CHANGES IN INTRA-ADBOMINAL, ILIAC VENOUS AND CENTRAL VENOUS PRESSURES IN PATIENTS UNDERGOING ABDOMINAL SURGERY DUE TO LARGE TUMORS OF THE COLON – A PILOT STUDY

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SUMMARY – Changes in intra-abdominal pressure during bowel tumor surgery have not been documented. The purpose of the present study was to analyze changes in intra-abdominal pressure (IAP), central venous pressure (CVP) and iliac venous pressure (IVP) in patients undergoing laparotomy due to large tumor of the bowel. Twenty-one adult patients undergoing elective abdominal surgery were examined. Intra-abdominal pressure, CVP and IVP were measured during anesthesia, surgery and early postoperative period. The mean IAP before anesthesia was 12.76±1.09 mm Hg and mean bowel tumor volume 1550±227.48 mL. Anesthesia induction decreased IAP to 10.52±1.32 mm Hg and excision of intra-peritoneal tumors to 5.24±1.51 mm Hg (49.7%). Ten minutes after anesthesia, IAP increased to 7.47±1.2 mm Hg and one hour after surgery decreased to 6.19±1.43 mm Hg. There was a strong overall correlation between IAP and CVP (P=0.0000; r=0.7779), as well as between IAP and IVP (P=0.0000; r=0.8635). Moreover, IAP correlated with IVP immediately after anesthesia and one hour after anesthesia. In conclusion, induction of anesthesia decreased IAP; excision of large bowel tumors decreased IAP; and IAP strongly correlated with CVP and IVP.

Key words: *Abdomen; Abdominal cavity – blood supply; Abdominal cavity – physiopathology; Pressure; Laparotomy – complications; Hypertension – physiopathology; Colonic neoplasms – surgery*

Introduction

Intra-abdominal pressure (IAP) is defined as the steady-state pressure in the abdominal cavity[1]. Normal values of IAP range from 0 to 7 mm Hg and depend on the elasticity of the abdominal diaphragm wall, abdominal capacity and body position[2,3]. Elevation of IAP to 12 mm Hg is not clinically significant, but values higher than 12 mm Hg are categorized as intra-abdominal hypertension (IAH). In 2007, the World Society of Abdominal Compartment Syndrome (WSACS, www.wsacs.org) divided IAP into the following grades: I: 12-15 mm Hg; II: 16-20 mm Hg; III: 21-25 mm Hg; and IV: >25 mm Hg[1]. A pathological increase in IAP may result in splanchnic, renal, respiratory, cardiovascular or neurological dysfunction, which are grouped together as abdominal compartment syndrome (ACS). The cardiovascular disorders seem to be most serious. The increase in IAP depresses cardiac function and alters systemic and pulmonary vascular resistance[1-5]. Decreases in cardiac output and cardiac index have been observed with IAP >12 mm Hg[4]; clinically significant hemodynamic dysfunction has been noted with IAP higher

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than 20 mm Hg[6,7]. Significant ventricular complications have been observed when IAP was higher than 30 mm Hg[8]. Cardiac dysfunctions were accompanied by increases in vascular resistance, pulmonary artery pressure and pulmonary capillary wedge pressure. Moreover, direct compression of the inferior vena cava increased iliac and femoral vein pressure[9]. Likewise, an increase in intrathoracic pressure led to elevated central venous pressure (CVP)[9]. Such changes in iliac venous pressure (IVP) and CVP significantly reduced blood return to the heart.

Several pathologies result in elevated IAP. An intra-peritoneal tumor such as colon tumor is one of such pathologies[1-3]. It is well known that intra-abdominal tumors result in elevated IAP; however, no study to date has correlated abdominal tumor volume and IAP. Therefore, we measured IAP in patients undergoing abdominal laparotomy due to a large tumor of the colon. Moreover, we correlated tumor volume with IAP, CVP and IVP. We also tried to determine the particular volume that would result in IAP increase by 1 mm Hg.

