

SCIENTIFIC ARTICLE

## Effects of caudal block in pediatric surgical patients: a randomized clinical trial



Anna Uram Benka<sup>a,b</sup>, Marina Pandurov<sup>id a,b,\*</sup>, Izabella Fabri Galambos<sup>a,b</sup>,  
Goran Rakić<sup>b,c</sup>, Vladimir Vrsajkov<sup>a,d</sup>, Biljana Drašković<sup>a,b</sup>

<sup>a</sup> University of Novi Sad, Medical Faculty, Department of Anesthesia and Perioperative Medicine, Novi Sad, Serbia

<sup>b</sup> Institute for the Healthcare of Children and Youth of Vojvodina, Clinic of Pediatric Surgery, Department for Pediatric Anesthesia, Intensive Care and Pain Therapy, Novi Sad, Serbia

<sup>c</sup> University of Novi Sad, Medical Faculty, Department of Emergency Medicine, Novi Sad, Serbia

<sup>d</sup> Clinical Centre of Vojvodina, Clinic of Anesthesia, Intensive Care and Pain Therapy, Novi Sad, Serbia

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### KEYWORDS

Caudal block;  
Stress response;  
General anesthesia;  
Children

### Abstract

**Background:** Surgery generates a neuroendocrine stress response, resulting in undesirable hemodynamic instability, alterations in metabolic response and malfunctioning of the immune system.

**Objectives:** The aim of this research was to determine the effectiveness of caudal blocks in intra- and postoperative pain management and in reducing the stress response in children during the same periods.

**Methods:** This prospective, randomized clinical trial included 60 patients scheduled for elective herniorrhaphy. One group (n = 30) received general anesthesia and the other (n = 30) received general anesthesia with a caudal block. Hemodynamic parameters, drug consumption and pain intensity were measured. Blood samples for serum glucose and cortisol level were taken before anesthesia induction and after awakening the patient.

**Results:** Children who received a caudal block had significantly lower serum glucose ( $p < 0.01$ ), cortisol concentrations ( $p < 0.01$ ) and pain scores 3 h ( $p = 0.002$ ) and 6 h ( $p = 0.003$ ) after the operation, greater hemodynamic stability and lower drug consumption. Also, there were no side effects or complications identified in that group.

**Conclusions:** The combination of caudal block with general anesthesia is a safe method that leads to less stress, greater hemodynamic stability, lower pain scores and lower consumption of medication.

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\* Corresponding author.

E-mail: [marina.pandurov@mf.uns.ac.rs](mailto:marina.pandurov@mf.uns.ac.rs) (M. Pandurov).

**PALAVRAS-CHAVE**

Bloqueio caudal;  
Reposta ao estresse;  
Anestesia geral;  
Crianças

## Efeitos do bloqueio peridural caudal em pacientes cirúrgicos pediátricos: estudo randomizado

**Resumo**

**Justificativa:** O estresse cirúrgico causa resposta neuroendócrina, resultando em instabilidade hemodinâmica indesejável, modificações na resposta metabólica e disfunção no sistema imune. **Objetivos:** O objetivo deste estudo foi avaliar em pacientes pediátricos a eficácia do bloqueio peridural caudal no controle da dor intra e pós-operatória e na redução da resposta ao estresse nesses períodos.

**Métodos:** Estudo clínico prospectivo randomizado que incluiu 60 pacientes submetidos à herniorrafia eletiva. Um grupo (n=30) recebeu anestesia geral, e o outro (n=30) anestesia geral combinada a bloqueio caudal. Foram medidos os parâmetros hemodinâmicos, o consumo de drogas e a intensidade da dor. Amostras de sangue para medir glicemia e cortisol plasmático foram obtidas antes da indução e após o despertar dos pacientes.

**Resultados:** As crianças que receberam bloqueio peridural caudal apresentaram valores significativamente mais baixos para glicemia ( $p < 0,01$ ), concentração de cortisol ( $p < 0,01$ ) e escores de dor de 3 horas ( $p = 0,002$  e 6 horas  $p = 0,003$  após a cirurgia, maior estabilidade hemodinâmica e menor consumo de drogas. Além disso, não foram observados efeitos colaterais ou complicações neste grupo.

