Efficacy and safety of general anesthesia with caudal block for inguinal hernioplasty in children: a randomized controlled trial

M. PANDUROV[1,2], I. FABRI GALAMBOS[1,2], R. ZDRAVKOVIC[1,3], A. URAM BENKA[1,2], G. RAKIC[1,2], N. BOSKOVIC[1,2], S. VICKOVIC[1,4], M. TATIC[1,5], M. LUKIC SARKANOVIC[1,4], T. TUBIC[1,4], M. PREVEDEN[1,3], N. DRAČINA[1,3], N. VIDENOVIC[6], D. KRTINIC[7,8], A. JAKOVLJEVIC[9], N. DJOKOVIC[9], A. JAKOVLJEVIC[6], B. DRASKOVIC[1,2]

[1]Faculty of Medicine, University of Novi Sad, Novi Sad, Serbia
[2]Department for Pediatric Anesthesia, Institute for the Healthcare of Children and Youth of Vojvodina, Clinic of Pediatric Surgery, Intensive Care and Pain Therapy, Novi Sad, Serbia
[3]Institute of Cardiovascular Diseases of Vojvodina, Clinic for Cardiovascular Surgery, Sremska Kamenica, Serbia
[4]University Clinical Center of Vojvodina, Clinic of Anaesthesia and Intensive Care, Novi Sad, Serbia
[5]Oncology Institute of Vojvodina, Sremska Kamenica, Serbia
[6]Faculty of Medicine, University of Pristina, Kosovska Mitrovica, Serbia
[7]Faculty of Medicine, University of Nis, Nis, Serbia
[8]University Clinical Center Nis, Clinic for Oncology, Nis, Serbia
[9]Clinical Hospital Center Kosovska Mitrovica, Kosovska Mitrovica, Serbia

Abstract. – OBJECTIVE: Caudal block is a type of regional anesthesia suitable for inguinal hernia surgery in children. Our goal was to determine the effectiveness of caudal block combined with general anesthesia in providing intra- and postoperative analgesia and its effect on hemodynamic stability and drug consumption.

PATIENTS AND METHODS: Prospective, randomized controlled study included 78 boys, 3-5 years, with an indication for inguinal herniorrhaphy, divided into groups G (general anesthesia, n=39) and G+C (general anesthesia + caudal block, n=39). We monitored hemodynamic parameters intraoperatively, postoperative pain, and total consumption of all medicaments in the perioperative period. The monitoring of complications and side effects of drugs was also carried out.

RESULTS: Boys in group G had statistically significantly higher values of heart rate in the 5th minute (p<0.01), in the 25th minute (p<0.01), and after awakening from anesthesia (p<0.01). We obtained similar results with systolic and diastolic pressure values in the 5th minute (p<0.01), 15th minute (p<0.01), 25th minute (p<0.01), before awakening from anesthesia (p<0.01) and after awakening (p<0.01). They also had significantly statistically higher total consumption of propofol, fentanyl, and acetaminophen (p<0.01). Boys in group G+C had significantly lower postoperative pain scores: initially (p<0.01), after 2 hours (p<0.01), and after 5 hours (p<0.01). No complications occurred in this group.

CONCLUSIONS: In children, the combination of general anesthesia with caudal block, compared to general anesthesia only, is more efficient in suppressing visceral pain, leading to better hemodynamic stability, and reducing the consumption of medicines in the perioperative period.

Key Words:
General anesthesia, Caudal block, Pain, Hemodynamic parameters.

Introduction

Every surgical intervention carries a certain level of fear, pain, discomfort, tissue destruction, tissue hypoxemia, pH imbalance in the blood, and other changes which, as a result, have a proportional activation of inflammatory and defense systems as well as many complex neuroendocrine reflexes, which significantly disrupt homeostasis and can be harmful[1-3]. Anesthesia cannot affect the degree of tissue damage; however, on the other hand, it can affect the progress of surgical

Corresponding Author: Ranko Zdravkovic, MD; e-mail: ranko.zdravkovic@mf.uns.ac.rs

treatment, suppressing pain among other things, and therefore suppress the stress response and its harmful effect on the body[4].

