Original Article

Evaluation of perfusion index as a predictor of successful caudal block in pediatric patients: A prospective randomized study

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Abstract

Background and Aims: Caudal block is among the most widely administered regional anesthesia in pediatric patients. The clinical signs and objective assessments are not fast and reliable enough to provide a good feedback. Perfusion index (PI) is considered as a sensitive marker to assess the efficacy of caudal block. We aim to assess PI as an indicator for success of caudal block in pediatric patients.

Material and Methods: Sixty pediatric patients scheduled for elective surgery of lower abdomen and below were included. Patients were randomly allocated into two groups (n = 30): Group 1 received caudal block after general anesthesia and Group 2 only received general anesthesia. PI, heart rate, mean arterial pressure, and anal sphincter tone (AST) were recorded at 5, 10, 15, and 20 min following induction of anesthesia.

Results: A persistent increase in the PI value was observed in Group 1 starting from 5 min till 20 min, as compared to Group 2, at all the time intervals. When mean PI was statistically compared between both the groups, it was found to be highly significant ($P = 0.001$). Group 1 patients have progressive laxity of AST which was found to be significantly different from Group 2 ($P < 0.001$).

Conclusion: We have found that both PI and AST are good indicators for assessing success of caudal block onset in pediatric patients but AST took slightly longer time (~20 mins). Therefore, we conclude that PI is simple, economical, and noninvasive monitor that predicts the caudal onset much earlier than AST.

Keywords: Caudal block, pediatrics, perfusion index

Introduction

A caudal epidural block is among the most widely administered techniques of regional anesthesia in pediatric patients.[1] It helps in reducing the intraoperative dose of inhalational anesthetic agent used for maintenance of anesthesia and in addition provides an excellent postoperative analgesia without the side effects of intravenous opioid medication, like nausea and vomiting during emergence, cardiovascular, and respiratory depression.[1-4]

After administration of a caudal block, reliable assessment of caudal block is very crucial to ascertain the success of block. The onset of caudal block is often assessed by cold stimuli and cutaneous temperature changes. Caudal block in pediatric patients is often performed under general anesthesia.

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Access this article online	
Quick Response Code:	Website: https://journals.lww.com/joacp
	DOI: 10.4103/joacp.joacp_228_22

How to cite this article: Vashishth S, Nandal N, Kaur K, Kadian YS, Johar S, Kaur S, *et al*. Evaluation of perfusion index as a predictor of successful caudal block in pediatric patients: A prospective randomized study. J Anaesthesiol Clin Pharmacol 2024;40:108-13.

Submitted: 25-Jun-2022 **Revised:** 10-Nov-2022
Accepted: 11-Nov-2022 **Published:** 29-Jul-2023

Hence, testing the sensory levels by above techniques cannot be used.[2,3] Cremasteric reflexes, laxity of the anal sphincter, and change in the hemodynamic parameters are few other assessment methods. These methods are to be used 15–20 min after block administration, to confirm the efficacy of a caudal block.[1,2]

Fall in the heart rate (HR) and mean arterial pressure (MAP) have also been evaluated by some authors as other objective predictors of a successful block.[3-5] Previous studies had shown that HR decreased[3-5], whereas few more recent studies have documented increase in HR and decrease in MAP as a predictor for caudal assessment.[1,2] Hemodynamic fluctuations are reported after 5 min of caudal administration but not considered as reliable indicators.[1]

Assessment of laxity of anal sphincter (LAS) is another objective predictor which is considered better than hemodynamic response for assessing the success of caudal block. However, the approximate time for sphincter to relax is 20 min or more and it depicts the successful block mainly of sacral segments.[3,6] The absence of cremasteric reflex (CR) is also used to assess the success of caudal block. The disadvantage is that it can be elicited in male patient only.[7]

Perfusion index (PI) measures the ratio of arterial blood flow (pulsatile flow) to venous, capillary, and tissue blood flow (non-pulsatile blood flow) and it is shown in percentage or absolute value.[8] It is based on the principle of spectrophotometry. It indicates the strength of infrared rays (940 nm) returning from a specific monitored site like hand, finger, toe, etc., It ranges from 0.02% (very weak pulse strength) to 20% (very strong pulse strength). It is independent of parameters like heart rate, oxygen saturation of blood, or body temperature.[2,9] PI is considered as a sensitive marker to assess the efficacy of caudal block.[1,10] It can detect the onset of caudal block, by increasing PI beyond the pre-induction values, which can be due to the sympathectomy induced after successful caudal administration, which increases the blood flow to the peripheral tissues.[11] This may increase within 2 min after the caudal administration. Hence, it provides earlier and more sensitive indicator to assess the onset of caudal block and considered expeditious of all assessment modalities. It enables clinicians to obtain reliable measurements even under difficult clinical conditions like movement of the patient, hypotension, or hypothermia.[1]

