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CHANGES IN THE INDICATORS OF ABDOMINAL ARTERIAL CIRCULATION WHEN APPLYING VARIOUS ANESTHETIC TECHNIQUES IN CHILDREN

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Summary

Intra-abdominal hypertension and abdominal compartment syndrome result from increased intra-abdominal pressure. In addition, intra-abdominal hypertension has been reported to be an independent risk factor for pediatric intensive care unit mortality.

The study aimed to compare the efficacy and the effect of various anesthetic techniques using regional anesthesia on the indicators of abdominal arterial circulation in anterior abdominal wall surgery in children.

Materials and Methods. *The study included 90 children at the age of 7-18 years. All children underwent anterior abdominal wall surgery under general anesthesia and were divided into 3 groups: Group I included 30 children who underwent anterior abdominal wall surgery under general anesthesia using morphine; Group II comprised 30 children who underwent anterior abdominal wall surgery under general anesthesia using the transversalis fascia plane block combined with the quadratus lumborum block 4 via a single injection; Group III included 30 children who underwent anterior abdominal wall surgery under general anesthesia using the TFPB.*

The manuscript was approved by the Ethics Committee of the Communal Non-Profit Enterprise "Ivano-Frankivsk Regional Children's Clinical Hospital of Ivano-Frankivsk Regional Council", as evidenced by an Excerpt from the Minute of the Committee Meeting No. 2 dated February 24, 2022.

The results obtained were statistically processed using statistical measures of variation, correlation analysis, Student's t-test. Differences were considered statistically significant at $p<0.05$. The proportions were statistically compared by using a z-test.

The study is a fragment of the research project of the Department of Children Diseases of Postgraduate Medical Education Faculty, Ivano-Frankivsk National Medical University "Health Status and Adaption of Children from the Precarpathian Region with Somatic Diseases, Their Prevention" 2021-2026, state registration number 0121U111129; the author is a co-researcher.

Results and Discussion. *The analysis of acute pain on the selected scales found significantly higher indicators of acute pain on the FLACC scale in the group of conventional anesthesia (Group I, $p<0.001$) as compared to Group II, where the TFPB in combination with the QLB-4 was used. The analysis of the Likert scale responses found that, over the course of treatment, there was a significant reduction in pain indicators among patients of Group II as compared to those in Group I and Group III ($p<0.001$). High pain intensity in children who received conventional anesthesia led to a prolonged length of hospital stay and increased IAP (FLACC scale ($r_{x,y}=0.38\pm0.16$, $p=0.02$).*

Conclusions. *A combination of regional anesthesia techniques and conventional anesthesia leads to a reduction in IAP, and increase in APP, a decrease in the resistance index in the superior mesenteric artery and shortens the length of hospital stay as compared to conventional anesthesia management.*

Keywords: *Children; Regional Anesthesia; Myofascial Blocks; Opioids.*

Introduction

The abdomen is a closed space enclosed by the spine, pelvis, diaphragm, and abdominal wall. The elasticity of the walls and character of abdominal contents determine the pressure within the abdominal cavity at a given time. Intra-abdominal pressure (AIP) is defined as the steady-state pressure concealed within the abdominal cavity [1]. Abdominal pressure varies depending on the patient's physiological status, increases with aspiration, use of abdominal muscles, and increase in fluid volume (e.g., ascites, blood). AIP is also affected by conditions limiting abdominal cavity expansion (e.g., third-spacing, burn eschars, contractures). Normal IAP ranges between 0 - 10 mm Hg. One study indicated that in children whose IAP was measured directly through the peritoneal dialysis catheter following cardiac surgery, median IAP was found to be 4 mm Hg with a range of 1 - 8 mm Hg [2]. Abdominal perfusion pressure (APP), similar to cerebral perfusion pressure, is defined as the mean arterial pressure minus IAP. In adults, it has been considered as a more accurate predictor of visceral perfusion. Increased IAP is an adverse complication often diagnosed in the postoperative period in children; it has a negative effect on organ functioning and can result in multiple organ failure [3]. Intra-abdominal hypertension and abdominal compartment syndrome result from increased IAP. Nevertheless, routine IAP measurement is not frequently used in pediatric practice and is not regarded as the standard for most intensive care units [4]. In addition, intra-abdominal hypertension has been reported to be an independent risk factor for pediatric intensive care unit mortality [5-10]. Risk factors for intra-abdominal hypertension and abdominal compartment syndrome are as follows: decreased compliance of the abdominal wall after abdominal surgery, increased intraluminal content, ascites, hepatomegaly, abdominal tumors, capillary leak syndrome in septic shock, congenital