**Conclusões:** O bloqueio peridural caudal combinado à anestesia geral é uma técnica segura e que se associa o menor estresse, maior estabilidade hemodinâmica, redução nos escores de dor e baixo consumo de drogas.

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**Introduction**

Caudal block is the most commonly used technique of regional anesthesia performed on children that is suitable for use during various types of surgical interventions located below the level of the navel (Th10 dermatome).<sup>1,2</sup> This technique provides a safe approach to the epidural space in children.<sup>3,4</sup>

Surgery generates a neuroendocrine stress response, resulting in undesirable hemodynamic instability, alterations in metabolic response and malfunctioning of the immune system.<sup>5</sup> The main benefit of caudal block is good intra- and postoperative analgesia. Pain is a common cause of stress in children, therefore it should be adequately evaluated and treated both during surgery and afterwards. Analgesics and local anesthetics used in regional anesthesia have a leading role in modulation and suppression of the stress response to surgical trauma.<sup>6</sup> Because of the inability of infants and children to communicate and describe pain intensity, caudal anesthesia represents the technique of choice for postoperative pain management due to its guaranteed effectiveness. Caudal blocks are most frequently used on children in addition to general anesthesia due to specific circumstances, namely their age and their inability to cooperate.<sup>7</sup>

Clinical experience showed that combining general and regional anesthesia allows for better control of bleeding and better hemodynamic and general patient stability, thus decreasing perioperative stress and facilitating early rehabilitation and recovery of children.<sup>8,9</sup>

The aim of this research is to determine the effectiveness of caudal blocks in intra- and postoperative pain management and in reducing the stress response in children during

these same periods. Furthermore, it is also the aim of this research to evaluate the impact of this technique on hemodynamic stability and on the decrease in consumption of anesthetics and analgesics both during and after surgery.

**Methods**

Research was conducted in accordance with the Helsinki Declaration after obtaining the approval of the local departmental ethical committee. The study was performed at the Clinic of Pediatric Surgery, Institute for Child and Youth Healthcare. Patients were recruited between March 2016 and April 2018. Patient inclusion criteria were boys, American Society of Anesthesiologists (ASA) physical status Class I, aged between 2 and 5 years, scheduled for elective inguinal herniorrhaphy. Exclusion criteria were skin infection of the caudal area, hypoglycemia and known allergy to anesthetics. This prospective, randomized clinical trial included 60 patients. We have targeted this number of patients after analysis of statistical power and from previous studies and our annual number of similar patients.<sup>10-12</sup> The power of our study was 0.8 with  $\alpha$  value of 0.05. Cohen's  $d = 0.75$  showed a medium effect size. According to differences in cortisol levels between groups with and without caudal block obtained in the previous studies, our sample size was supposed to be 54. We had a goal to randomize more than 54 patients wishing more powerful results, but we had to satisfy with 60 patients because of insufficient number of possible participants per year. After obtaining written parental consent, all eligible participants were divided into two equal groups. The Chief Statistician of the Clinical Centre of Vojvodina was in

charge of creating and concealing the allocation sequence. We used sealed envelopes and blinded the participants. The control group ( $n = 30$ ) received general anesthesia (Group G) and the caudal group ( $n = 30$ ) received general anesthesia with a caudal block (Group C). All patients were operated by two surgeons with similar surgical skills, age and time of working experience. Three experienced anesthesiologists performed anesthesia in both groups.

All patients were preoperatively prepared by a pediatric psychologist in order to lower anxiety and thereby reduce the stress response to surgery. Enteral intake was suspended 6 h prior to intervention, with the purpose of avoiding complications during airway management and interference with blood glucose levels. Moreover, perioperative fluid requirements were managed according to a standardized protocol and we used only Ringer's lactate to prevent interference with blood glucose levels. All surgical interventions were performed between 9 and 11 a.m. to avoid hormonal level variations. All patients were premedicated with  $0.5 \text{ mg} \cdot \text{kg}^{-1}$  (maximum dose 15 mg) midazolam orally 30 min prior to surgery. For the induction of general anesthesia, all examinees received  $1 \mu\text{g} \cdot \text{kg}^{-1}$  fentanyl,  $2.5 \text{ mg} \cdot \text{kg}^{-1}$  propofol and  $0.6 \text{ mg} \cdot \text{kg}^{-1}$  rocuronium bromide. The airway was maintained using a laryngeal mask (I-gel®).

