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Effectiveness of Perfusion index for Predicting Onset of Paediatric Caudal Block under Sevoflurane Anaesthesia

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Abstract:

Introduction: *The caudal block is widely used in paediatric day case surgery as a regional anaesthesia technique. Assessing the onset of caudal block can be challenging since paediatric surgeries are typically performed under general anaesthesia. Clinical signs and objective assessments may not provide timely or reliable feedback. The perfusion index (PI) is viewed as an early and efficient indicator for detecting the onset of caudal block.*

Methodology: *This observational study took place at the Department of Anaesthesia and Pain Medicine in Evercare Hospital Dhaka over 12 months after protocol approval. Purposive sampling was used to select 120 individuals, and detailed data were collected using a structured data collection sheet.*

Results: *In this study analyzing caudal anaesthesia, 10 patients (8.3%) were excluded, leaving data from 110 patients for analysis. Results show that Perfusion Index (PI) most promptly confirms the onset of caudal block, followed by loss of Cremasteric Reflex (CR), while Heart Rate (HR) and Mean Blood Pressure (MBP) reductions confirm it later. At 10 minutes, many patients show a e"100% increase in PI, with similar trends in other parameters. AUC values suggest moderate discriminatory ability for PI increase (0.364) and absent CR time (0.329) compared to HR and MBP. PI and CR slightly outperform HR and MBP in predicting successful caudal block, but parameter selection depends on clinical context and the importance of sensitivity, specificity, PPV, and NPV.*

Conclusion: *Perfusion index (PI) proves to be a reliable and continuous indicator for promptly identifying the initial stages of caudal block in paediatric patients undergoing general anaesthesia.*

Key Words: *Pulse Oximeter Perfusion Index (PI), cremasteric reflex (CR), Caudal Block in paediatrics, Sevoflurane Anaesthesia.*

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Introduction:

Regional anaesthesia techniques have become common in paediatric medical practice, with caudal and lumbar epidural blocks, as well as ilioinguinal, iliohypogastric, and penile nerve blocks, emerging as preferred choices. Among these techniques, caudal block stands out as particularly popular, especially for paediatric patients undergoing sub-umbilical surgeries. These surgeries typically include procedures in the abdominal, pelvic, genital, or lower limb regions, where prolonged strong analgesia isn't necessary postoperatively. Common surgeries where caudal anaesthesia is indicated include inguinal or umbilical herniorrhaphy, orchidopexy, hypospadias repair, and clubfoot surgery [1]. Caudal block is lauded for its simplicity, safety, and effectiveness in paediatric cases. [2]

Combining caudal block with general anaesthesia has been shown to reduce the need for inhalational or opioid agents during surgery. Additionally, combining sevoflurane anaesthesia with caudal block has demonstrated efficacy in reducing postoperative pain and preventing emergence agitation [3,4]. Sevoflurane, a widely used inhalational anesthetic, is valued for its rapid onset and offset, non-irritant odor, and low blood:gas partition coefficient. It provides precise control over anaesthesia depth and smooth induction and emergence from anaesthesia, making it particularly suitable for paediatric patients [5].

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Assessing the success of caudal block is crucial for optimizing anesthesia management in pediatric patients. Traditional methods like pinpricking or cold stimuli assessment may not provide fast or reliable feedback under deep sedation or general anesthesia [4,6-7]. However, advancements in pulse oximeter technology, particularly the measurement of perfusion index (PI), offer a promising solution. PI, which reflects the ratio of pulsatile to non-pulsatile blood flow at a monitoring site, has been shown to reliably indicate the onset of anesthesia [8]. An increase in PI signals successful anesthesia onset, while a lack of increase may indicate anesthesia failure [9]. PI measurement is non-invasive, objective, and can be easily integrated into routine patient monitoring during surgery [10], making it a valuable tool for assessing caudal block efficacy under sevoflurane anesthesia in pediatric patients.

In this study, our objective was to assess the efficacy of incorporating pulse oximeter perfusion index (PI) monitoring along with mean arterial pressure (MAP), heart rate (HR), and cremasteric reflex (CR) in detecting the onset of paediatric caudal block under Sevoflurane anaesthesia. The hypothesis posited was that utilizing PI monitoring via pulse oximetry would offer a valuable approach for promptly evaluating the initiation of Paediatric Caudal Block under Sevoflurane Anaesthesia. As the other clinical parameters that are traditionally used cannot always monitor the effectiveness under general anaesthesia.