Patients and Methods

The study was approved by Bioethics Committee and included adult male and female patients undergoing elective abdominal surgery due to intestinal tumors. All patients gave their informed consent. We excluded patients that required massive intraoperative blood transfusion or massive fluid resuscitation, those with a history of alcoholism or peritoneal dialysis therapy, and those with chronic circulatory or pulmonary diseases. Patients that required artificial anus after tumor excision were also excluded.

Anesthesia

The day before surgery, all patients were premedicated with a single oral dose of estazolam, 2 mg (Estazolam, Polfa, Warsaw, Poland). One hour before surgery, they received an intramuscular dose of pethidine hydrochloride, 1 mg/kg body weight (b.w.) (Dolcontral, Polfa, Warsaw, Poland) and hydroxyzine hydrochloride, 1 mg/kg b.w. (hydroxyzinum, Polfa, Warsaw, Poland). All patients were routinely monitored. Systolic blood pressure, diastolic blood pressure and heart rate were monitored to assess cardiovascular function. Central venous pressure was also measured. General anesthesia was induced intravenously with a single dose of fentanyl (Fentanyl, Polfa, Warsaw, Poland) and thiopental or etomidate (Hypnomidat, Janssen, Melsungen, Germany). To facilitate tracheal intubation, a bolus of 0.1 mg/kg b.w. vecuronium bromide (Norcurone, Organon Teknika, mjesto, država F) was administered to all patients; the amount was titrated to maintain an adequate level of muscle relaxation. Anesthesia was maintained throughout the procedure using a mixture of nitrous oxide (60%) and oxygen (40%), fractionated doses of fentanyl and inhaled isoflurane (Forane, Abbott, UK). During anesthesia, all subjects were ventilated using intermittent positive pressure ventilation (IPPV). The following ventilation parameters were monitored: tidal volume (6-7 mL/kg b.w.) and respiration rate (9-12/min). Ventilation was controlled by $EtCO_2$ and pulse oximetry (SpO_2). The respired mixture of gases was monitored with a SpaceLab monitor. Upon surgery completion, isoflurane and nitrous oxide were discontinued. Neuromuscular blockade was reversed using a single dose of atropine (0.5 mg) and neostigmine (2.5 mg). All patients were extubated upon satisfactory emergence from general anesthesia and transferred to Postoperative Intensive Care Unit (PICU). Postoperative pain was treated with fractionated doses of paracetamol (Perfalgan, Polfa, Poland).

Surgery

Laparotomy was performed using transverse or medial access. Transverse access was obtained between both breast lines in the epigastric region. Once the abdominal cavity was opened, the tumor was excised and the healthy parts of the bowels were joined together using staplers. The abdominal wall was closed using single sutures. All tumors were excised *in toto*; none of the patients required second-look laparotomy. All patients were discharged in a relatively good general condition and referred for chemotherapy.

Study protocol and methodology

Intra-abdominal pressure measurements were performed intermittently in the urinary bladder using a clipped Foley's catheter, through which 25 mL of a sterile saline solution was first administered (Kron's technique). The added volume of saline was then sub-

Table 1. Demographic data. Patients received 2461.9±821.87 mL of crystalloids and 738.09±255 mL of colloids during the study period; diuresis was within the normal limits; fluid balance was 2561.9±915.27 mL

Value	Age (yrs)	BMI	BSA	Duration of: anesthesia	Duration of: surgery	Crystalloid	Colloid	Diuresis	Fluid balance
Median	61.05	27.19	1.97	193.81	153.33	2461.9	738.09	638.09	2561.9
SD ±	7.01	4.04	0.22	27.11	21.05	821.87	255.88	321.29	915.27

BMI = body mass index; BSA = body surface area

tracted from the urine volume recorded to assess fluid balance. Under local anesthesia, a triple-lumen catheter and singe-lumen catheter (ARROW, USA) were placed *via* the right internal jugular vein and *via* the left or right femoral vein for CVP and IVP measurements, respectively. The observations were made at five time points: 1) immediately before anesthesia and surgery, 2) just after the induction of anesthesia and jugular vein catheterization, before surgery, 3) just after surgery completion, 4) ten minutes after anesthesia, before patient transfer to PICU, and 5) one hour after anesthesia.