diaphragmatic hernia, gastroschisis [11].

Abdominal wall surgeries account for 88% of all pediatric surgeries. To provide analgesia and protect from aggressive surgical management, due to psychological characteristics of children, general anesthesia is used; however, the main reason for using this type of anesthesia is that pediatric anesthesiologists have insufficient knowledge of the technique and methods of regional anesthesia due to the prevalence of the myth about excessive invasiveness of regional analgesia [12]. Analgesic efficacy of different types of regional anesthetic blocks has not been studied sufficiently; therefore, peripheral nerve blocks can have advantages over central nerve blocks due to their safety and analgesia duration [13, 14]. As the perioperative pain control may involve long-term and persistent opioid use, the application of regional anesthesia, as a part of multimodal approach to pain management, results in reducing opioid use after surgery, thereby providing an adequate postoperative analgesia as compared to opioids [15].

In general, despite the advantages of this analgesia type, the implication of regional anesthesia techniques is still insufficient [16, 17]. According to the recently published data, peripheral nerve blocks were used only in 25.5% out of 12 million surgeries; regional anesthesia techniques were used in 3.3% of these cases only [18]. If opioids had a universal effect and caused no side effects, there would be no acute pain. For success of regional anesthesia, it should be indicated correctly, block the target nerve, and use the appropriate technique and equipment [19-22]. In addition, regional anesthesia should be an integral part of the Enhanced Recovery after Surgery (ERAS) program, while opioids should be avoided whenever possible due to their unfavorable side effects [23-27].

The aim of the study was to compare the efficacy and the effect of various anesthetic techniques using regional anesthesia on the indicators of abdominal arterial circulation in anterior abdominal wall surgery in children.

Materials and Methods

The study included 90 (49 boys and 41 girls) children at the age of 7-18 years who were treated at the surgical department of a Communal Non-Profit Enterprise "Ivano-Frankivsk Regional Children's Clinical Hospital of Ivano-Frankivsk Regional Council", Ivano-Frankivsk, Ukraine, and underwent anterior abdominal wall surgery for inguinal hernia, appendicitis using different analgesic techniques during 2020-2022. Inclusion criteria were children with inguinal hernia and appendicitis ASA grades I-II at the age of 7-18 years, with the mandatory parental consent to involve their child in clinical research. Exclusion criteria included children less than 7 years of age; those with ASA grade III or higher, mental disorders, neoplasms, or tumors, acute or inflammatory processes of any etiology and localization, sepsis, shock; those who previously underwent lower abdominal surgery; those who experienced pain for six months prior to surgery; those who refused to participate in the research; children whose parents refused to give consent and children who gave no consent.

All children were divided into 3 groups: Group I included 30 children who underwent anterior abdominal wall surgery under general anesthesia using morphine; Group II comprised 30 children who underwent anterior abdominal wall surgery under general anesthesia using the transversalis fascia plane block (TFPB) combined with the quadratus lumborum block 4 (QLB-4) via a single injection; Group III included 30 children who underwent anterior abdominal wall surgery under general anesthesia using the TFPB.

All children underwent anterior abdominal wall surgery under general anesthesia. Postoperative pain management included multimodal analgesia. The assessment of acute pain and the quality of pain management was carried out by means of the Visual Analogue Scale (VAS), the Face, Legs, Activity, Cry, Consolability (FLACC) scale, the Likert psychometric survey scale. The VAS, FLACC, and Likert scale scores were determined 6, 12, 72 hours after surgery and at discharge in all children.