Inappropriate body reactions to pain in children can affect numerous hormonal, metabolic, autoimmune, and psychological disorders, which can consequently jeopardize the growth and development of a child. Neural plasticity in development, together with an immature descending pain modulation pathway, can predispose children with acute pain to the development of hyperalgesia and chronic pain to a greater extent than in cases of adult patients. Therefore, it is of utmost importance, primarily in children, to accurately assess and adequately manage pain to minimize potential adverse effects[5,6].

Consequently, our goal was to determine the effectiveness of caudal block combined with general anesthesia in providing intra and postoperative analgesia. Also, the purpose of this research was to examine the effect of caudal block on hemodynamic stability and drug consumption.

Patients and Methods

A prospective, randomized clinical study was conducted in the Pediatric surgery clinic at the Institute for Health Care of Children and Youth of Vojvodina (Novi Sad, Serbia). Research has been conducted according to the Helsinki Declaration after receiving consent from the Ethical Committee of the Institute for Health Care of Children and Youth of Vojvodina (No. 3340-1-42; date of approval: 09.10.2015.). The parents of the children included in the study previously gave their written informed consent. The study protocol was registered at ClinicalTrials.gov (identifier NCT05958589). The study included boys aged 3 to 5 years (I status, according to the American Society of Anesthesiologists - ASA) scheduled for elective inguinal hernioplasty. The head of the statistics department was responsible for the concealment of the allocation sequence by using sealed envelopes with sequence and arrangement, and patients were the ones who did not know to which group they belonged. The patients were divided into groups G (general anesthesia, n=39) and G+C (general anesthesia + caudal block, n=39).

All patients were examined preoperatively by an anesthesiologist and underwent psychological preparation. Patients underwent a usual fasting regime according to ASA guidelines for preoperative fasting. On the day of operation, all patients received midazolam 0.5 mg/kg (maximum dose 15 mg) orally. Induction of anesthesia was the same for all patients and consisted of intravenous anesthetic propofol (2-3 mg/kg), opioid analgesic fentanyl (1-1.5 mcg/kg), and muscle relaxant rocuronium - bromide (0.6-1 mg/kg). The airway was obtained by placing a laryngeal mask (I-gel®) (Intersurgical Ltd, Crane House, Molly Millars Lane, Wokingham, Berkshire, UK).

In group G+C, after the induction, a single shot caudal block was performed. Levobupivacaine 0.25% was administered (2.5 mg/kg; maximal dose 75 mg). After the increase of the perfusion index on the big toe [PI- Massimo pulse oximetry (SET Radical®)] (Masimo Corp., Irvine, CA, USA) and sphincter dilatation, surgery was performed.

In both groups, the depth of anesthesia was maintained by continuous infusion of propofol (6-10 mg/kg/h) according to the Bispectral index values (BIS 40-50) (Medtronic, Covidien llc, Mansfield, MA, USA). In case of increased pulse or blood pressure for 20% from basal values, bolus doses of fentanyl were given 1 mcg/kg. Rocuronium bromide was repeated in case of need depending on the neuromuscular Train-of-four monitoring as a single dose of 0.15-0.2 mg/kg. In cases where it was necessary, on emergence, a reversion of neuromuscular block was administered with neostigmine. All patients in group G received i.v. acetaminophen 15 mg/kg.

Intraoperatively, from clinical parameters that may indicate pain, in both groups, the following hemodynamic parameters were recorded: electrocardiogram, heart rate per minute (HR), and non-invasive blood pressure measurement. In total, eight measurements were included in the statistical processing: initial values before the induction, values immediately after the induction, values before the incision, 5 minutes, 15 minutes, and 25 minutes after the incision, just before the end of surgical intervention and on emergence.

Postoperative pain was assessed on three occasions in the post-anesthesia recovery room 30 minutes, 2 hours, and 5 hours after emergence from anesthesia. To measure postoperative pain level, a visual analog scale (VAS) and Wong-Baker Faces pain rating scale were used. In case of pain (VAS scale and Faces scale pain intensity 4 or above), acetaminophen was given (15 mg/kg i.v.). In cases of persistent pain, ketorolac (0.5 mg/kg) was administered intravenously. The administration time of the first dose of systemic analgesic was recorded postoperatively, as well as the total consumption of systemic analgesic.