Aim of the study was to assess, perfusion index (PI) as an indicator for success of caudal block onset in pediatric patients and to compare PI with laxity of anal sphincter tone and hemodynamic parameters.

Material and Methods

A prospective randomized study was conducted from July 2020 to March 2021 at our tertiary care institute, after approval from Institutional Ethical Committee Pt B D S, PGIMS UHS, Rohtak, Haryana, India, and was registered in clinical trial registry, India (CTRI/2020/06/026252). Study was conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects, outlined in the 1975 Declaration of Helsinki (revised 2013). A total of 60 pediatric patients aged between 2 and 10 years of either sex, belonging to American Society of Anesthesiologists (ASA) physical status I or II scheduled for elective surgery of lower abdomen, pelvic region, genital region, or lower limbs, were included in the study. Patients having any neurological disorders, bleeding disorder, bony deformity of vertebral column, infection at the injection site, drug allergy, and undergoing anal surgery were excluded from the study.

Patients were examined preoperatively and detailed clinical history, general physical examination as well as systemic examination were recorded. All routine investigations were carried out. Written informed consent was taken from parents/guardian of all the patients for the study. The patients were kept fasting for six hours for solids, four hours for breast milk, and two hours for clear liquids prior to the scheduled time of surgery. They were premedicated with oral promethazine syrup 0.5 mg/kg one hour prior to the scheduled surgery.

In the operation theater, routine monitoring was established. PI was recorded using Masimo Radical-7 SET® monitor. The PI can be easily read from the display screen. Pulse oximeter probe for monitoring the PI was placed on the left second toe and was wrapped in a sponge. A baseline reading (T0) of PI, HR, and MAP was recorded. Patients were randomly allocated into two groups, using sealed envelope containing code numbers of either of the two groups. Group 1 ($n = 30$) received caudal block after general anesthesia and Group 2 ($n = 30$) only received general anesthesia. Induction of anesthesia was done using injection propofol 2 $mgkg^{-1}$, fentanyl 1 μgkg^{-1}, and atracurium 0.5 mg kg^{-1} intravenously. Intermittent positive pressure ventilation was done for 3 min following which laryngeal mask airway of appropriate size as per manufacturer's guidelines was inserted. Maintenance of anesthesia was done with oxygen/nitrous (50:50), sevoflurane, and intermittent bolus of injection Atracurium.

Group 1 patients received caudal block after induction. Caudal block was administered in lateral decubitus position and 0.75 $mlkg^{-1}$ volume of 0.25% bupivacaine was injected (maximum dose 20 ml). Group 2 patients only received general anesthesia. PI, HR, and MAP were further recorded at 5, 10, 15, and 20 min following induction of anesthesia in both the groups and were designated as T_5, T_{10}, T_{15}, and T_{20}. Surgery commenced after 20 min in both the groups. The demographic data of all the patients were recorded. The data collection was done by the Junior Resident. All caudal anesthesia were administered by one of the authors. Anal sphincter tone (AST) was assessed by single pediatric surgeon in all the cases to avoid subjective bias by finger palpation method. AST was assessed at T_5, T_{10}, T_{15}, and T_{20}. Complete AST laxity was recorded as YES (Y), and tight sphincter was recorded as NO (N). Absolute and relative change in PI, HR, and MAP was further derived from observed values at all the above intervals. Absolute change in PI (aPI) was recorded as the changes in PI with respect to baseline (T0) [$aPI = PI_{(T5/T10/T15/T20)} - PI_{(T0)}$]. Relative change in PI (rPI%) was expressed as percentage changes in PI from T_0 at specific time point [$rPI\% = aPI_{(T5/T10/T15/T20)}/PI_{(T0)} \times 100$]. Using the same formula, absolute and relative changes of HR and MAP were also calculated. For the patients of Group 2, postoperative paracetamol suppositories were used for postoperative analgesia.