Statistics

Mean and standard deviation (SD) were calculated. Student's unpaired t-test was used for variables with normal distribution. For variables with non-normal distribution, the Wilcoxon signed-rank, U-Mann-Whitney, Kruskal-Wallis ANOVA and post-hoc Dunnett's multiple comparison tests were used. Additionally, Spearman's rank correlation tests were used for inter-point and overall comparisons. The level of significance was set at $P<0.05$. The power of correlation was assessed by the G*Power test.

Results

Twenty-one adult patients (12 women and 9 men) aged 61±7.01 were examined. The mean duration of anesthesia and surgery was 194±27.1 min and 153±21.05 min, respectively (Table 1). The mean body mass index (BMI) and body surface area (BSA) were 27.19±27.1 kg/m^2 and 1.97±0.21 m^2, respectively. The mean colon tumor volume was 1550 ± 227.48 mL (maximum 2050 mL; minimum 1150 mL). The mean IAP before anesthesia was 12.76±1.09 mm Hg; values higher than 12 mm Hg were noted in 12 patients (60%). At this time point, IAP moderately correlated with BMI (P=0.0146; r=0.5368, power of analysis 0.9547, effect size 0.5367). Anesthesia induction significantly decreased IAP to 10.52±1.32 mm Hg (by approximately 17.5%; power of analysis 1.00, effect size 1.8249). The

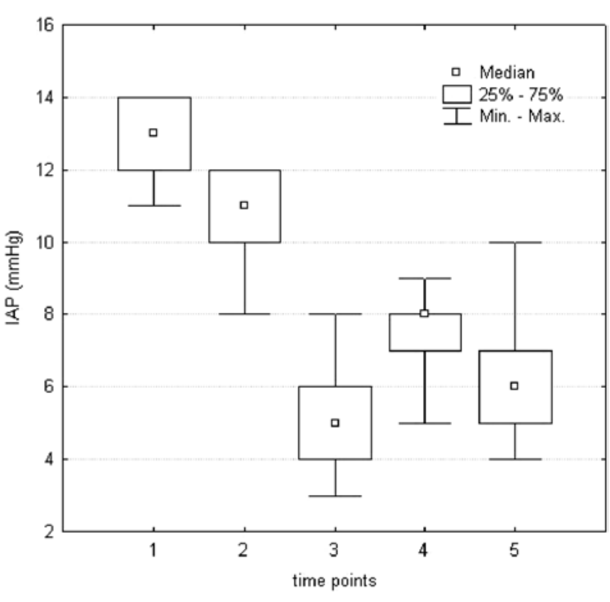

Fig. 1. Changes in IAP during anesthesia, surgery and one hour after anesthesia induction. Time points: 1) just before anesthesia and surgery (baseline value); 2) after the induction of anesthesia but before surgery; 3) just after completion of surgery; 4) just after anesthesia, before patient transfer to postoperative intensive care unit; and 5) one hour after anesthesia. The mean IAP was 12.76±1.09 mm Hg at time point 1. The induction of anesthesia decreased IAP to 10.52±1.32 mm Hg (P<0.001). Next, intra-abdominal pressure decreased to 5.24±1.51 mm Hg (P<0.001 compared with time points 1 and 2). Anesthesia completion increased IAP to 7.47±1.2 mm Hg (P<0.001 compared with time point 3); however, this value was still significantly lower than IAP at time points 1 and 2 (P<0.001). One hour after surgery, IAP decreased to 6.19±1.43 mm Hg (P<0.01 compared with time point 4 and P<0.001 compared with time points 1 and 2).