The duration of anesthesia, surgery, caudal block (time to first analgesic), and total consumption of all medicaments in the perioperative period were recorded. During the whole process, complications and side effects of drugs were observed and documented.

Statistical Analysis

The data were analyzed using the IBM® SPSS 23.0 (IBM Corp., Armonk, NY, USA) statistical software package. The value $p<0.05$ indicated a statistically significant result. For all continuous variables, mean values and standard deviation (SD) were calculated, and frequencies were calculated for pain scores. Characteristics of the two groups were compared using Student's *t*-test for continuous variables, general data, and medication consumption, while the Chi-square test was applied to compare categorical variables. Friedman's test was used to determine differences among groups for repeated measures. Mann-Whitney's test was used to calculate differences between groups in all time intervals, and Wilcoxon's test to determine differences between two measurements for each group. The sample size was calculated using the PASS software version 11 (NCSS LLC, East Kaysville, USA) for Two-Sample *t*-test Power Analysis. After analysis of statistical power from a previous study[7], our sample size was supposed to be 56 to achieve a power of 80% and a one-sided 95% confidence interval (Cohen's d=0.75). Considering the Consort allocation process and our annual number of those patients, we had to consider more than that.

Results

This research initially included 92 patients. On the day of the surgery, five patients did not meet the inclusion criteria for the study. Parents of four patients have refused to be included. The parents of one patient confirmed that he consumed food just before the surgery; therefore, his surgery had to be postponed. Due to the development of acute infection on the day of the surgery, two patients were excluded. In intraoperative period, two patients were excluded from the further research; the first patient because of the development of skin erythema in sacral region, while the other one was excluded because of surgical complications and duration of surgery longer than 60 minutes. After the randomization, the complete protocol and analysis were performed on 78 patients divided into two equal groups: the group that received general anesthesia (G) n=39 and the group that received general anesthesia and caudal block (G+C) n=39 (Figure 1).

