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RESEARCH

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# Evaluating the effect of caudal epidural block on optic nerve sheath diameter in pediatric patients: randomized controlled study

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## Abstract

**Introduction** Caudal epidural block is a widely performed procedure for postoperative pain control of pediatric patients. As the local anesthetic acts by spreading cranially after caudal block, it may lead to several effects on the cerebrospinal fluid and intracranial region.

**Method** Children aged 1–7, ASA I-II were included in this study. The patient population was assigned into two groups as the Caudal Block Group (Group CB) and the Control Group (Group C) Caudal block with 0.25% bupivacaine 1 ml/kg was performed on patients in Group CB. Optic nerve sheath diameter was measured at the following timeline: $T_0$: Following laryngeal mask placement, $T_1$: Following caudal block. $T_{15}$:15. min, $T_{30}$:30. min. Heart rate, non-invasive blood pressure, $SpO_2$ and $PCO_2$ values were also recorded at every time point.

**Results** There was no significant difference between two groups considering demographic data, intraoperative hemodynamic parameters, intraoperative $SpO_2$ and $PCO_2$ values. While optic nerve sheath diameter findings were not significantly different between the groups at T0 and T1 points($P > 0.05$), the measurements at T15($4.18 \pm 0.56$ for Group C and $4.62 \pm 0.47$ for Group CB, $P = 0.006$) and T30($4.20 \pm 0.53$ for Group C and $4.76 \pm 0.52$ for Group CB) were statistically higher in the Caudal Group.

**Conclusion** Evaluation of optic nerve sheath diameter has high diagnostic precision for detecting increased intracranial pressure in children. The findings in this study display that local anesthetic applied for caudal block in pediatric surgeries spread cranially resulting in an increase in the intracranial pressure and optic nerve sheath diameter. However, this increase does not cause intraoperative hemodynamic changes.

**Keywords** Caudal epidural block, Optic nerve sheath diameter, Non-invasive intracranial pressure monitoring

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## Introduction

Caudal block was first introduced in 1933 for use in pediatric anesthesia, it has become the most frequently performed regional anesthesia technique due to its safety and efficacy[1] for intraoperative and postoperative analgesia especially during pediatric surgeries below the umbilicus, affecting the region between the T10 and S5 dermatomes [1, 2]. Depending on the site of surgery, different volumes are preferred for caudal block procedure: 1–1.25 ml/kg of local anesthetic is advised for abdominal incisions up to the thoracic dermatomes[2], while injection of a higher volume of 1.5 ml/kg raises safety concerns on possible deleterious effects on the intracranial pressure of children [3, 4].

Increased intracranial pressure may cause some hemodynamic changes to maintain cerebral perfusion. It increases systemic vascular resistance and blood pressure. Baroreceptors detect high blood pressure and activate the vagal response, causing bradycardia with hypertension [5]. Intracranial pressure measurement in brain parenchyma or directly in the ventricle is the gold standard method although it is a highly invasive procedure [6]. Alternatively, intracranial pressure can be measured by the assessment of optic nerve sheath diameter (OND) by ultrasonography. The optic nerve originates from the diencephalon and is an extension of the white matter tract of the central nervous system which then extends into the orbital cavity [7]. As the optic nerve is capsulated by the distensible subarachnoid space, any change of intracranial pressure would theoretically reflect on this measurement [7]. Several studies have reported evidence supporting that optic nerve sheath diameter is a well correlated parameter with intracranial pressure and has high diagnostic precision for detecting altered intracranial pressure in children [8].

Our primary aim in this study is to investigate the effect of the caudal block on optic nerve sheath diameter in pediatric patients. Our secondary aims are to evaluate the effects of caudal anesthesia on heart rate and blood pressure.

## Materials and method

Ethical approval was obtained for this prospective randomized study from the Ethical Committee of Ataturk University. The study was registered with a clinical trial registry (ClinicalTrials.gov, identifier NCT05216211). This randomized controlled study was designed and conducted according to the guidelines of the Consolidated Standards of Reporting Trials (CONSORT).