Sample size and statistical analysis

The sample size was determined by using the PI to compare the effectiveness by assuming a difference of 1 in PI at subsequent time points from baseline as clinically significant;[1] thus, sample size of 24 patients per group were considered necessary to detect statistical significances with an effect size of 0.67 at alpha 0.05 and power of 90%. Considering a drop rate 20% in the subjects, 30 patients were included in each group. Statistical analysis was performed by the SPSS version 17.0. Continuous variables were presented as mean ± SD and categorical variables was presented as absolute numbers and percentage. Data were checked for normality before statistical analysis. Normally distributed continuous variables were compared using the unpaired *t* test; otherwise, Mann–Whitney U test was used for not normally distributed continuous variables. Categorical variables were analyzed using either the Chi-square test or Fisher's exact test. Within the group comparisons, continuous variables and values over time were analyzed using repeated measures analysis of variance (ANOVA) followed by Bonferroni's *post hoc* testing. $P < 0.05$ was considered statistically significant

Results

Data of all the 60 patients enrolled in the study were included in the analysis. The age, weight, and sex of patients were comparable in both the groups [Table 1].

PI was measured at baseline and at 5, 10, 15, and 20 min (T_5, T_{10}, T_{15}, and T_{20}, respectively). A persistent increase in the PI value was observed in Group 1 starting from 5 min till 20 min, as compared to Group 2, at all the time intervals. However, in Group 2 mean PI value was observed to be near baseline at all intervals [Table 2]. When mean PI was statistically compared between both the groups, it was found to be highly significant ($P = 0.001$).

No statistically significant difference between the mean HR and MAP was observed among the two group at all time points ($P > 0.05$) [Figures 1 and 2]. In Group 1, lax AST at T5, T10, T15, and T20 was observed in 36.7%, 90%, 96.7%, and 100% subjects. AST in all the subjects of Group 2 was tight at all the time intervals. When statistically compared, the significant difference in the laxity of AST was found between both the groups at all the time intervals ($P = 0.001$). The significant statistical difference in aPI change ($P = 0.001$) and rPI change ($P = 0.02$) was found between both the groups [Table 3]. The absolute and relative changes in HR and MAP were comparable among both the groups ($P > 0.05$). None of the children

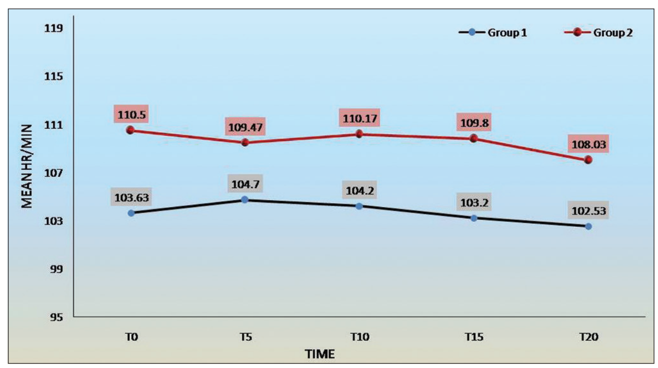

Figure 1: Comparison of HR among both groups

Table 1: Demographic profile

Demographic profile	Group 1 (*n*=30)	Group 2 (*n*=30)	*P* (significance cutoff=0.05)
Mean age (years)	5.83±3.495	6.83±2.984	0.23
Mean weight (Kgs)	20.72±9.932 kg	20.23±8.160	0.83
Male	26 (86.7%)	24 (80%)	0.48
Female	4 (13.3%)	6 (20%)	

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

Time points	PI% Mean±SD		*P* (significance cutoff=0.05)
	Group 1	Group 2	
T0	2.933±3.63	2.13±1.75	0.28
T5	5.92±3.82	2.72±1.92	0.001 (S)
T10	6.46±4.09	2.45±1.31	0.001 (S)
T15	6.91±4.39	2.46±1.39	0.001 (S)
T20	7.27±5.27	2.27±1.45	0.001 (S)