mean dose of vecuronium used for intubation was 8.2±0.16 mg. The excision of intra-peritoneal tumors decreased IAP from 10.52±1.32 mm Hg to 5.24±1.51 mm Hg (49.7%). Ten minutes after anesthesia completion and reversal of neuromuscular blockade, IAP increased to 7.47±1.2 mm Hg and then decreased to 6.19±1.43 mm Hg (Fig. 1). There was a strong overall correlation between IAP and CVP (P=0.0000; r=0.7779 (Fig. 2); power of analysis 0.9535, effect size 0.7778) as well as IAP and IVP (P=0.0000; r=0.8635 (Fig 3); power of analysis 0.7456, effect size 0.9592). Moreover, IAP correlated with IVP ten minutes after anesthesia and one hour after anesthesia (P=0.0004; r=0.6966 and P=0.0275; r=0.4803, respectively). The power of analysis was 0.9618 (effect size 0.6965) and 0.9520 (effect size 0.4802), respectively.

The mean baseline value of CVP was 13.33±1.74 mm Hg. The induction of anesthesia resulted in reduced CVP (P<0.001); significantly lower values of CVP were noted during the remaining study period, as compared with time point 1 (Table 2). There was a strong overall correlation between CVP and IVP

*Table 2. Changes in central venous pressure (CVP), iliac venous pressure (IVP), mean artery pressure (MAP) and heart rate (HR) during the study period. The excision of intestinal tumors resulted in decreases in CVP and IVP. Central venous pressure and iliac venous pressure were significantly lower from time points 2 to 5 (*P<0.05; **P<0.001; P<0.001 compared with time point 1)*

Parameter	Value	Time points 1	2	3	4	5
CVP (mm Hg)	Quartile 1	12	10	6	8	7
	Median	13	11***	7***	9***	8***
	Quartile 3	15	13	8	10	9
IVP (mm Hg)	Quartile 1	14	12	4	7	7
	Median	15	13***	5***	7***	7***
	Quartile 3	16	14	6	8	8
MAP (mm Hg)	Quartile 1	85	80	84	89	81
	Median	90	82**	88	95	86*
	Quartile 3	97	87	94	99	91
HR (../min)	Quartile 1	65	62	72	78	66
	Median	73	71	78	87*	76
	Quartile 3	81	84	85	91	84

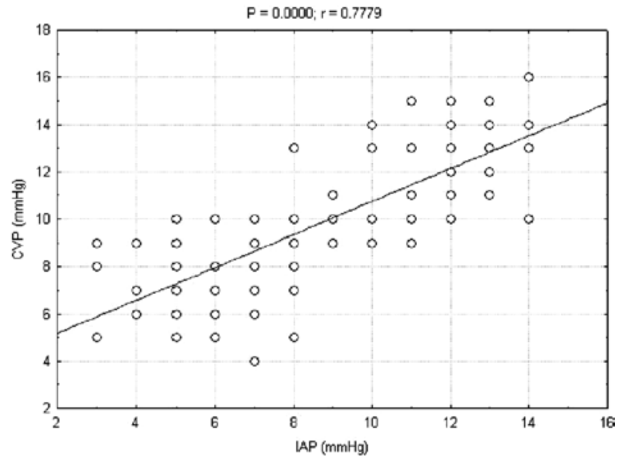

Fig. 2. Overall correlation between IAP and CVP in study population (P=0.0000; r=0.7779); power of analysis 0.9535; effect size 0.7778.

(P=0.0000; r=0.8653, power of analysis 0.9615, effect size 0.8652). Additionally, there was strong correlation between CVP and IVP before anesthesia and one hour after anesthesia completion (P=0.0064; r=0.5743 and P=0.0001; r=0.7352, respectively). The power of analysis was 0.9538 (effect size 0.5742) and 0.9520 (effect size 0.7351), respectively. Iliac venous pressure, similarly to CVP, decreased after the induction of anesthesia; significantly lower values persisted until the end of the study (Table 2).