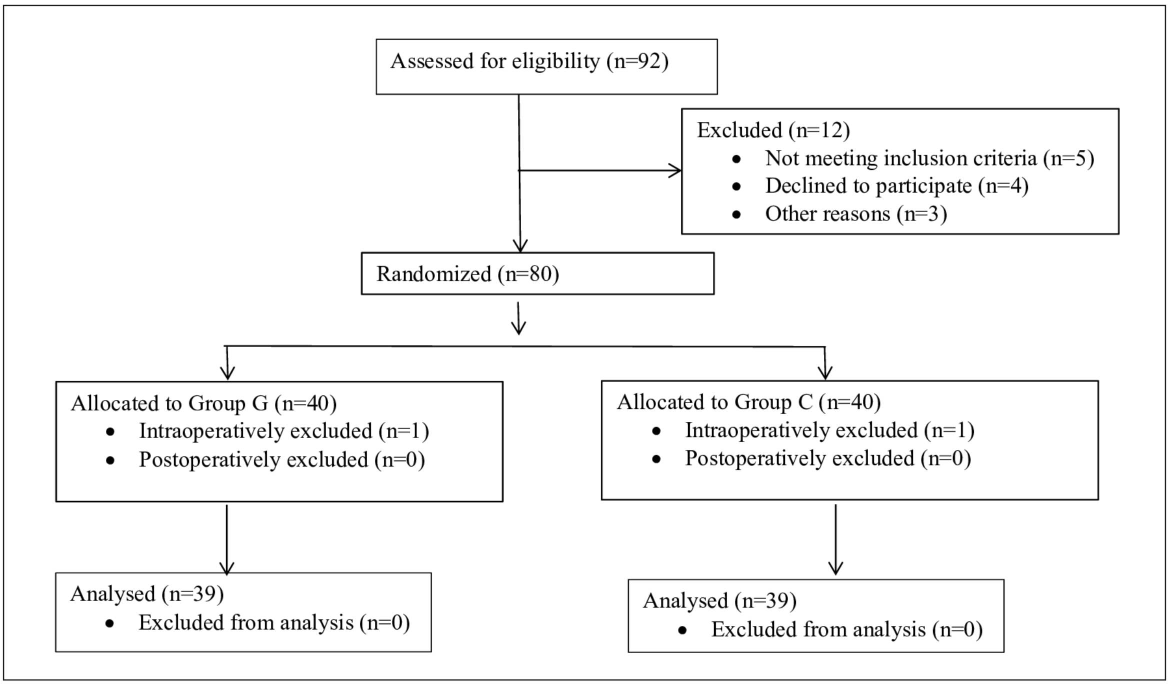

Figure 1. Flow chart of the study.

Table I. Demographic and monitored data during anesthesia.

	Group G (n =39) mean (SD)	Group G+C (n =39) mean (SD)	*p*
Age (years)	3.92 (0.95)	3.62 (1.07)	0.146
Weight (kg)	18.11 (4.11)	16.87 (3.85)	0.179
Caudal block before surgery (min)		14.9 (2.72)	
Anesthesia duration (min)	42.18 (7.36)	64.76 (6.57)	**0.0000**
Surgery duration (min)	38.5 (3.79)	41.8 (4.33)	0.62
Caudal block duration (min)		263.68 (70.5)	

General Patients' and Anesthesia Data

By statistical processing of general data, we have obtained results that indicate normal distribution. Patients from both groups did not differ significantly regarding age and weight. The difference in duration of surgical intervention was also not significant. However, there was a statistically significant difference between groups related to the duration of general anesthesia because of the time it takes to perform a caudal block (Table I).

The duration of the caudal block was measured from the moment of administration of local anesthetic to the caudal space until the moment of pain occurrence. The average duration of caudal anesthesia in the entire sample was 263.68±70.50 minutes, with a range of 120 to 360 minutes; the median was 240 minutes. The block was primarily achieved with the first puncture (84.2%). 7.9% of patients needed two punctures and 7.9% required three punctures.

Intra and Postoperative Drug Consumption

Considering that only patients from group G+C received caudal 0.25% levobupivacaine (2.44±0.28 mg/kg; 0.97±0.11 ml/kg), intraoperative consumption of levobupivacaine was not compared between the groups. Total consumption of propofol, fentanyl, and acetaminophen in group G was significantly higher in comparison to group G+C, which is shown in Table II. In patients of group G+C, there was no need to administer ketorolac.

Analysis of Hemodynamic Parameters

Analysis of variance with repeated measurements applied to the variable (HR) in relation to two factors, group and time, shows that the interaction of group and time is statistically significant (F=20.3, *p*=0.00). This result means that the variation of HR in time varies statistically significantly between the groups (Figure 2). We got the same results when systolic pressure (SP) (F=25.9, *p*=0.00) and diastolic pressure (DP) (F=12.8, *p*=0.00) were analyzed (Figure 3).

Analysis of Postoperative Pain

In group G+C, initially, all patients' values were 0. In the second measurement, after 2 hours, the mean value was 0.16±0.55, and after 5 hours, it was 1.97±1.33. In group G, the initial mean value was 2.13±1.26, while values recorded after 2 hours and in the third measurement were 2.76±1.65 and 5.18±1.75, respectively. In all three moments when measuring pain *via* pain scales, statistically significantly higher values were found in group G, initially (z=6.11, *p*<0.01),

Table II. Drug consumption between the groups.

Drugs	Group G+C mean (SD)	Group G mean (SD)	*p*
Levobupivacain (mg/kg)	2.44 (0.29)		
Propofol in total (mg/kg)	11.29 (0.49)	11.7 (0.53)	**0.0008**
Fentanyl in total (μg/kg)	1.04 (0.1)	3.82 (0.71)	**0.0006**
Rocuronium (mg/kg)	0.12 (0.1)	0.14 (0.18)	0.224
Neostigmin (mg/kg)	0.03 (0.06)	0.03 (0.02)	0.137
Acetaminophen – postoperative (mg/kg)	13.03 (7.93)	35.53 (8.11)	**0.0009**
Ketorolac (mg/kg)		0.25 (0.32)	