Method and Study procedure:

This observational study was conducted after getting approval from the institutional Ethical Review Board. A total of 120 paediatric patients with American Society of Anesthesiologists (ASA) physical statuses I and II, scheduled for circumcision, were enrolled in the study from January 2023 to January 2024. 10 paitents were excluded due to failed reading. Parental written informed consent was obtained after approval from the Anesthetic Department's ethics committee. Exclusion criteria included a history of drug allergy, recent respiratory tract infection, and bronchial asthma, infection at the insertion site, neuromuscular disease, cerebral palsy, mental retardation, and bleeding disorders. Baseline measurements of heart rate (HR), mean arterial pressure (MAP), perfusion index (PI), and Creamastric Reflex (CR) were recorded preoperatively. Anaesthesia induction was achieved using 8% Sevoflurane via facemask, followed by maintenance with a mixture of oxygen, nitrous oxide. Standard monitoring was applied, and intravenous cannulation was performed after loss of consciousness. Propofol(1mg/kg) and Fentanyl(1mcg/min) were administered intravenously, and a laryngeal mask was inserted once jaw relaxation was achieved.

The caudal block was performed three minutes after anaesthesia induction with the patient in the left lateral decubitus position. The sacral hiatus was identified, and after careful cleaning, a needle was inserted until the sacro-coccygeal ligament was pierced [11]. A test dose of lidocaine was injected followed by slow administration of bupivacaine (0.2%) volume 0.5 ml/kg. Patients were then positioned supine, and vital signs were monitored at specified intervals. The PI was monitored using a pulse oximeter probe and compared across different time points. Creamastric Reflex (CR) was assessed by stroking the upper inner side of the thigh and observing the response.

Adequate caudal block was defined as a 100% increase in PI from baseline. The time taken for PI to increase by 100% or more from baseline was recorded. The other gold standard of clinical parameters are not always reliable under general anaesthesia and can be interpreted very late. On the other hand, PI has very swift onset and with recent advancements of pulse oximetry equipment can be seen very early. CR was considered absent in patients with adequate caudal block, and the time until CR loss was noted. Onset of caudal block was defined as a 15% decrease in HR or MAP from baseline. Patients experiencing a e"15% increase in HR or MAP after surgical stimulation with positive CR after 20 minutes were considered to have block failure and were excluded from the study. In case of block failure, supplemental doses of Fentanyl and injectable paracetamol were administered.

Data were collected, recorded, and analysed with the assistance of a statistician.

Result and observations:

Total numbers of 120 children were included in this prospective observational study. Children were selected according to inclusion and exclusion criteria. They were given General Anaesthesia (GA) with Laryngeal Mask Airway (LMA) as per standard protocol. Then all the patients received caudal block. Total ten (10) patients

were excluded as four of them had lost signal from pulse oximeter and six patients had block failure as per operational definition. So finally data of 110 patients were calculated as expressed as below:

Table-I

Demographical characteristic of the patients (n=120)

Character		Value
Age (years)		5.7±1.1
Weight (Kg)		18.7±2.3
ASA class	Class-I	95
	Class-II	15

Table I shows average age of the patients is 5.7 years, with a standard deviation of ±1.1 years. The average weight of the patients is 18.7 kg, with a standard deviation of ±2.3 kg.

Table-II

Excluded patient after caudal anaesthesia (n=120)

Criteria	Numbers	Percentage (%)
Failure of block	6	5%
Lost signal of PI	4	3.3%
Total	10	8.3%

Table II represents the reasons for excluding patients after caudal anaesthesia. The actual count of patients who were excluded based on each criterion.

Six patients (5%) were excluded due to failure of the caudal block. This could mean that the anaesthesia did not effectively block the targeted area or provide the intended pain relief.

Four patients (3.3%) were excluded because the signal of perfusion index (PI) was lost. This could indicate technical issues with monitoring equipment or complications during the procedure that led to the loss of signal.

Time to increased PI ≥100% from baseline: The mean time for the perfusion index (PI) to increase by 100% or more from baseline is 9.5 minutes, with a relatively low standard deviation (±2.4). This parameter shows the earliest confirmation of the caudal block among the listed parameters.