After inducing general anesthesia, patients in Group C were placed in the lateral position. After preparing the puncture field, following measures of asepsis and antisepsis, caudal block was performed under the control of ultrasound (GE® Venue 40) with a single-shot 22 G needle. Patients received  $2.5 \text{ mg} \cdot \text{kg}^{-1}$  (maximum dose 75 mg) levobupivacaine. After the injection of the medication, patients were flipped back into a supine position. The Masimo pulse oximeter (SET Radical®) was used to monitor the Perfusion Index (PI) via the examinee's toe. Dilatation of the anal sphincter and a rise of PI were considered signs of a successful caudal block due to skin vasodilatation at the monitoring site.

In both groups anesthesia was maintained with propofol by continuous infusion at  $6\text{--}10 \text{ mg} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$ , which was managed according to Bispectral Index (BIS) readings during the entire surgical intervention. Rocuronium bromide was administered intravenously in bolus injections when needed ( $0.15 \text{ mg} \cdot \text{kg}^{-1}$ ), according to neuromuscular Train-of-four monitoring. Fentanyl bolus injections ( $1 \mu\text{g} \cdot \text{kg}^{-1}$ ) were administered in both groups for a rise in heart rate and arterial blood pressure by 20% from baseline values. If necessary, reversal of the neuromuscular block with neostigmine was administered at the end of the surgery.

Blood samples from an intravenous cannula were taken for assessment of blood glucose and cortisol levels on two occasions. An intravenous cannula was placed 30 min following midazolam premedication. Samples were taken immediately after insertion (they were considered basal values before anesthesia induction). During anesthesia, a second peripheral venous cannula was inserted; solely for the purpose of secondary blood sampling 30 min after the patient awakes.

Intraoperative Electrocardiography (ECG), non-invasive Blood Pressure (BP) and Heart Rate (HR) were monitored, along with pulse oximetry end tidal  $\text{CO}_2$  and BIS. The first measurement was observed before induction, the second measurement immediately after and the third, before surgical incision. Further measurements were performed 5 min

after incision and then at every 15 min up to the last measurement, which was after awakening the child (eight measurements in all).

Total consumption of anesthetics, muscle relaxants, opioid analgesics and postoperatively used analgesics was monitored. Additionally, the durations of surgery and anesthesia were measured.

The need for postoperative analgesia was assessed with the modified Comfort scale. Scores were: 1, Sleeping peacefully; 2, Awake and calm; 3, Awake and slightly stressed; 4, Agitated; 5, Crying in distress. Pain assessment was performed 30 min, 3 h and 6 h following the awakening after surgery. The study was designed to administer postoperative analgesia using  $15 \text{ mg} \cdot \text{kg}^{-1}$  paracetamol intravenously for a pain score of 3 or more. Additionally, any side effects and complications were monitored and recorded.

Data were analyzed with the IBM® SPSS 23.0 program package (free trial). Statistical significance was determined at  $p < 0.05$ . Mean and Standard Deviation (SD) were calculated for all continuous variables. Frequencies were calculated for pain scores. A linear diagram was used for presentation of the variation in mean values of pulse and systolic BP in the observed time period. Friedman's test was used to determine differences among groups for repeated measures. Wilcoxon's test was used to determine differences between two measurements for each group. Differences between groups in all time intervals were determined with the Mann-Whitney test. Student's *t*-test was used to determine differences in variables for general data and for medication consumption.

## Results

The study involved 60 boys who were randomly divided into two equal groups. We initially allocated 79 eligible patients into groups by using the random numbers table method, however, six patients were excluded because of parental disapproval, a further four because of absence of the physicians responsible for surgery, another due to the appearance of a new rash in the caudal area and another due to newly revealed hypoglycemia before the induction of anesthesia. Unbalanced group sizes and technical problems with the ultrasound led to the removal of a further seven patients from the study, leaving a total of 60 patients. Participant flow is shown in Fig. 1.