Parents' or caregivers' informed consent was obtained for this research. Sixty patients aged between 1 and 7 of ASA I-II scheduled for operations of elective circumcision, inguinal hernia, cryptorchidism, and hydrocele were included in this study between December 2021 and October 2022. Patients with severe systemic disease, neurologic or spinal abnormalities, coagulation disorders, allergies for local anesthetics, infection on the area of block or history of premature birth, increased intracranial pressure or any ophthalmic pathologies were excluded from the study.

The patients were assigned equally into two groups as the Caudal Block Group (Group CB) and Control Group (Group C) via a computer-generated randomization program. Patients who agreed to participate in the study were included in the study. On the day of surgery, the patients were transferred to the premedication room with a relative and after an intravenous cannula was placed, they were premedicated with midazolam and later taken into the operation room.

Patients were monitored in the operation room with routine 3-lead ECG, $SpO_2$ and noninvasive blood pressure; and the basal measurements were recorded. Induction of anesthesia was performed intravenously using thiopental sodium (5–7 mg/kg) and fentanyl (1–1,5 mcg/kg), and as soon as enough depth of anesthesia was reached through an inhalation of oxygen mixed with sevoflurane (%2–4) with 1 MAC a laryngeal mask was placed.

Caudal block was performed on patients in Group CB. Following sterile preparation of the block site, sacral corns and sacrococcygeal hiatus were palpated in left lateral decubitus position. A pediatric 20–22 G caudal epidural needle was inserted at 60–80 degrees. The sacrococcygeal ligament was advanced as a "pop" was sensed, and the needle was moved 2–3 mm further into the sacral hiatus at 20–30 degrees. Following negative aspiration of blood or cerebrospinal fluid to exclude inadvertent intravascular or intrathecal placement, 1 ml / kg of 0.25% bupivacaine was administered at a rate of 0.5 ml/sec. Block failure was defined as an increase of > 20% of the basal levels in heart rate and blood pressure after the surgical incision.

In group C, wound infiltration was performed with 0.25% bupivacaine at the end of surgery. Patients in both groups were given 15 mg/kg of paracetamol intravenously at the end of the surgery.

### Optic nerve sheath diameter measurement

Following the application of general anesthesia, the patients were taken into supine position. A thick layer of sterile coupling gel was applied on top of the closed eyelid. Linear ultrasound probe with a reduced power output to avoid ultrasonic energy-induced eye injury was positioned gently in axial plane and the eyeball was displayed. As the ultrasound probe was tilted, optic nerve was viewed. 3 mm deep to the eyeball, optic nerve sheath diameter was measured and recorded (Fig. 1). Two subsequent measurements were made effort both eyes and mean values were calculated. Four measurements for each patient were recorded as follows: $T_0$: Following laryngeal mask placement, $T_1$: Following caudal block (Measurement at 5th minute for the control group). $T_{15}$: 15. min, $T_{30}$: 30. Min. Heart