Time when cremasteric reflex (CR) lost was 12.8 minutes, with a slightly higher standard deviation (±2.5) compared to PI increase. CR loss confirms the caudal block slightly later than PI increase.

The mean time for heart rate (HR) to reduce by 15% or more from baseline is 16.5 minutes, with a standard deviation of ±3.2. This parameter confirms the caudal block later than both PI increase and CR loss.

The mean time for mean blood pressure (MBP) to reduce by 15% or more from baseline is 17.1 minutes, with a standard deviation of ±3.3. Similar to HR reduction, MBP reduction confirms the caudal block later compared to PI increase and CR loss.

Overall, the data suggests that PI increase confirms the caudal block earliest, followed by CR loss, while HR reduction and MBP reduction confirm it later. The low P values indicate statistically significant differences in mean time between the parameters, suggesting that these differences are unlikely to have occurred by chance.

- At 5 minutes post-caudal block, a small proportion of patients had a PI increase ≥100%, absent CR, HR reduction ≥15%, or MBP reduction ≥15%.

Table-III

Time of confirmation of caudal Block by various parameters (n=110)

Parameters	Mean time (minutes)	±SD	*p value
Time to increased PI ≥100% from baseline	9.5	2.4	0.001
Time when CR lost	12.8	2.5	0.001
Time to reduce HR ≥15% from baseline	16.5	3.2	0.001
Time to reduce MBP ≥15% from baseline	17.1	3.3	0.001

*t-test was done to analyze data

Table-IV

Comparison of numbers of patients having onset of caudal block at various interval (n=110)

Time	PI ≥100% increased	Absent CR	HR reduced ≥15%	MBP reduced ≥15%	*p value
5min	19 (17.3%)	3 (2.7%)	7(6.3%)	6 (5.5%)	0.004
10min	70 (63.7%)	15 (13.7%)	13 (11.8%)	11 (10%)	0.004
15min	16 (14.5%)	66 (60%)	21 (19.1%)	18 (16.3%)	0.004
20min	5 (4.5%)	26 (23.6%)	69 (62.8%)	75 (68.2%)	0.004

Data were present as numbers of patient and percentage showed within parenthesis. *ANOVA was done.

- By 10 minutes, a significant increase is observed in the number of patients experiencing PI increase ≥100%, while the numbers for other parameters also show a noticeable increase.

- At 15 minutes, there's a substantial increase in the number of patients with absent CR, while the numbers for other parameters vary.

- At 20 minutes, the number of patients with HR reduction ≥15% and MBP reduction ≥15% peaks, indicating a delayed onset for these parameters compared to PI increase and absent CR.

Overall, the data suggests variations in the onset time of different parameters related to the caudal block, with some showing earlier onset (PI increase) compared to others (HR and MBP reduction), which peak later. Additionally, the significant P values indicate statistically significant differences between the time intervals for each parameter.

Table-V

Area under the curve of Test result variables

Test result variables	Area under the curve
Time to increased PI ≥100%	0.364
Time of absent CR	0.329
Time to reduce HR ≥15%	0.246
Time to reduce MBP ≥15%	0.257

Time to increased PI ≥100% (0.364) represents the time taken for perfusion index (PI) was increased by 100% or more. The AUC value of 0.364 suggests that this variable has a moderate discriminatory ability.

Time of absent CR represents the time when cremasteric reflex (CR) was absent. The AUC value of 0.329 indicates that this variable also has a moderate discriminatory ability.

Time to reduce HR ≥15% (0.246) represents the time was taken to achieve a reduction in heart rate (HR) of 15% or more. The AUC value of 0.246 suggests that this variable has a relatively weaker discriminatory ability compared to the others.

Time to reduce MBP ≥15% (0.257) represents the time was taken to achieve a reduction in mean blood pressure (MBP) of 15% or more. The AUC value of 0.257 indicates that this variable also has a relatively weaker discriminatory ability.