### General data

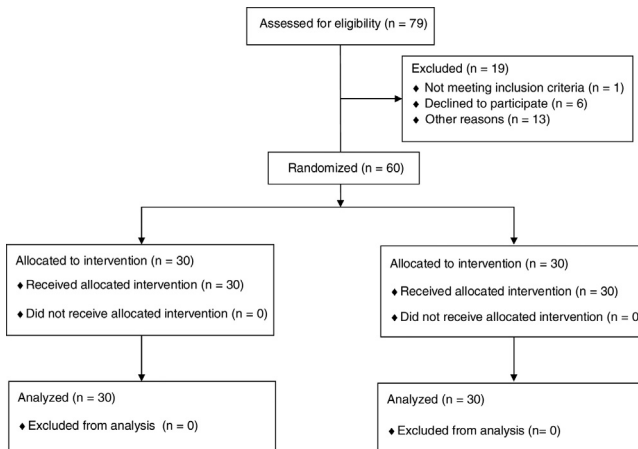
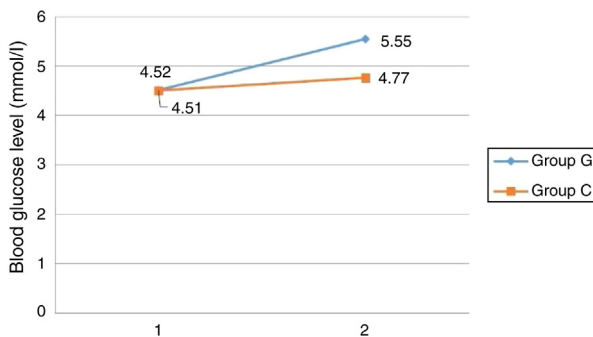
Our statistical analysis showed normal distribution of general data. The members of the two observed groups did not differ significantly in age or weight. The difference between the durations of surgical intervention was not statistically significant and hence the groups were comparable. The difference between the durations of general anesthesia was statistically significant (Table 1).

Variables like glycaemia, cortisol levels, blood pressure, heart rate and pain after the surgery were not normally distributed.

**Table 1** Comparison of patients' demographic and monitored data during anesthesia.<sup>a</sup>

	Mean $\pm$ SD		<i>p</i> -value <sup>a</sup>
	Group G (n = 30)	Group C (n = 30)	
Age (years)	4.2 $\pm$ 0.56	4.0 $\pm$ 0.58	0.46
Weight (kg)	19.9 $\pm$ 1.70	21.7 $\pm$ 2.02	0.64
Caudal block before surgery (min)	–	12.9 $\pm$ 1.52	–
Anesthesia duration (min)	47.6 $\pm$ 1.66	62.3 $\pm$ 4.86	0.02
Surgery duration (min)	36.50 $\pm$ 1.79	40.4 $\pm$ 4.23	0.58
Caudal block duration (min)	–	600 $\pm$ 69.96	–

<sup>a</sup> Student's *t*-test:  $p < 0.05$  was considered statistically significant.

**Fig. 1** CONSORT 2010 Flow Diagram.**Fig. 2** Comparison of mean blood glucose values between groups at Measurements 1 (baseline) and 2 (30 min after awakening).

### Variation of glycemia over time

All patients were normoglycemic at the beginning of measurement (Measurement 1) and there was no statistically significant difference in mean glucose values between groups (Mann-Whitney test,  $p = 0.2$ ). At Measurement 2 both groups had an increase in blood glucose levels, but the increase in Group G was statistically significant (Wilcoxon's test,  $p < 0.01$ ). This was not the case in Group C (Wilcoxon's test,  $p = 0.18$ ). At Measurement 2 the mean values of blood glucose were significantly higher in Group G (Mann-Whitney test,  $p < 0.01$ ) (Fig. 2). None of the patients had pathological blood glucose levels during the study.