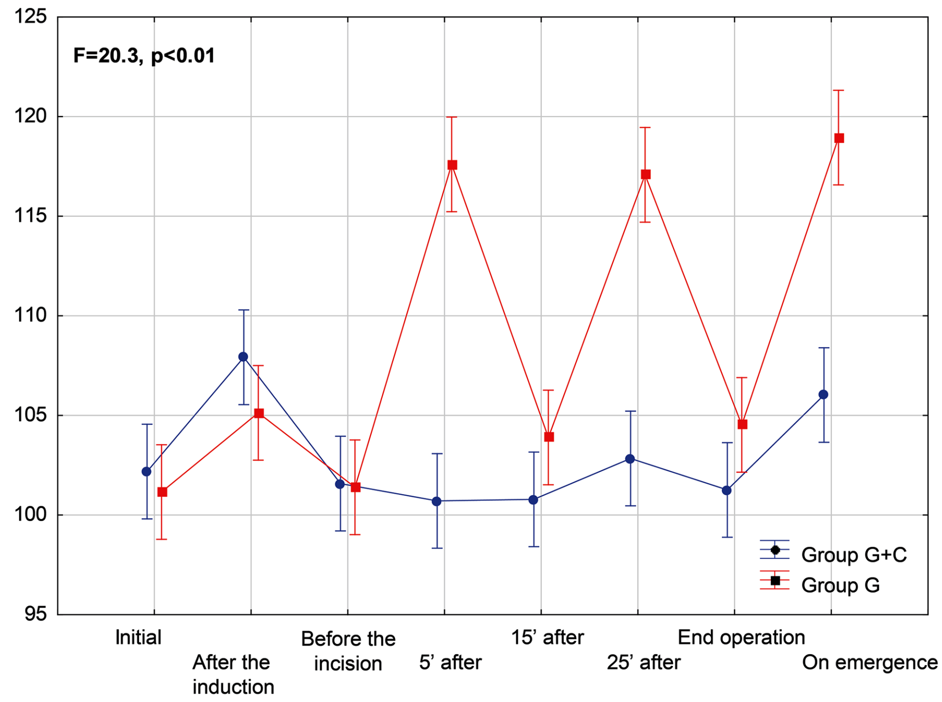

Figure 2. Trend of the average heart rate values of both groups, in the observed time intervals.

after 2 hours (z=5.84, $p<0.01$), and after 5 hours (z=6.33, $p<0.01$). The distribution of patients based on the values measured by pain scales (VAS/Faces scale) is shown in Figure 4.

Based on the stated postoperative findings in group G, a significantly higher consumption of acetaminophen was determined (35.52±8.11 mg/kg) in comparison to group G+C (13.02±7.93 mg/kg).

In group G, the average consumption of ketorolac was 0.47±0.5, while in group G+C, there was no need for ketorolac (Table II).

Analysis of Complications

During anesthesia and in the postoperative period, anesthesia complications were tracked and noted. In group G+C, there were no complications, while in group G, one child had nausea and one had vomiting ($\chi^2=4.22$, $p=0.121$).

Discussion

Different anesthesia techniques are used to prevent and minimize pain and stress caused by surgery[8]. Inguinal hernioplasty in children can be performed in general anesthesia and/or in regional anesthesia, and the most used technique of regional anesthesia in pediatric patients is caudal block[7]. Due to very few prospective, randomized controlled studies, it is difficult to compare regional anesthesia and the administration of systemic analgesics in children postoperatively[9]. Having this in mind, we can confirm with certainty that there was a need to conduct, such research that could determine the exact pain level and clinically significant difference between the effects of general anesthesia with caudal block and general anesthesia without block.