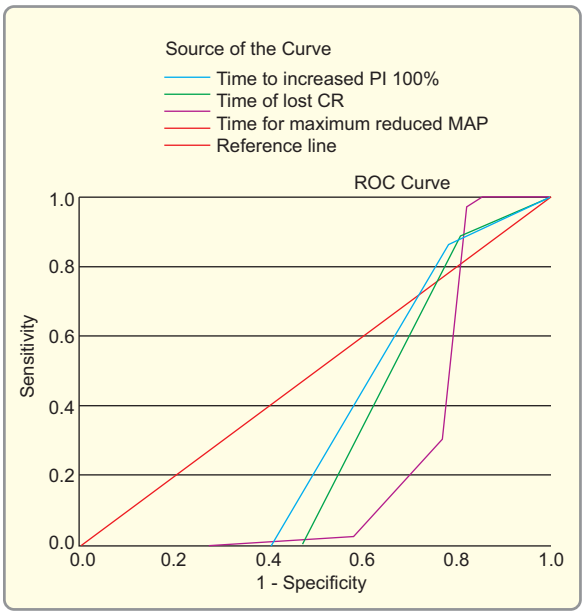

Figure 1: *ROC showing various parameters of onset of caudal block*

Table-IV

Ability of the various parameters to predict successful caudal block.

Parameter	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy	AUC (95% CL)
PI	94.6%	87.2%	94.3%	74%	91.8%	0.364
CR	90%	80%	92.3%	75%	87.7%	0.329
HR	90%	61.8%	84.1%	75%	81.8%	0.246
MBP	87.8%	73.5%	85.5%	73.5%	81.8%	0.257

In summary, the interpretation suggests that the first two variables (time to increased PI ≥100% and time of absent CR) have relatively better discriminatory abilities compared to the other variables, as indicated by their higher AUC values. The last two variables (time to reduce HR e"15% and time to reduce MBP ≥15%) have weaker discriminatory abilities, but all variables contribute to the overall assessment or understanding of the test results.

The table provides sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, and area under the curve (AUC) values for various parameters in predicting successful caudal block. Here's the interpretation:

PI shows high sensitivity and PPV, indicating that it correctly identifies a high proportion of successful caudal blocks and has a high probability of correctly predicting success when it does. However, its specificity is moderate.

CR also exhibits good sensitivity and PPV, along with moderate specificity. It correctly identifies a high proportion of successful caudal blocks and has a relatively high probability of correctly predicting success.

HR shows high sensitivity but lower specificity compared to PI and CR. This means it identifies most successful caudal blocks but also generates more false positives.

MBP demonstrates good sensitivity and moderate specificity, similar to HR. It has a slightly lower PPV compared to PI and CR.

In summary, all parameters have some predictive ability for successful caudal block, with PI and CR showing slightly better overall performance based on the AUC values. However, the choice of parameter may depend on the specific clinical context and the relative importance of sensitivity, specificity, PPV, and NPV in the given scenario.

Discussion

Most paediatric caudal blocks are administered under sedation or general anaesthesia. Sevoflurane and propofol are commonly used for inducing and maintaining general anaesthesia in children, but they both have vasodilatory effects. One study investigated the effects of 25 minutes of intermuscular sulcus block followed by anaesthesia induction using propofol and fentanyl, with sevoflurane used for maintenance. The results showed no significant difference in the perfusion index (PI) values between the two limbs, although baseline values were relatively high [12]. Sevoflurane is known to increase blood flow to muscle tissue, leading to an elevated PI value in the unblocked limb while the PI value in the blocked limb remains unchanged, indicating maximal vasodilation in the regional tissue. Another study found that PI values increased after general anaesthesia without regional block, using propofol for induction and sevoflurane for maintenance. Both propofol and sevoflurane anaesthesia influence PI values[8]. Currently, there is no research investigating changes in PI after caudal block following sevoflurane and propofol-based anaesthesia in children.

The timing data regarding confirmation of caudal block by different parameters shows that PI increase is the earliest indicator, followed by CR loss, with HR and MBP reductions confirming it later. Low P-values suggest statistically significant differences in mean time between these parameters, indicating these differences are not due to chance. At the 10-minute mark, there's a noticeable increase in patients showing a PI increase of ≥100%, with similar trends seen in other parameters.

AUC analysis indicates that time to increased PI e"100% and time of absent CR have better discriminatory abilities compared to other variables, with higher AUC values. PI exhibits high sensitivity and PPV, accurately identifying successful caudal blocks with a high likelihood of predicting success. However, its specificity is moderate. CR also demonstrates good sensitivity and PPV, with moderate specificity, accurately identifying successful caudal blocks with a relatively high probability of correctness.