### Cortisol variation over time

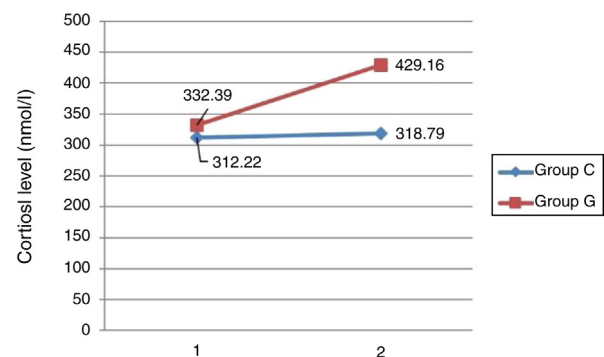
At Measurement 1 there was no statistically significant difference in cortisol levels between groups (Mann-Whitney test;  $p = 0.08$ ). However, at Measurement 2 both groups had an increase in plasma cortisol concentrations; the increase in Group G was statistically significant (Wilcoxon's test,  $p = 0.02$ ) but the increase in Group C was not (Wilcoxon's test,  $p = 0.1$ ). Also, at Measurement 2 the mean values of plasma cortisol concentrations were significantly higher in Group G compared to Group C (Mann-Whitney test,  $p < 0.01$ ) (Fig. 3).

### Heart rate variation

A statistically significant increase in HR was detected in Group G at Measurements 4, 6 and 8 (Wilcoxon's test,  $p = 0.04$ ), but this was not the case in Group C (Wilcoxon's test,  $p = 0.78$ ). There was a statistically significant difference in HR between the two groups at every measurement point (Friedman's test,  $p = 0.02$ ). We recorded no arrhythmia during the observed periods in either groups (Fig. 4).

### Variation of systolic blood pressure

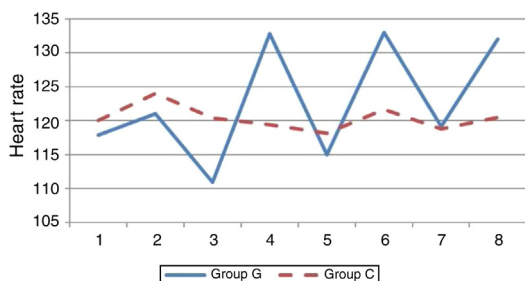
An increase in systolic BP was statistically significant at Measurements 3, 5 and 7 in Group G patients (Wilcoxon's test,  $p = 0.03$ ). Children in Group C who received a caudal block did not have a statistically significant alteration in systolic

**Fig. 3** Comparison of mean serum cortisol values between groups at Measurements 1 (baseline) and 2 (30 min after awakening).

**Table 2** Consumption of medication in the groups.<sup>a</sup>

	Group G (n = 30)	Group C (n = 30)	p-value <sup>b</sup>
Fentanyl ( $\mu\text{g. kg}^{-1}. \text{h}^{-1}$ )	$4.09 \pm 0.28$	$1.4 \pm 0.3$	< 0.01
Propofol ( $\text{mg. kg}^{-1}. \text{h}^{-1}$ )	$9.09 \pm 0.17$	$8.7 \pm 0.45$	0.08
Rocuronium bromide ( $\text{mg. kg}^{-1}$ )	$0.82 \pm 0.11$	$0.67 \pm 0.12$	0.1
Paracetamol ( $\text{mg. kg}^{-1}. 24 \text{h}^{-1} \text{ iv}$ )	29	4.5	< 0.01

<sup>a</sup> Student's *t*-test:  $p < 0.05$  was considered statistically significant.



**Fig. 4** Comparison of heart rate variation between groups for Measurements 1–8.

BP levels at these measurement intervals (Wilcoxon's test,  $p = 0.67$ ).

The values of systolic BP were statistically higher in patients who did not receive a caudal block in all the measurement points (Friedman's test,  $p < 0.01$ ). None of the patients had a pathological BP level during the study (Fig. 5).

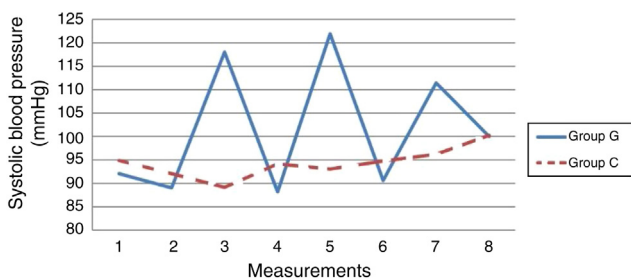
### Drug consumption

Average consumption of anesthetics, muscle relaxants, opioid analgesics and postoperatively used analgesics is shown in Table 2. Consumption of propofol and rocuronium was higher in Group G in comparison to Group C, but the difference between groups was not statistically significant. On the other hand, there was a statistically significant higher consumption of fentanyl and paracetamol in Group G (Table 2).

