33 ± 11.281 in Group G, P = 0.004). Similarly, MAP in Group C remained lower than in Group G from T5 to T20 (e.g., T5: 86.72 ± 7.103 vs. 91.51 ± 6.948, P = 0.022) (Tables 3 and 4). Statistically significant differences in HR were observed between Group C (caudal block) and Group G (general anesthesia alone) at all post-baseline time points (T5–T20), with P < 0.05. Group C consistently exhibited lower HR values compared to Group G. (Table 3) Mean arterial pressure (MAP) was measured and compared between the two groups at five time points: T0, T5, T10, T15, and T20. At baseline (T0), there was no difference in MAP between Group C and Group G (P = 0.342). However, from T5 onward, Group G consistently exhibited significantly higher MAP values compared to Group C. This trend persisted across all post-baseline time points (P < 0.05), indicating a sustained hemodynamic difference between the groups Table 4. Statistically significant differences in MAP were observed at all post-baseline time points (T5–T20), with Group C consistently exhibiting lower MAP values compared to Group G (P < 0.05 for all comparisons).

Table 1: Demographic data among both groups

Demographic data	Group C (n=30)	Group G (n=30)	p-value
Mean age (years)	6.49±3.492	6.237±6.237	0.41
Mean weight (Kgs)	19.86± 6.4420	20.41±8.4813	0.78
Male	28 (93.33%)	26 (86.66%)	0.74
Female	2 (6.66%)	4 (13.33%)	

Table 2: Distribution of perfusion index (PI) among groups

Time points	PI (Mean±SD)		p- value
	Group C	Group G	
T0	4.70±1.088	4.30±1.343	0.21
T5	5.63±1.217	4.57±1.431	0.003*
T10	6.13±1.196	4.90±1.689	0.002 *
T15	6.30±1.489	5.03±1.245	0.001*

p-value significant <0.05 * = Independent t test

Table 3: Distribution of heart rate (HR) among groups

Time points	HR (Mean ± SD)		p-value
	Group C	Group G	
T0	105.90±8.817	109.23±12.508	0.238
T5	103.87±11.281	113.33±11.281	0.004
T10	102.37±13.606	112.73±11.423	0.002*
T15	101.53 ± 12.103	111.03 ± 10.287	0.001*

p-value significant <0.05 * = Independent t test

Table 4: Distribution of Mean arterial pressure (MAP) among groups

Time points	MAP (Mean ± SD)		p- value
	Group C	Group G	
T0	85.90 ± 6.517	88.23 ± 7.204	0.342
T5	86.72 ± 7.103	91.51 ± 6.948	0.022*
T10	87.56 ± 7.312	92.65 ± 7.101	0.013*
T15	88.12 ± 6.912	93.04 ± 7.413	0.008*
T20	89.13 ± 6.603	94.02 ± 6.312	0.002*

p-value significant <0.05 * = Independent t test

DISCUSSION

This observational study was conducted to evaluate the utility of the perfusion index (PI) as an early and objective predictor of successful caudal block in pediatric patients. The study involved 60 children divided into two groups, and it focused on the comparative analysis of PI, heart rate (HR), and mean arterial pressure (MAP) across different time intervals following caudal block administration.

At baseline (T0), the PI values between the two groups were comparable, indicating that pre-block perfusion status was similar. However, from 5 minutes post-block (T5) onward, Group C, which was presumed to have a successful caudal block, showed a significant and sustained increase in PI compared to Group G. This progressive rise in PI is consistent with the result seen by Rajan K et. al in which 23 of 25 patients with working caudal had increased PI at all time intervals (P<0.0001).[11]

The ability of PI to detect changes in peripheral perfusion rapidly makes it a valuable non-invasive tool, particularly in pediatric patients where traditional indicators of block success such as a drop in HR or MAP, anal sphincter relaxation, or loss of cremasteric reflex can be unreliable under deep sedation or general anesthesia.[12] These conventional signs often have a delayed onset and are challenging to assess objectively in anesthetized children, limiting their utility in real-time block assessment.

In contrast, PI offers continuous, real-time feedback and can detect subtle changes in peripheral blood flow that may not yet be reflected in systemic hemodynamic parameters. In our study, Group C consistently demonstrated higher PI values at T5, T10, T15, and T20, strongly suggesting that PI changes precede or at least coincide with the clinical effectiveness of the block. Vashishth S et. al had similar finding of increased PI trend from 5 to 20 minutes in patient receiving caudal (P=0.001).[10] Rajan K et. al had also shown an increase in PI at all time intervals till 20 minutes & an increase of 100 % of PI at 10 minutes.[11] Hence, PI can be a sensitive marker for detecting sympathetic blockade and regional anesthesia efficacy.

Moreover, HR and MAP did show statistically significant differences between the two groups from T5 onward further supporting the success of the caudal block in Group C. In the study by Khan et al. (2024) and Kumar et al. (2013), both heart rate (HR) and mean arterial pressure (MAP) demonstrated statistically significant differences between the groups from time point T5 onward, further supporting the effectiveness of caudal blocks in pediatric patients under general anesthesia. These findings align with the results of our study as well while traditional clinical indicators such as HR and MAP are commonly used to assess the adequacy of regional anesthesia, they may not always provide timely and precise confirmation of block success, particularly under deep anesthesia.[14,15]

The alterations in HR and MAP starting at T5 provide useful clinical markers for monitoring the initiation and progression of the caudal block. However, as the literature suggests, these physiological parameters may not be sensitive enough to detect early signs of block failure or incomplete block. The perfusion index (PI), a non-invasive marker derived from pulse oximetry, has shown potential as a more sensitive predictor in such cases. The PI has been highlighted in multiple studies (Vashishth et al., 2023 and Demi Rci C et al.,2024) as an early and reliable indicator for assessing the adequacy of regional blocks in pediatric anesthesia. This is especially important when considering pediatric patients, who may exhibit subtle changes in clinical signs compared to adults, and where rapid assessment is crucial for ensuring patient safety.[10,17]

Moreover, combining PI with traditional hemodynamic parameters such as HR and MAP could provide a more comprehensive approach to monitoring, enabling clinicians to detect both early block failure and hemodynamic changes that may indicate complications. This multidimensional monitoring approach could potentially reduce the need for more invasive methods or prolonged observation periods to confirm block success.[14]

In this study by its sample size. While the trends observed were statistically significant, future studies with larger populations and including direct confirmation of block success (example through sensory testing post-anesthesia) would strengthen the conclusions. Additionally, while PI was a useful predictor in this setting, its specificity and sensitivity across various patient populations and procedural types warrant further investigation.

CONCLUSION

In conclusion, the perfusion index emerges as a complementary and promising tool in predicting the success of caudal blocks in pediatric anesthesia. The integration of PI monitoring into routine clinical practice could enhance the accuracy and efficiency of anesthesia management, ultimately improving patient outcomes and safety.

It provides an objective, quantifiable measure that is easy to monitor and interpret without the need for invasive techniques or additional sedation-based assessments. Routine use of PI monitoring could improve clinical confidence in block success and aid in timely decision-making in perioperative care.

It is also an early marker for successful caudal block which can enhance perioperative care. Hemodynamic Changes due to successful caudal block can be masked by other factors, hence integration of PI in regular anesthetic management helps find block success even with varying hemodynamic parameters.

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