Examination by ultrasonography involving gray scale (B-mode), color flow, and spectral Doppler imaging allows for timely assessment of central hemodynamics and early detection of inadequate pain management. Abdominal arterial circulation was assessed by means of a Philips Lumify handheld ultrasound device using a low-frequency (2-5 MHz) convex transducer.

All clinical and laboratory studies were conducted in accordance with the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects". According to the Law, prior to a subject's participation in the study, a written informed consent form was signed by each subject (parents/adult guardians). The manuscript was approved by the Ethics Committee of the Communal Non-Profit Enterprise "Ivano-Frankivsk Regional Children's Clinical Hospital of Ivano-Frankivsk Regional Council", as evidenced by an Excerpt from the Minute of the Committee Meeting No. 2 dated February 24, 2022.

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The assessment of children's age, body weight, and gender found no difference, indicating a representative sample. The analysis of acute pain on the selected scales revealed that from the moment of awakening after surgery until the discharge time, children of Group I (conventional anesthesia, $p<0.001$) had significantly higher indicators of acute pain on the FLACC scale as compared to Group II, where the TFPB in combination with the QLB-4 was used. The comparison of the indicators in Group I and Group III revealed significantly lower rates in

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Group III only in the postoperative period (7.29±0.13 vs 5.13±0.18, p2<0.001) and on the first day after surgery (4.31±0.19 vs 2.97±0.09, p2<0.001). Meanwhile, single-shot TFPB combined with the QLB-4 was found to result in reducing pain intensity throughout the entire treatment period (p3<0.001), except for the first postoperative day (2.80±0.13 vs 2.97±0.09, p3>0.05) (Table 1).

The comparison of pain intensity between Group I and Group II found a statistically significant difference in the VAS score throughout the entire treatment period (p<0.001). The same comparison between Group I and Group III confirmed the difference only in the postoperative period and six hours postoperatively (p<0.001), with no significant difference until discharge. Children who received the combined regional block responded to pain management better than those receiving the TFPB alone (Table 1).

The analysis of the Likert scale responses found the following: according to the Fisher's least significant difference (LSD) test for pairwise comparison of groups, over the course of treatment, patients of Group II had significantly lower pain indicators as compared to those in Group I and Group III (p<0.001). The application of the combined regional block in Group II was accompanied by significantly lower postoperative pain intensity – by 1.72 and 1.7 times, as compared to Group I and Group III (5.93±0.19 in Group II vs 10.57±0.18 and 10.12±0.15 in Group I and Group III, respectively, p<0.001). At the time of discharge, pain intensity was lower in Group II – by 1.87 and 1.55 times, respectively, as compared to other anesthetic techniques (3.50±0.15 in Group II vs 6.57±0.14 and 5.45±0.22 in Group I and Group III, respectively, p<0.001) (Table 1).