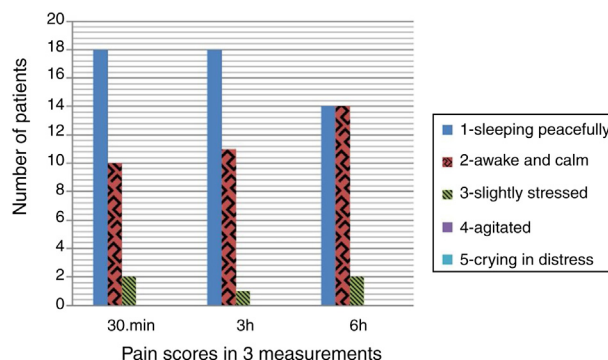
### Pain assessments

In Group G there were remarkably higher pain scores in all three measurements (Figs. 6 and 7).

After 30 min of the operation ending, we obtained a pain score of  $1.46 \pm 0.11$  for Group C and  $1.86 \pm 0.2$  for Group G. This difference was not statistically significant (Mann-



**Fig. 5** Comparison of systolic BP variation between groups for Measurements 1–8.



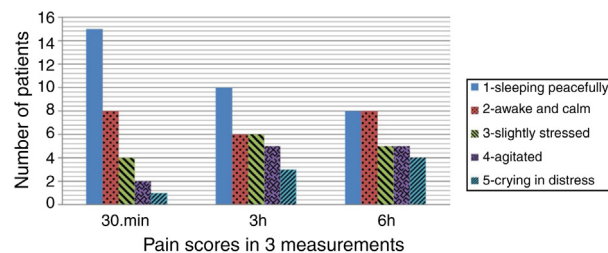
**Fig. 6** Distribution of pain scores in Group C for three measurements.

Whitney,  $p = 0.27$ ). After 3 h, the pain score was  $1.43 \pm 0.1$  in Group C and  $2.5 \pm 0.25$  in Group G. This difference was statistically significant (Mann-Whitney,  $p = 0.002$ ). After 6 h, the pain score was  $1.60 \pm 0.11$  for Group C and  $2.63 \pm 0.26$  for Group G. These results also showed significant differences between groups (Mann-Whitney,  $p = 0.003$ ).

In Group G there was a single case of vomiting and two cases of nausea, but otherwise there were no other side effects or complications identified during this study.

### Discussion

Caudal anesthesia represents an epidural injection of a local anesthetic or a combination of local anesthetics and adjuvants (opioids, clonidine, ketamine, epinephrine, magnesium etc.) through a needle or catheter placed in the sacral canal. Stress associated with surgery leads to the release of catecholamine and cortisol, which have an anti-insulin effect, resulting in increased plasma glucose levels.<sup>10</sup> In one study it was shown that caudal block leads to a smaller increase in epinephrine, cortisol and glucose.<sup>11,12</sup> When added to general anesthesia, caudal block significantly



**Fig. 7** Distribution of pain scores in Group G for three measurements.

reduces the neurohormonal response by making an efferent blockade at the level of the spinal cord.<sup>13</sup> In another study it was also concluded that if given preoperatively, caudal block reduces the stress response to a greater extent compared to a postoperatively given caudal block. Lower blood glucose levels were probably caused by the suppression of cortisol after the caudal block.<sup>14</sup> Our results also showed that when given preoperatively, caudal block prevents an increase in blood glucose and plasma cortisol levels postoperatively. In the literature we found that systolic and diastolic BP and HR changes were not significant in groups of patients that received caudal analgesia compared with those who did not.<sup>15</sup> In our study, caudal block also led to a greater hemodynamic stability intraoperatively that could probably be a reflection of the lower stress response.