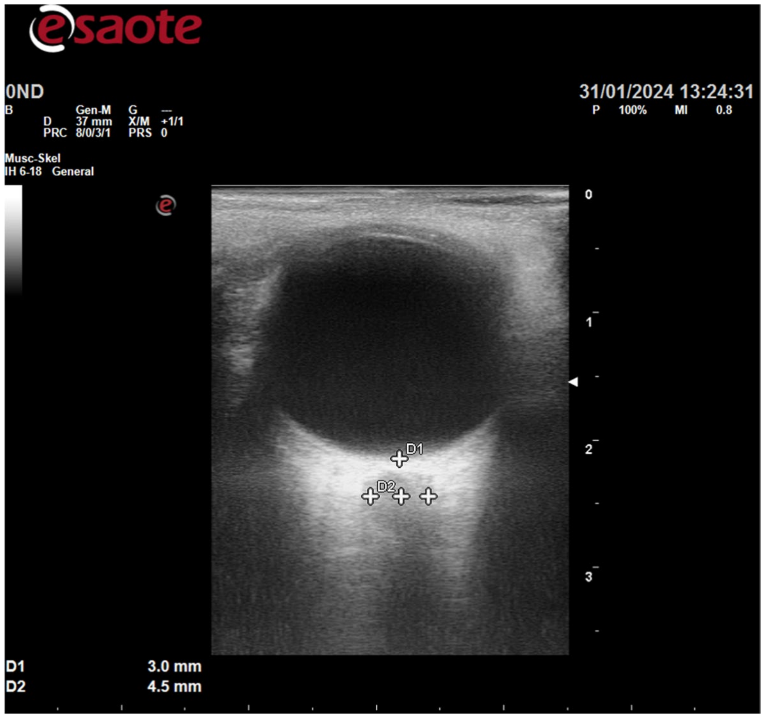


**Fig. 1** Sonographic anatomy of optic nerve sheath diameter. D1: 3 mm deep to the eyeball. D2: Optic nerve sheath diameter

rate, non-invasive blood pressure, $SpO_2$ and $PCO_2$ values were also recorded at every time point. All data are collected by an anesthetist who is blinded to the group classification.

### Sample size estimation and statistical analyses

The primary aim was to evaluate the optic nerve sheath diameter at the fifteenth minute. In our pilot study, we found that OND was 3.88 ± 0.48 mm in Group C ($n = 10$) and 4.20 ± 0.39 ($n = 10$) in Group CB. It was estimated that a sample size of 24 patients per study group (a total of 48 patients) would provide 95% power with an α error of 0.05. To account for an estimated dropout, the required sample size was adjusted to 30 patients for each group.

The SPSS 22.0 (IBM SPSS Corp Armonk, NY, ABD) software was used for statistical analyses. The Chi-squared test was employed to compare the categorical variables between the groups. Normal distribution of numerical parameters was investigated using the Kolmogorov– Smirnov and histogram tests. Student's t-test was utilized to compare the normally distributed parameters, and the Mann–Whitney test was used for the non-normally distributed parameters. $P < 0.05$ were regarded as statistically significant.

## Results

The eligible patients were analyzed for the primary outcomes and were presented in a flow diagram of Consolidated Standards of Reporting Trials (Fig. 2).

As derived from Table 1 displaying the demographic data of the patient population, there is no significant difference between two groups in terms of age, sex, weight, and height ($P > 0.05$). Moreover, evaluation of the duration of surgery and anesthesia no significant difference between the groups ($P > 0.05$). In Group CB, the caudal block performing time was 4 ± 0,96 min, including patient position and injection.

The intraoperative hemodynamic parameters of heart rate, systolic and diastolic blood pressure on Table 2 show that there is no significant difference between the groups ($P > 0.05$).

Intraoperative peripheral oxygen saturation and end-tidal carbon dioxide were recorded at specific time points as well (Table 3), and there is no statistical difference between the two groups in terms of these parameters either. ($P > 0.05$).

While optic nerve sheath diameter findings were not significantly different between the groups at T0 and T1 points ($P > 0.05$), the measurements at T15 (4.18 ± 0.56 for Group C and 4.62 ± 0.47 for Group CB, $P = 0.006$) and T30 (4.20 ± 0.53 for Group C and 4.76 ± 0.52 for Group