Table 1

Acute pain assessment scales

		Group I n=30	Group II n=30	Group III n=30	p_1	p_2	p_3
		M±m	M±m	M±m			
FLACC	immediately after surgery	7.29±0.13	4.57±0.14	5.13±0.18	<0.001	<0.001	<0.05
	six hours after surgery	6.29±0.17	3.73±0.17	5.87±0.17	<0.001	>0.05	<0.001
	twelve hours after surgery	5.26±0.17	3.20±0.14	4.92±0.09	<0.001	>0.05	<0.001
	one day after surgery	4.31±0.19	2.80±0.13	2.97±0.09	<0.001	<0.001	>0.05
	three days after surgery	3.77±0.18	2.40±0.18	3.32±0.16	<0.001	>0.05	<0.001
	at discharge	3.26±0.19	1.77±0.14	2.86±0.07	<0.001	>0.05	<0.001
VAS	immediately after surgery	7.54±0.11	4.33±0.15	4.9±0.16	<0.001	<0.001	<0.05
	six hours after surgery	6.63±0.14	3.70±0.17	4.07±0.20	<0.001	<0.001	>0.05
	twelve hours after surgery	5.66±0.16	3.10±0.15	5.12±0.22	<0.001	>0.05	<0.001
	one day after surgery	4.6±0.18	2.97±0.16	4.08±0.19	<0.001	>0.05	<0.001
	three days after surgery	3.89±0.15	2.27±0.14	3.47±0.16	<0.001	>0.05	<0.001
	at discharge	3.17±0.19	1.73±0.13	2.7±0.14	<0.001	>0.05	<0.001
Likert	before surgery	13.8±0.16	13.53±0.21	13.17±0.19	>0.05	<0.05	>0.05
	after surgery	10.57±0.18	5.93±0.19	10.12±0.15	<0.001	>0.05	<0.001
	at discharge	6.57±0.14	3.50±0.15	5.45±0.22	<0.001	<0.001	<0.001

Notes:
p_1 - a statistically significant difference between Group I and Group II;
p_2 - a statistically significant difference between Group I and Group III;
p_3 - a statistically significant difference between Group II and Group III.

The analysis of the correlation coefficient between pain intensity and length of stay suggested that high pain intensity in children who received conventional anesthesia led to a prolonged length of hospital stay (FLACC scale (rx,y=0.38±0.16, p=0.02). In patients of Group I, a moderate positive correlation was seen. In addition, in children of Group III who received the TFPB alone, there was a moderate positive correlation on the VAS (VAS (rx,y=0.42±0.18, p=0.02) (Table 2).

The analysis of IAP indicators confirmed increasing IAP in the group of opioid anesthesia (14.9±2.2 mm Hg after surgery, 14.4±4.1 mm Hg 12 hours following surgery, 14.9±2.0 mm Hg 24 hours after surgery, 10.1±1.8 mm Hg 72 hours postoperatively, p<0.05), which was not observed in patients treated with regional anesthesia techniques (Table 3). Patients who received opioid anesthesia had the lowest

APP 24 hours following surgery (52.2±2.6 mm Hg, p<0.05) as compared to patients who received regional myofascial blocks (69.5±2.8 mm Hg and 63.5±2.8 mm Hg in Group II and Group III, respectively), that was a sign of IAP normalization and, probably, the adequacy of pain management and elimination of intra-abdominal hypertension

frequently present in the postoperative period after abdominal surgeries.

To confirm the difference between the methods of analgesia and intra-abdominal hypertension assessment, blood flow in the superior mesenteric artery and renal arteries was studied. In children receiving opioids for pain management (Group I), 12, 24, and 72 hours after surgery, high resistive indices (IR) in the superior mesenteric artery were found - 0.94±0.02, 0.90±0.04 and 0.83±0.07 ($p<0.05$), respectively, while in children who received myofascial blocks, these indices were within the normal range (0.60±0.03, 0.60±0.01, 0.67±0.07 and 0.64±0.03, 0.62±0.02, 0.68±0.07 in Group II and Group III, respectively), that pathogenetically reflected the block of microcirculatory blood flow and, as a result, ineffective pain management when using traditional anesthesia methods only (Table 3).

Table 2

Correlation between pain intensity and length of stay

Group I	FLACC/length of stay	r_{xy}=0.38±0.16	p=0.02
	VAS/length of stay	r_{xy}=0.14±0.16	p=0.39
	Likert/length of stay	r_{xy}=-0.12±0.17	p=0.51
Group II	FLACC/length of stay	r_{xy}=-0.07±0.19	p=0.70
	VAS/length of stay	r_{xy}=0.09±0.18	p=0.62
	Likert/length of stay	r_{xy}=-0.06±0.18	p=0.77
Group III	FLACC/length of stay	r_{xy}=0.16±0.17	p=0.41
	VAS/length of stay	r_{xy}=0.42±0.18	p=0.02
	Likert/length of stay	r_{xy}=-0.04±0.19	p=0.82