Preoperative fear, anxiety and the premedication method are among the factors that can increase the hormonal response.<sup>16</sup> Because of all the above-mentioned reasons, we premedicated all examinees with midazolam orally instead of using intramuscular premedication, which is painful and could be a very traumatic experience for children.

Complications that accompany this anesthetic technique are rare and usually transient.<sup>17</sup> Ultrasound could be used as an adjuvant tool in caudal blocks because it can provide a real-time image and confirmation of the needle's position in the epidural space. Also, intravascular and intrathecal injections can be avoided with ultrasound visualization and with previous aspiration.<sup>18</sup> Ultrasound is safe, radiation free, simple to perform and could be very helpful in patients with spinal anatomy variations.<sup>19,20</sup> In our study, we used ultrasound guidance while performing caudal blocks and recorded no complications during the puncture process. We have also minimized the possibility of a caudal fail by waiting for the increase in PI. The PI on the pulse oximeter could be used to demonstrate vasodilatation following sympathectomy.<sup>21</sup> An increase of PI provides earlier and clearer confirmation of sympathectomy due to epidural anesthesia than skin temperature and arterial pressure.<sup>22,23</sup>

In our study, we have shown that caudal block provides excellent intraoperative and postoperative analgesia and certainly leads to statistically significant lower opioid and anesthetic consumption. The advantage of reduced drug consumption, in addition to reducing their side effects and neurotoxicity, can also be reflected in the lowering of treatment cost. Our results have also shown that caudal block leads to lower pain scores and to a reduced consumption of postoperative analgesics. These results are similar to those of another study in which patients who received caudal block had significantly lower pain scores compared with the control group.<sup>24</sup> The reason for this could be because caudal anesthesia provides highly effective analgesia.

During this study, for Group C there were no side effects to drugs applied intraoperatively or postoperatively, which is consistent with the data in many studies.<sup>25,26</sup> In Group G there was a single case of vomiting and two cases of nausea, which can be explained by the use of higher doses of opioid analgesics during surgery.

There are no specific guidelines, only recommendations, for when caudal block should be performed. Although the choice of anesthesia technique depends on the condition of

the patient and the personal affinities of the anesthetist, the efficacy and safety of caudal block is well documented. When we consider caudal blocks, we should also have in mind the results of Golladay et al. that caudal block can lower total hospital costs.<sup>27</sup>

We are aware that ultrasound-guided peripheral nerve blocks in the last decade have become an important part of multimodal analgesia in pediatric and adult surgery, but according to studies by Sahin et al. and Ahmed et al., the Transversus Abdominis Plane (TAP) block is the peripheral block most often used for pediatric hernia surgery and is the only method that can achieve similar results to caudal block.<sup>28,29</sup> When caudal block is performed under ultrasound guidance, the possibility of complications (the primary fault of the classic application of the technique) is decreased, therefore nullifying the earlier advantage of the TAP block. On the other hand, the effect of the TAP block, like every other interfascial block, depends primarily on the content of the local anesthetics injected between the two fascia layers. This can sometimes interfere with the quality of the TAP block.<sup>29</sup> We consider that the effect of caudal block under ultrasound guidance is less dependent on the anesthetist's manual skills.

We are aware that this study has several limitations. The first limitation is the small number of patients, but unfortunately our university clinic is just one of several places in the northern region of Serbia where this kind of intervention is performed and we hope that our conclusions will prove to be an incentive for new and larger studies. The second significant limitation is the use of a non-validated scale for assessment of postoperative pain. In our study the observed patients were aged 2–5 years. Because some of the patients were preverbal and some verbal, the self-report pain assessment tool was not appropriate for all of them. We have modified the Comfort pain scale in order to simplify the process of pain assessment in our hospital and to establish a clear protocol for easier data analysis. The fact that we used modified Comfort scale for assessment of postoperative pain represents a slight limitation of our study, but we hope that obvious differences in average pain score and analgesic consumption between groups can intensify the generalization of our conclusions.

In summary, our results demonstrate that the combination of caudal block with general anesthesia is a safe method that generates less stress, greater hemodynamic stability, lower pain scores and lower consumption of medication, based on which pediatric anesthesiologists should consider caudal anesthesia in everyday practice.

## Conflicts of interest

The authors declare no conflicts of interest.

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