Due to the specificity of young age, which usually equals a lack of cooperation, regional anesthesia in children is generally not applied independently but in combination with some form of general anesthesia or sedation. Although there is some doubt present in the professional public opinion when it comes to the safety of regional anesthesia in children and the matter of administration of "double anesthesia", there is very little actual evidence that would confirm that the risk exists[10]. According to guidelines brought by a consensus of leading national associations for regional anesthesia, most of the regional techniques

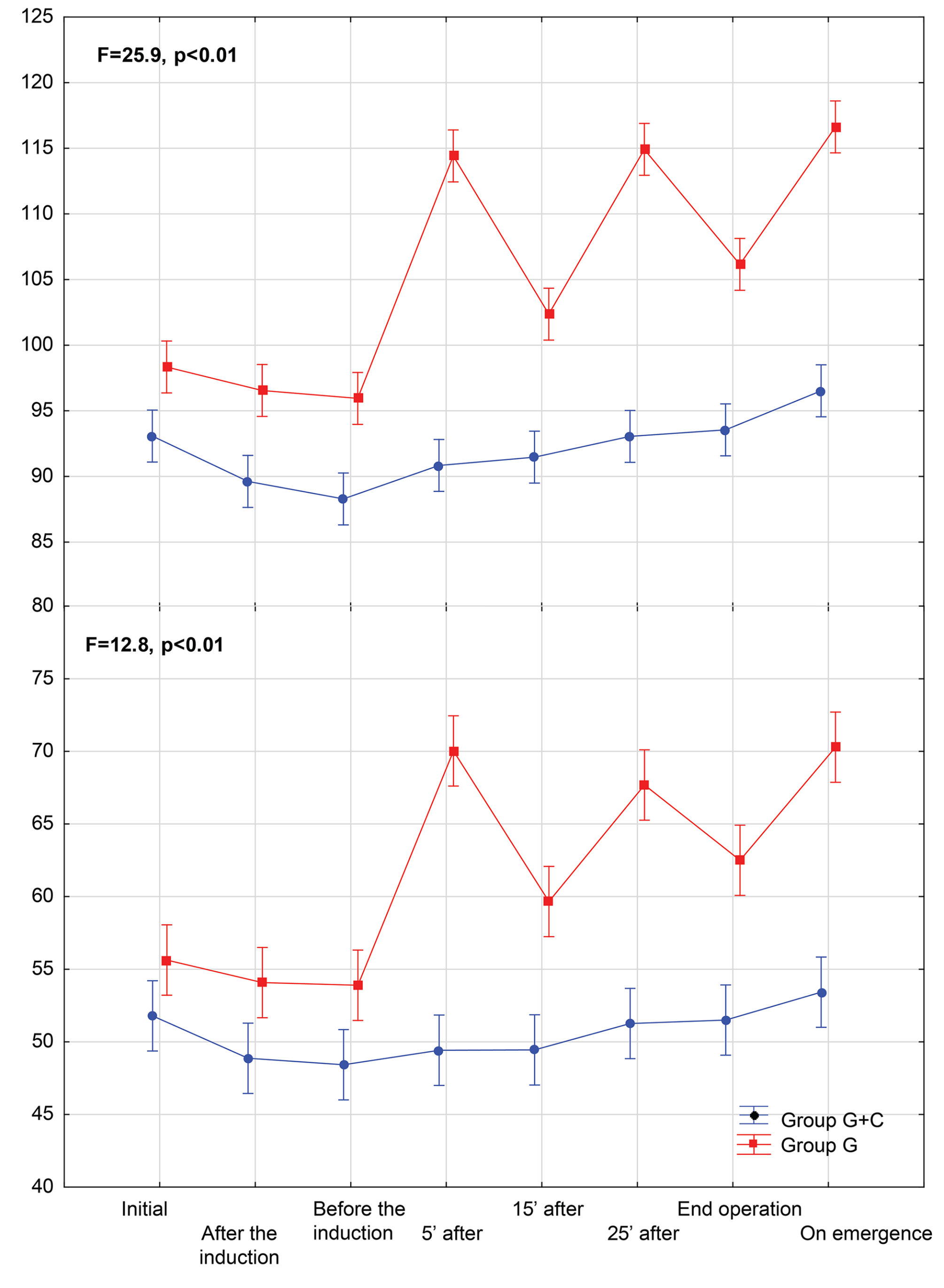

Figure 3. Trend of the average systolic and diastolic pressure values of both groups, in the observed time intervals.

in children should be administered in general anesthesia or deep sedation in order to achieve maximal safety and reduce the incidence of morbidity and mortality[11].