Table 3

Changes in the indicators of abdominal circulation and intra-abdominal pressure (M±m)

Indicators	Study period			
	immediately after surgery	12 hours after surgery	24 hours after surgery	72 hours after surgery
Opioid anesthesia, n=30				
IAP, mm Hg	14.9±2.2*	14.4±4.1*,**	14.9±2.0*,**	10.1±1.8*,**
APP, mm Hg	60.8±4.4*	55.5±3.2*,**	52.2±2.6*,**	52.4±6.0*,**
IR (a.mes.sup.)	0.79±0.02	0.94±0.02*,**	0.90±0.04*,**	0.83±0.07*,**
IR (a.renal.dex.)	0.70±0.04	0.97±0.03*,**	0.96±0.08*,**	0.89±0.03*,**
IR (a.renal.sin)	0.78±0.02	0.91±0.03*,**	0.94±0.04*,**	0.85±0.02*,**
General anesthesia and QLB+TFPB, n=30				
IAP, mm Hg	6.7 ±2.2	5.4±4.1	5.8±2.0	5.2±1.8
APP, mm Hg	70.4±4.4	69.2±4.0	69.5±2.8	68.3±5.4
IR (a.mes.sup.)	0.74±0.04	0.60±0.03	0.60±0.01	0.67±0.07
IR (a.renal.dex.)	0.64±0.04	0.63±0.04	0.72±0.04	0.68±0.04
IR (a.renal.sin)	0.68±0.06	0.64±0.04	0.68±0.04	0.68±0.04
General anesthesia and TFPB, n=30				
IAP, mm Hg	9.1 ±2.2	7.4±4.1	5.9±2.0	5.4±1.8
APP, mm Hg	64.4±4.4	65.2±4.0	63.5±2.8	65.3±5.1
IR (a.mes.sup.)	0.74±0.04	0.64±0.03	0.62±0.02	0.68±0.07
IR (a.renal.dex.)	0.68±0.06	0.63±0.04	0.70±0.04	0.69±0.05
IR (a.renal.sin)	0.70±0.08	0.66±0.04	0.72±0.02	0.78±0.07

Notes:
** - a statistically significant difference in the indicators between Group I and Group II, ($p<0.05$);*
*** - a statistically significant difference in the indicators between Group I and Group III, ($p<0.05$).*

The results obtained may be indicative of the following: patients receiving general anesthesia have high acute pain scores on the FLACC, VAS, and Likert scales. The efficacy of regional anesthesia techniques combined with conventional anesthesia is based on the possibility to affect various mechanisms of pain generation, both central and peripheral. Regional analgesia using a local anesthetic (bupivacaine 0.25% solution) allows for significant reducing the need for opioids, while their combination can restore the analgesic potential of the latter.

The analysis of the length of stay in the surgical

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department revealed that children who underwent conventional anesthesia stayed at the hospital much longer as compared to those who received regional anesthesia (3.28±0.24 days in Group I vs 2.1±0.16 and 3.0±0.30 days in Group II and Group III, respectively, p<0.05). Children who received the QLB-4 combined with the TFPB were discharged from the hospital on day 2.1±0.16, while children who were treated with the TFPB only – on day 3.0±0.30 (p<0.05), that indicated the efficacy of the proposed method of combining regional blocks via a single injection (Table 4).

Table 4

Length of stay in the surgical department

Indicator	Group I n=30	Group II n=30	Group III n=30
	M±m	M±m	M±m
Length of stay in the department	3.28±0.24	2.1±0.16*	3.0±0.30*

Note:
** - a statistically significant difference in the corresponding age groups as compared to Group I (p<0.05).*

Conclusions

1. Acute pain assessment in the postoperative period should become a routine pediatric practice in Ukraine.

2. The application of pain assessment scales - FLACC, VAS and Likert psychometric survey scale, allows for timely diagnosis and early treatment with analgesics that can be regarded as a measure for the prevention of chronic pain, the prevalence of which can reach up to 40%.