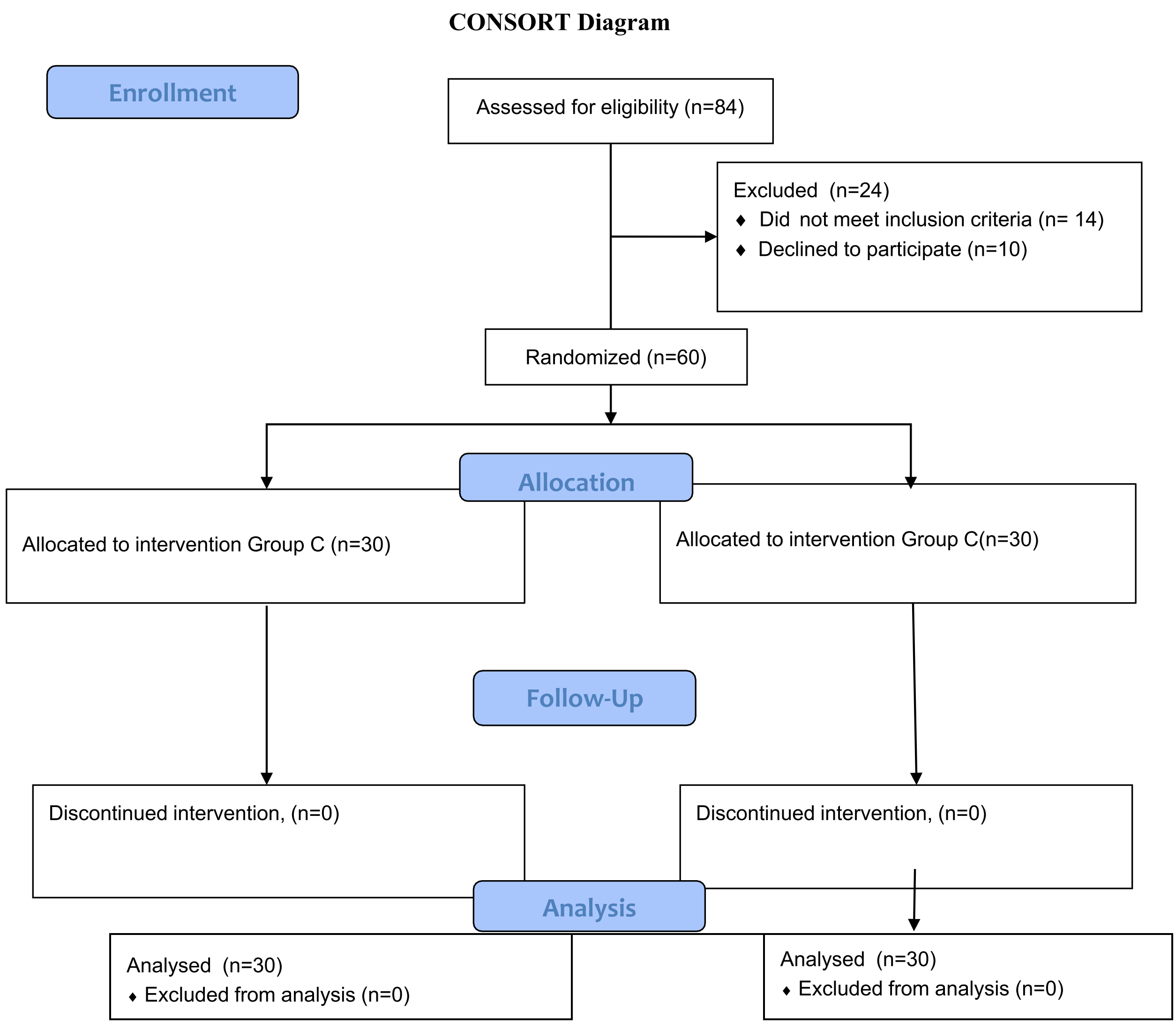


**Fig. 2** Consolidated Standards of Reporting Trials

**Table 1** Demographic characteristic of study patients

| | Group C (*N* = 30) | Group CB (*N* = 30) | *P* |
|---|---|---|---|
| Age (y) | 3,90 ± 1,92 | 3,87 ± 1,76 | 0,976[1] |
| Weight (kg) | 15,60 ± 4,28 | 17,83 ± 7,69 | 0,170[2] |
| Height (cm) | 103,70 ± 14,38 | 104,47 ± 16,56 | 0,849[2] |
| Duration of anesthesia (min) | 42,83 ± 7,15 | 46,50 ± 10,43 | 0,177[1] |
| Duration of surgery (min) | 29,00 ± 6,62 | 31,33 ± 7,18 | 0,202[1] |
| Types of surgery (Circumcision/inguinal hernia/cryptorchidism/hydrocele) | 10/13/3/4 | 7/17/4/2 | 0,599[3] |

[1] Mann Whitney U-Test, [2] Independent Sample t-test, [3] Chi-Square test, Group C: Control Group, Group CB: Caudal Block Group, y: years, kg: kilogram, cm: centimeter, min: minutes