According to the literature, caudal anesthesia is easier to perform and learn than lumbar epidural or spinal anesthesia for adults[12]. In our study, the caudal epidural block was successful in 100% of cases, mainly at the first puncture (84.2%), while in 7.9%, a second puncture and in 7.9%, a third puncture was necessary.

Hemodynamic changes caused by caudal anesthesia are still not fully clarified. One of the leading explanations is that in children, during

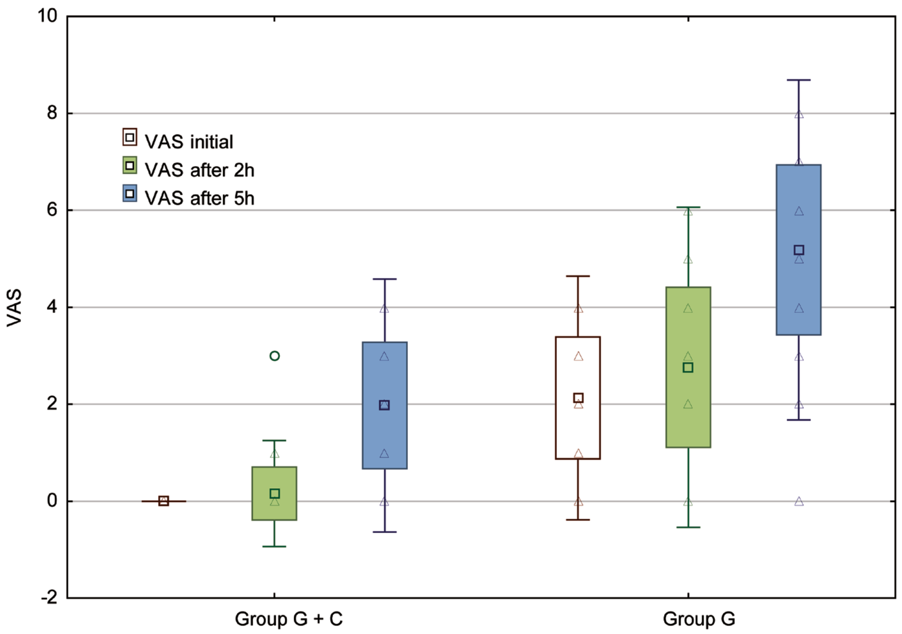

Figure 4. Distribution of patients by groups, based on pain scale values (Visual analogue scale, Wong Baker faces scale).

caudal anesthesia, arterial blood pressure is maintained because of the lower basal sympathetic tone present in children[13]. An explanation for such occurrence hides in the immaturity of the sympathetic nervous system, which leads to minimal vasodilatation in the lower parts of the body, followed by vasoconstriction in other parts of the body[14,15]. Therefore, in children, there is no need for preoperative compensation of infusion solutions. In our research, by checking the statistical significance of the mean values of heart rate, it was noted that the tested groups were significantly different from each other over time. Major changes in heart rate and borderline tachycardia occurrence (in the 5th minute after the incision, the 25th minute after the incision, and after waking up) were found in group G. In contrast, the heart rate in group G+C was stable and varied within the limits of referent values. Also, it was determined that arterial pressure in patients from both groups significantly varied during the observed time intervals. In group G, changes in SP and DP were observed, while in group G+C, the SP and DP were more stable. One of the possible explanations for this phenomenon could be that more effective analgesia was achieved in the G+C group, and intraoperative pain accompanied by tachycardia and hypertension did not even occur. Researching the data from the literature, we came across very similar results. In one study[16] performed on 40 patients that compared intraoperative hemodynamic stability between caudal block with intravenous continuous analgosedation and general endotracheal anesthesia, it was determined that changes in SP, DP, and HR were not of statistical significance only in the group that had caudal block performed preoperatively. Another similar study[17] revealed that when adding a caudal block to general anesthesia during ilioinguinal hernioplasty, the activation of stress response in children is significantly reduced, leading to hemodynamic stability. Such data confirm our results, which indicate that caudal block combined with general anesthesia – blocking the efferent nerve pathways of the spinal cord – activates, to a lesser extent, the sympathetic autonomous nervous system, leading to better hemodynamic stability than just general anesthesia.