3. Ultrasound-guided myofascial blocks in pediatric anesthesiology are safe and effective.

4. A combination of regional anesthesia techniques and conventional anesthesia leads to a reduction in IAP, an increase in APP, a decrease in the RI in the superior mesenteric artery and shortens the length of hospital stay as compared to conventional anesthesia management.

5. The TFPB combined with the QLB-4 via a single injection is a priority over the TFPB alone, that is confirmed by pain assessment scales and length of hospital stay.

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ЗМІНИ ПОКАЗНИКІВ АБДОМІНАЛЬНОГО АРТЕРІАЛЬНОГО КРОВООБІГУ ПРИ ВИКОРИСТАННІ РІЗНИХ МЕТОДИК ЗНЕБОЛЕННЯ У ДІТЕЙ

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Резюме

Внутрішньочеревна гіпертензія і абдомінальний компартмент-синдром виникають внаслідок підвищеного внутрішньочеревного тиску. Крім того, повідомляється, що внутрішньочеревна гіпертензія є незалежним фактором ризику смертності в педіатричному відділенні інтенсивної терапії.

Метою дослідження було порівняти ефективність та вплив різних методів знеболення із використанням методик регіонарної анальгезії на показники абдомінального артеріального кровообігу при оперативних втручаннях на передній черевній стінці у дітей.

Матеріали та методи дослідження. У дослідженні взяли участь 90 дітей віком 7-18 років, яким виконувалось оперативне втручання на передній черевній стінці під загальним знеболенням. І групу склали 30 дітей, оперованих на передній черевній стінці під загальним знеболенням із використанням морфіну. ІІ групу склали 30 дітей, оперованих на передній черевній стінці, під загальним знеболенням із застосуванням регіонарного блоку поперечної фасції живота, в поєднанні з блокадою квадратного м'яза попереку із одного уколу. ІІІ групу склали 30 дітей, оперованих на передній черевній стінці, під загальним знеболенням із застосуванням регіонарного блоку поперечної фасції живота.

Стаття пройшла комісію з питань етики на базі КНП «Івано-Франківська обласна дитяча клінічна лікарня ІФОР», що підтверджується витягом з протоколу комісії №2 від 24.02.2022 року.

Статистичну обробку отриманих даних проводили із застосуванням методів варіаційної статистики, кореляційного аналізу, критерію Стьюдента. Вірогідними вважались відмінності при $p<0,05$. Порівняння часток здійснювалось за допомогою z-критерія.

Робота є фрагментом науково-дослідної роботи кафедри дитячих хвороб ПО ІФНМУ: «Стан здоров'я та особливості адаптації дітей Прикарпаття із соматичними захворюваннями, їх профілактика», номер державної реєстрації 0121U111129, терміни виконання 2021-2026 рр., автор є співвиконавцем теми.

Результати дослідження та їх обговорення. Аналіз гострого болю згідно вибраних шкал встановив, що достовірно вищі показники гострого болю за шкалою FLACC у пацієнтів групи традиційного знеболення (Ігрупа, $p<0,001$) порівняно із ІІ групою, де використовувався комбінований міофасціальний блок. ІІ група мала значно нижчий показник болю за опитувальником Likert на етапі всього лікування в порівнянні з І та ІІІ групами ($p<0,001$). Висока інтенсивність болю в дітей, яким використовувалось традиційне знеболення веде до зростання внутрішньочеревного тиску ($p<0,05$) та тривалості перебування (шкала FLACC ($rx,y=0,38\pm0,16$, $p=0,02$).

Висновки. Регіонарні методики знеболення в комплексі із традиційною анальгезією приводять до зниження внутрішньочеревного тиску, зростання абдомінального перфузійного тиску та зниження індексу резистентності в брижовій артерії, а також скорочення термінів перебування у стаціонарі, порівняно із виключно традиційною анестезією.

Ключові слова: діти; регіонарна аналгезія; міофасціальні блоки; опіоїди.

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