S: Statistically significant

Table 3: Absolute and relative perfusion index change between both groups

Perfusion index change	% Mean±SD		*P* (significance cutoff=0.05)
	Group 1	Group 2	
Absolute perfusion index change			
T5	3.35±3.42	0.41±0.855	0.001 (S)
T10	3.98±4.62	0.33±1.654	0.001 (S)
T15	4.13±4.26	0.32±1.22	0.001 (S)
T20	4.34±3.95	0.22±1.24	0.001 (S)
Relative perfusion index change			
T5	352.79±542.22	95.66±247.34	0.02 (S)
T10	476.11±992.39	85.09±222.67	0.02 (S)
T15	487.73±1050.87	84.49±239.41	0.02 (S)
T20	499.35±939.07	59.27±121.62	0.02 (S)

S: Statistically significant

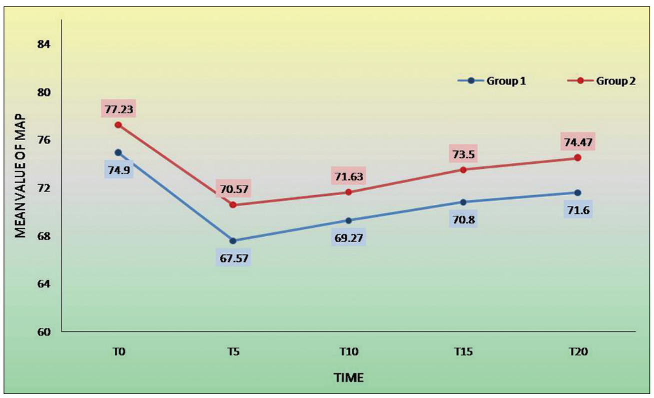

Figure 2: Comparison of MAP among both groups

developed hypothermia. The temperature range was from 37–38°C.

Discussion

The success of the caudal block can be assessed by various objective parameters like fall in heart rate, fall in mean arterial pressure, laxity of anal sphincter tone, and loss of cremasteric reflex. All these variables are known to have steady onset and are not dependable enough in children who are under deep sedation or general anesthesia.[1,2]

Perfusion index is another such indicator that can be used to evaluate the success of caudal block. PI is a noninvasive and indirect technique for measuring peripheral perfusion.[8] It reflects the status of peripheral perfusion in the body.[2] Caudal block causes sympathectomy of the infraumbilical area, affecting the autonomic regulation which causes smooth muscle relaxation, vasodilatation, and decreased cardiac output, hence increasing the blood flow to peripheral tissues, which further results in increased PI value.[12,13] Hence, it provides earlier and more sensitive indicator to assess the onset of caudal block and considered swift of all assessment modalities. It enables clinicians to obtain authentic measurements in problematic clinical conditions like patient movement, hypotension, or hypothermia.[1]

PI is an assessment of pulsatile strength at specific monitoring sites like hand, finger, or foot. Masimo signal extraction technology pulse oximetry yields continual and simultaneous absolute values and trends with arterial oxygen saturation and pulse rate.[1,4] Very few studies[1,2,4] have shown that PI can detect the onset of caudal block, that induces sympathectomy, hence increasing the blood flow in the tissues.

In this study, PI was measured at different intervals (5, 10, 15, and 20 min) to assess the change in PI following the administration of caudal block and compared it with non-caudal group. The value of the baseline PI was comparable in both the groups. Further after the administration of caudal block, the mean value of PI increased persistently in linear fashion in Group 1 and maximum rise was observed up to 7.27 ± 5.27 at 20 min, from baseline value of 2.93 ± 3.63. In contrast, no significant change in the mean PI was recorded in Group 2. PI change was found to be statistically significant at all the time intervals (P = 0.001) when compared among both the groups. El-Sonbaty *et al.*,[1] Xu *et al.*[2], and Devadas *et al.*[4] observed the similar findings in PI with maximum PI change at about 20 min following caudal administration. The maximum change in absolute (4.34 ± 3.95) and relative PI value (499.35 ± 939.07%) [Table 3], calculated in this study, was also observed at 20 min interval following caudal administration, which was in concordance to the findings of Xu *et al.*[2] The probable reason for this rise of PI is because of the fact that the maximum vasodilatation due to sympathectomy, following drug injection in caudal, occurs at about 20 min.[1,2,4]