Children can have difficulties in understanding, expressing, and communicating their pain. Their level of emotional and cognitive development can dramatically worsen their pain[18]. Considering that pain is one of the primary stress activators in the pediatric population during the perioperative period, it requires adequate treatment. As a part of regional anesthesia, analgesics and local anesthetics can play a key role in modulating and suppressing the stress response to surgical trauma, which can help reduce pain[19]. In our research, we have determined that caudal block provides excellent intraoperative and postoperative analgesia. Given that the patients in group G+C received caudal levobupivacaine, there was no need to repeat the bolus of fentanyl intraoperatively or analgesic bolus immediately after the operation. This data is significant because of the fact that by reducing the total amount of opioids and other analgesics, the occurrence of their side effects is reduced.

Also, in addition to fentanyl, our results prove that by adding the caudal block to general anesthesia, there is a statistically significantly lower use of propofol intraoperatively. Banerjee et al[20] describe the effect of the caudal block on bispectral index targeted propofol administration in children, showing a reduction of propofol consumption. These results are consistent with a previously reported study in adults by Kim et al[21] demonstrating a reduced anesthetic requirement followed by the neuraxial blockade. In professional literature, the impact of regional anesthesia on long-term outcome parameters remains unclear. Nevertheless, given the ongoing discussion about the neurotoxicity of medications used for general anesthesia, especially in the younger pediatric population, and their impact on neurodevelopment, we assumed that the use of regional anesthesia could offer some advantages by reducing perioperative consumption of anesthetics and other medications[22,23]. The advantage of reduced drug consumption, other than the unwanted side effects reduction and neurotoxicity, can be found also in treatment cost reduction. Golladay et al[24] confirmed that by use of a caudal block, overall hospital costs can be lowered.

No complications were observed during or after the caudal block procedure in this study. These results are consistent with results gathered in literature in which it can also be concluded that caudal anesthesia is a safe method. Results from an extensive study from the database of the pediatric network of regional anesthesia were analyzed with 18,650 caudal blocks, pointing to the fact that complications that follow this anesthesia technique are highly infrequent, harmless and in most cases of transitory character[15].

Limitations

This study has some limitations. The VAS scale and the Faces scale are subjective methods and, therefore, can give non-objective results. Since children between the ages of 3 and 5 may have difficulty in comprehending and assessing the severity of pain, the use of this particular scale has been found to be highly beneficial in such cases. It is worth noting that the self-report pain assessment tool may not be suitable for all children in this age group.

Conclusions

In children, the combination of general anesthesia with caudal block, compared to general anesthesia only, is more efficient in suppressing visceral pain, leading to better hemodynamic stability and reducing the consumption of medicines in the perioperative period.

Conflict of Interest

The authors declare that they have no conflict of interests.

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Authors' Contribution

All authors had major roles in the conception, design, planning, and carrying out of the study. All authors contributed to the analysis of the data and the writing and editing of the manuscript.

ORCID ID

Marina Pandurov: 0000-0002-0821-0825
Izabella Fabri Galambos: 0000-0001-5032-671X
Ranko Zdravkovic: 0000-0001-7383-6771
Goran Rakic: 0000-0001-5974-4002
Nikola Boskovic: 0000-0002-6316-4120
Sanja Vickovic: 0000-0002-2153-3135
Milanka Tatic: 0000-0002-7885-1249
Teodora Tubic: 0000-0001-8094-4607
Nebojsa Videnovic: 0000-0001-5875-6300
Dane Krtinic: 0000-0002-9781-8727

Ethics Approval

Research has been conducted according to the Helsinki Declaration after receiving consent from the Ethical Committee of the Institute for Health Care of Children and Youth of Vojvodina (No. 3340-1-42; date of approval: 09.10.2015.).

Informed Consent

The parents of the children included in the study gave their written informed consent.

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