**Table 2** Intraoperative Hemodynamic Parameters

| | Group C (*N* = 30) | Group CB (*N* = 30) | *P* |
|---|---|---|---|
| Heart rate (beats.min$^{-1}$) | | | |
| T0 | 116,47 ± 19,68 | 109,07 ± 16,68 | 0,122[1] |
| T1 | 110,10 ± 22,69 | 110,63 ± 16,66 | 0,918[1] |
| T15 | 110,43 ± 23,00 | 107,80 ± 11,35 | 0,367[2] |
| T30 | 109,30 ± 18,76 | 105,50 ± 12,79 | 0,363[1] |
| Systolic blood pressure (mmHg) | | | |
| T0 | 92,87 ± 14,38 | 88,23 ± 10,50 | 0,159[1] |
| T1 | 90,97 ± 11,87 | 90,40 ± 11,71 | 0,853[1] |
| T15 | 88,33 ± 11,71 | 88,63 ± 11,86 | 0,922[1] |
| T30 | 90,40 ± 11,99 | 88,53 ± 10,77 | 0,528[1] |
| Diastolic blood pressure (mmHg) | | | |
| T0 | 49,37 ± 11,53 | 47,23 ± 9,28 | 0,544[2] |
| T1 | 49,77 ± 10,68 | 48,37 ± 9,19 | 0,588[1] |
| T15 | 47,13 ± 7,86 | 47,37 ± 8,20 | 0,911[1] |
| T30 | 48,77 ± 7,46 | 48,13 ± 7,46 | 0,744[1] |

[1] Independent Sample t-test, [2] Mann Whitney U-Test, Group C: Control Group, Group CB: Caudal Block Group, $T_0$: following laryngeal mask placement, $T_1$: following caudal block (Measurement at 5th minute for the control group). $T_{15}$: 15. minutes, $T_{30}$: 30. minutes

**Table 3** Intraoperative peripheral oxygen saturation and end-tidal carbon dioxide values

| | Group C (*N* = 30) | Group CB (*N* = 30) | *P* |
|---|---|---|---|
| Peripheral oxygen saturation (%) | | | |
| T0 | 99,23 ± 0,97 | 99,33 ± 0,61 | 0,634 |
| T1 | 99,53 ± 0,63 | 99,60 ± 0,62 | 0,681 |
| T15 | 99,57 ± 0,57 | 99,57 ± 0,57 | 1,000 |
| T30 | 99,60 ± 0,67 | 99,57 ± 0,63 | 0,843 |
| End-Tidal carbon dioxide (mmHg) | | | |
| T0 | 36,37 ± 5,14 | 35,30 ± 5,13 | 0,424 |
| T1 | 34,83 ± 3,72 | 35,80 ± 4,48 | 0,367 |
| T15 | 35,37 ± 3,48 | 35,33 ± 3,83 | 0,972 |
| T30 | 36,43 ± 2,93 | 36,30 ± 4,61 | 0,894 |

Independent Sample t-test, Group C: Control Group, Group CB: Caudal Block Group, $T_0$: following laryngeal mask placement, $T_1$: following caudal block (Measurement at 5th minute for the control group). $T_{15}$: 15. minutes, $T_{30}$: 30. Minutes

CB, $P < 0{,}001$) were statistically higher in the Caudal Group CB (Table 4).

Changes in optic nerve sheath diameter in measurement differences at T1, T15 and T30 times compared to T0 were evaluated. Accordingly, while there was no significant difference between the groups in the changes in the T1-T0 time intervals and, there was a significant increase in the changes in the T15-T0 (0.80 ± 0.56 vs 0.40 ± 0.39) and T30-T0 (0.95 ± 0.60 vs 0.41 ± 0.44) time intervals in Group CB compared to Group C ($P < 0.05$) (Table 4).