The PI change after administration of various blocks (sciatic nerve block, spinal anesthesia, and brachial plexus block) in non-pediatric patient observed by Buono *et al.*[8] also exhibited a linear pattern, similar to this study. They reached an inference that the onset of PI increase precedes the change in any other modality used to assess the success of the block. In contrary, the few studies proclaimed that determinants like pain and stressful stimuli lead to vasoconstriction of peripheral bed, which contributes to decrease in PI.[1,2,4,8]

The changes in peripheral PI depend on many factors inclusive of blood volume, elasticity of vascular wall, and peripheral resistance of small vessels. Peripheral vascular resistance regulated by the autonomic nervous system is supposed to be the prime factor resulting in the changes in PI.[2]

Fall in HR is also another objective predictor of successful caudal block. No statistically significant change in HR was observed in either of the groups in all time points ($P > 0.005$) in the this study. Xu *et al.*[2] and El-Sonbaty *et al.*[1] had a related observation. Ghai *et al.*[5] conducted a study to relate the fall in baseline HR as a predictor of successful caudal block. They stated that the fall in baseline HR of >3 beats/min after initial drug administration can be used as measure for successful caudal block. HR change can be used as an immediate predictor of successful block, which was suggested by Dave *et al*.[3] Devadas *et al.*[4] also correlated this change with the success of caudal block. The decrease in HR was unsubstantial at an interval of five and 10 min but it was statistically significant at 15 and 20 min, in both the groups which was in contradiction to the this study.

Possible mechanism stated in the literature, for decrease in HR following caudal block could be stimulation of pressure receptors in sacral epidural space. It has been postulated that the drug injection into the caudal space can stimulate the pressure receptors within or outside the sacral nerve roots in the space. The decrease in HR is proportionate to the volume of drug injected i.e., a higher the volume of drug injected and greater the fall in the HR.[5] Hence, above studies reached an inference that a fall of >3 beats per minute during or within 1 min of caudal drug injection can be used as a simple and objective test of successful caudal block.

MAP value did not change significantly with time in either of the groups, and was comparable in both the groups. Xu *et al.*[2] noted significant fall in MAP in only two out of 20 patients following caudal block, which is similar to this study. El-Sonbaty *et al.*[1] observed that the mean baseline value of MAP in Group 1 and 2 was comparable. The decrease in MAP was significant in Group 1 (caudal block), unlike in current study. Conversely, Devadas *et al.*[4] recorded a significant decrease in MAP 10, 15, and 20 min following caudal block, which was significantly different from baseline value.

Fall in MAP was being used as an indicator of successful caudal block for long. But after establishment of PI as an indicator, researchers deduced that the sensitivity of fall in MAP is quite less as compared to PI increase. Significant decrease in MAP was observed by El Sonbaty *et al.*[1] after 10, 15, and 20 min of caudal block administration. They concluded that PI changes occur earlier, before any changes in HR or MAP were observed, hence suggesting that PI could be a more reliable indicator in detecting the onset of caudal block.

A nonsignificant change in absolute and relative change in HR and MAP was observed in this study. Xu *et al.*[2] observed slightly higher relative HR and MA*P* value change compared to the current study. This marginal increase could be because of use of ketamine as an induction agent resulting in more vasoconstriction.

The laxity of anal sphincter tone (AST) proved to be another reliable indicator for successful block. The laxity of anal sphincter was assessed in both the groups at an interval of 5, 10, 15, and 20 min from induction in this study. In Group 2, the AST continued to be tight at all the intervals, because these subjects received general anesthesia which does not cause sufficient sympathectomy to decrease the tone of the sphincter. In contrast, Group 1 patients have progressive laxity of anal sphincter which was found to be statistically significant ($P < 0.001$), on comparing with non-caudal group. Our results were supported by studies of Dave *et al.*[3] and Verghese *et al*.[6]

This study had some limitations. Any stimulus increasing sympathetic activity could change PI values. Any change in limb or body temperature can also alter the PI values. Further the fact that older pulse oximeters may not be enabled for PI calculation, we used Masimo Radical-7 SET® monitor and this is a limitation of the study. Statistically proven results and adequate sample size with power of study being 90% are strengths of our study.

Conclusion

We conclude that PI is simple, economical, and noninvasive monitor that is faster, easier to use, and highly valuable parameter compared to other objective indicators for assessing success of caudal block. It is a more reliable indicator compared to hemodynamic parameters or anal sphincter tone to evaluate successful caudal block in pediatric patients.

Declaration of patient consent

The authors certify that we have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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