Rajan and colleagues [13] conducted a study involving 25 children aged 1 to 6 years, where they administered a caudal block under general anaesthesia for postoperative pain management. They measured parameters such as mean arterial pressure (MAP), perfusion index (PI), and heart rate before and after the caudal block at various time points, including at the onset of skin incision. Their criteria for determining an effective block included a 15% decrease in MAP and heart rate, and a 100% increase in PI. Their findings suggested that PI was a more sensitive and early indicator of block effectiveness compared to heart rate and MAP [13]. Similarly, Umera et al.[10] conducted a comparable prospective study involving 40 children undergoing inguinal herniorrhaphy to assess the utility of PI monitoring in predicting the success of epidural block under general anaesthesia. A reduction in heart rate by 2 to 3 beats per minute during or shortly after the initial or complete caudal drug injection, along with the median perfusion index, proved to be reliable predictors of the success of caudal anaesthesia [14]. A study was carried out a prospective study involving 140 paediatric patients undergoing surgery under sevoflurane anaesthesia, with one group receiving a caudal block. The study aimed to evaluate the efficacy of perfusion index (PI) during the caudal block. Their findings revealed that the pulse oximeter PI showed a significant increase in the group that received the caudal block, indicating alterations in peripheral perfusion induced by the caudal block [3]. They concluded that the significant increase in PI reflected the vasodilation induced by the successful block, which was consistent with our findings.

Similar studies conducted by Ginosar et al. [15] and Bai et al. [16] also demonstrated comparable results with PI, although their comparison involved other parameters such as cremasteric reflex and skin temperature gradients. The loss of cremasteric reflex has long been considered a reliable indicator of a successful caudal block, but it applies only to male patients and often takes longer to manifest the effects of a caudal block. Cutaneous temperature recordings, including leg-to-toe temperature gradient, have been utilized as an effective indicator of sympathectomy. However, this approach is not always practical due to a lack of multiple temperature probes and standardization of ambient temperature [17,18].

The loss of the cremasteric reflex (CR) has traditionally been considered a more dependable indication of a successful caudal block. However, this indicator is applicable solely to male paediatric patients, and it typically takes longer to manifest the effects of the caudal block [19]. Researchers discovered that in 85% of the children studied, there was a more than 100% increase in PI on the toe within 5 minutes of administering the caudal block, while the cremasteric reflex remained intact in all twenty patients tested. By the 15-minute mark, only 45% of patients had experienced disappearance of the cremasteric reflex, though it disappeared in all patients after 20 minutes following the caudal block. In comparison to the cremasteric reflex, the researchers further demonstrated that PI was a timelier and objective indicator for detecting the early onset of caudal anaesthesia under ketamine anaesthesia, and it may be applicable to a broader patient population [20].

In this research, when examining other indicators like CR, HR, and MAP, it was noted that HR remained largely unchanged following the caudal block. While MAP did exhibit a significant decrease after 10 minutes, the magnitude of change was considerably smaller in comparison to PI. This implies that PI functions as a more sensitive and reliable early indicator for assessing the effectiveness of the caudal block when contrasted with other parameters. Conversely, the lack of a PI increase could signal to the anesthesiologist a potential insufficiency in the caudal block, prompting them to adjust and optimize the anaesthesia management strategy.

Conclusion:

Perfusion index (PI) is indeed an efficient, continuous, and dependable marker for detecting the early onset of caudal block in paediatric patients under general anaesthesia. Furthermore, measuring PI offers a quicker and more cost-effective means of assessing peripheral perfusion.

Limitation:

- Paediatric nerve blocks are commonly conducted under sedation or general anaesthesia. During various time intervals after the administration of sevoflurane or propofol, different situations may arise. For instance, when the vasodilatory effect of propofol is at its maximum, the perfusion index (PI) may reach its peak value. Consequently, following the administration of a nerve block, the PI may not further increase.
- There is agreement on the proposition that perfusion index (PI) effectively indicates the success of the block. However, it's important to acknowledge that PI values were measured at relatively broad time intervals.

Conflict of interest: None

Recommendation:

- Further investigation into PI monitoring is necessary for exploring its potential in various clinical scenarios where data on peripheral perfusion or circulatory status would be beneficial.

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