**Table 4** Optic nerve sheath diameter measurement values

| | Group C (*N* = 30) | Group CB (*N* = 30) | *P* |
|---|---|---|---|
| Optic nerve sheath diameter (mm) | | | |
| T0 | 3,78 ± 0,43 | 3,82 ± 0,54 | 0,799[1] |
| T1 | 4,04 ± 0,50 | 4,25 ± 0,54 | 0,122[1] |
| T15 | 4,18 ± 0,56 | 4,62 ± 0,47 | **0,006[2]** |
| T30 | 4,20 ± 0,53 | 4,76 ± 0,52 | **0,000[2]** |
| Changes in optic nerve sheath diameter (mm) | | | |
| T1-T0 | 0,25 ± 0,31 | 0,43 ± 0,45 | 0,079[1] |
| T15-T0 | 0,40 ± 0,39 | 0,80 ± 0,56 | **0,002[1]** |
| T30-T0 | 0,41 ± 0,44 | 0,95 ± 0,60 | **0,000[1]** |

[1] Independent Sample t-test, [2] Mann Whitney U-Test, Group C: Control Group, Group CB: Caudal Block Group, $T_0$: following laryngeal mask placement, $T_1$: following caudal block (Measurement at 5th minute for the control group). $T_{15}$: 15. minutes, $T_{30}$: 30. minutes

## Discussion

The present study shows that, after the caudal epidural block is performed for pediatric surgery, the local anesthetic spreads cranially and leads to an increase in intracranial pressure and the optic nerve sheath diameter. However, the scope of this increase is within the physiological limits.

During caudal epidural block, local anesthetic acts by spreading cranially and while volume of the solution determines the height of the block, its concentration determines the intensity. Various effects may be observed on the cerebrospinal fluid and intracranial space depending on the volume of the local anesthetic and how fast it is administered. It has been postulated that caudal injection leads to a bidirectional flow of cerebrospinal fluid, followed by a secondary cranial spread. As inspected by ultrasound, this so-called shift is by approximately 15–20% of the injected volume of the local anesthetic, which would result in a spread by four spinal segments cranially. The cranial shift of epidural injection has been verified by magnetic resonance imaging in adults as well [9].

In a previous study Lundblad et al. carried out to observe whether a high-volume caudal block would impact cerebral blood flow in children, they reported that it is indeed related with significant reduction in transcranial Doppler flow velocity immediately after the injection. This reduction persisted for 5 min after the injection, which they believed was a supportive data for the secondary spread of caudal block. Furthermore, a significant fall in cerebral regional oxygenation (CRSO2) was observed rapidly after the injection and no recovery was seen at 5 min post-injection [1].

In a recent study by Gönen et al. evaluating the effect of low and high volumes of bupivacaine for caudal epidural block on optic nerve sheath diameter and regional cerebral oximetry, it was found that caudal injection with volumes of 0.8 and 1.25 ml/kg did not have a significant effect on ICP and did not reduce CrSO2 significantly. They concluded that caudal injections with these volumes are considered safe in children if no intracranial pathology is present [10]. In our study, we performed caudal blocks using local anesthetic at a volume of 1 ml/kg. In the measurements we made at 4 different time points, the highest values were obtained at the 30th minute after caudal block. However, none of them were above physiological limits.

We carried out our optic nerve sheath diameter measurements in correlation with the CLOSED protocol by Aspide et al. [11]. To evaluate our findings on optic nerve sheath diameter, we based our results on the data from a study by Padayachy et al. They suggested cut-off values as follows: optic nerve sheath diameters wider than 5.16 mm in infants younger than one year and 5.75 mm in older children would favor the diagnose of intracranial pressure increase by 20 mmHg under general anesthesia [12]. Additionally, the treatment threshold for increased intracranial pressure in children with traumatic brain injury was reported to be 20 mmHg [13].

Anesthetic agents all have influence on intracranial pressure and cerebral blood flow; therefore, it was vital to provide a standard induction of anesthesia and medication protocol. Additionally, if crying triggered by the anxiety of transfer to the operation room would affect the intracranial pressure, we provided intravenous access before in the premedication room and administered midazolam. Although midazolam itself would alter intracranial pressure, this effect would be negligible as it was given to all patients in the same dose. This helped eliminate the possible effect of anxiety and crying on our first measurements.

ICP has important effects on systemic circulation. These effects are particularly related to the compensatory mechanisms and reflexes developed by the body against increased intracranial pressure. The most obvious effect of ICP on systemic blood pressure is a physiological response known as the Cushing reflex [5]. This reflex is the body's effort to protect cerebral perfusion pressure against increased intracranial pressure. When ICP increases, the medullary centers in the brainstem are stimulated. The sympathetic nervous system is activated and systemic vascular resistance increases. Cardiac output increases and as a result, systemic blood pressure increases. This response is a mechanism developed to protect cerebral perfusion pressure. Increased systemic blood pressure is detected by carotid sinus and aortic arch baroreceptors. Baroreceptors increase vagal activity to slow the heart rate. Therefore, bradycardia is seen with hypertension [5]. In our study, there was no increase in ICP that could cause hemodynamic changes. Hemodynamic changes were within physiological limits.

We standardized the rate and mode of injection as well as the position of the patient during caudal block. Pauses during injection are associated with milder effects on cerebral blood flow velocity parameters than those with uninterrupted caudal injection of the same total volume [14]. On the other hand, the sitting position leads to lower epidural pressure compared with the lateral decubitus position [15].

No established consensus exists on how best to assess the cutaneous sensory segmental level in an anaesthetized infant [16]. In this study, block failure was defined as an increase in heart rate and blood pressure after the surgical incision. However, the researchers did not encounter such consequences in patients during the study. The caudal block was successful in all patients.

There are some limitations in this study. First, since the patient group included in the study was between the ages of 1–7, all blocks had to be performed under anesthesia. Therefore, the dermatomal levels of anesthesia could not be evaluated. Block success was evaluated only by hemodynamic changes after surgical incision. It could not be evaluated whether there was any relationship between the level of anesthesia reached and the optic nerve sheath diameter. Second, this study was not a double-blind study, only measurements and data were made by an anesthetist blinded to the group classification. The anesthetist who administered caudal anesthesia was aware of which group the patients were in. No sham injection was administered to the control group. Third, caudal anesthesia and intracranial pressure increase may cause serious changes in cranial blood flow and cerebral perfusion. Monitoring doppler velocity and cerebral oxygenation could have yielded different results in the study. Fourth, the sample size of the study was determined based on the increase in optic nerve diameter, which is the primary purpose of the study. Side effects of the caudal block procedure are not fully identifiable with a small sample size, and hence, further studies involving larger sample sizes may be needed.

In conclusion, the results from this study demonstrate that, after the caudal epidural block is performed for pediatric surgery, the local anesthetic spreads cranially and leads to an increase in intracranial pressure and the optic nerve sheath diameter. However, this increase does not cause intraoperative hemodynamic changes.

**Abbreviations**

| | |
|---|---|
| ASA | American society of anesthesiologists |
| $PCO_2$ | Partial pressure of carbon dioxide |
| ECG | Electrocardiography |
| NIBP | Non-invasive blood pressure |
| SpO2 | Oxygen saturation |
| OND | Optic nerve sheath diameter |

MAC Minimum alveolar concentration
$CRSO_2$ Cerebral regional oxygen saturation
ICP Intracranial pressure

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None

**Authors' contributions**
AMY, EOA, and ECC contributed to the study conception and design. MSOY, BF, and IA contributed to the study conduct. ECC, MEA and AA contributed to data analysis. EOA, MEA, and AA contributed to manuscript preparation. AMY is a guarantor. The author(s) read and approved the final manuscript.

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**Data availability**
Data is provided within the manuscript or supplementary information files.

## Declarations

**Ethics approval and consent to participate**
The study has been conducted in accordance with the principles set forth in the Helsinki Declaration. Parents' or caregivers' informed consent was obtained for this research. Ethical approval was obtained for this prospective randomized study from the Ethical Committee of Ataturk University (Approval number: B.30.2.ATA.0.01.00/4). The study was registered with a clinical trial registry (ClinicalTrials.gov, identifier NCT05216211).

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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## Publisher's Note