Transverse laparotomy was performed in 15 (71%)

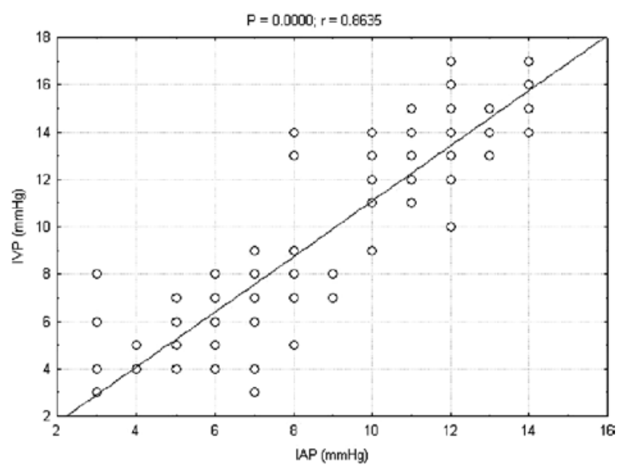

Fig. 3. Overall correlation between pressure in the main inferior vein (IVP) and intra-abdominal pressure (IAP): P=0.0000; r=0.8635; power of analysis 0.7456; effect size 0.9592.

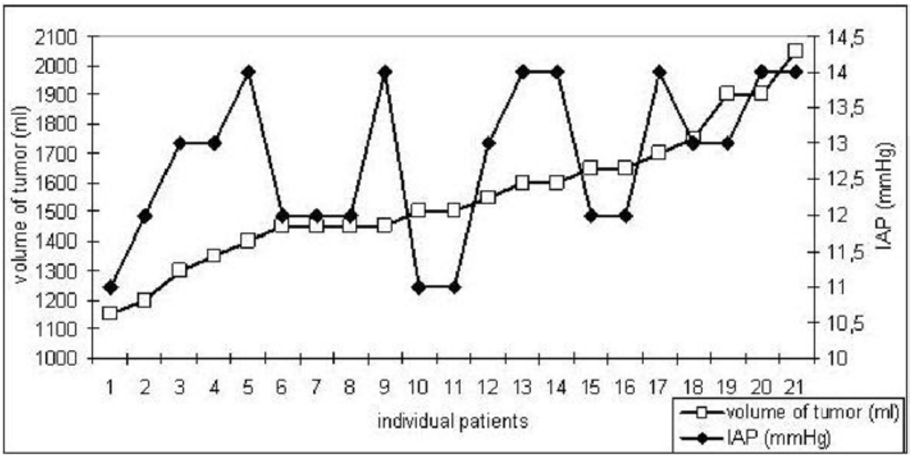

Fig. 4. Relation between intra-abdominal pressure (IAP) at time point 1 and tumor volume in individual patients. The mean tumor volume in patients with IAP=11 mm Hg was 1400±218 mL; with IAP=12 mm Hg 1475±167 mL; with IAP=13 mm Hg 1560±258 mL; and with IAP=14 mm Hg 1672±234 mL. The mean volume increase of 272 mL caused an increase in IAP of 3 mm Hg (90.6 mL per 1 mm Hg of IAP).

and medial in five (29%) patients. The tumor was located in transverse colon in ten (47.2%), descending colon in seven (33.3%) and ascending colon in four (19.5%) patients.

The mean tumor volume in patients with IAP=11 mm Hg was 1400±218 mL; with IAP=12 mm Hg 1475±167 mL; with IAP=13 mm Hg 1560±258 mL; and with IAP=14 mm Hg 1672±234 mL (Fig. 4). The mean increase in tumor volume of 272 mL resulted in IAP increase by 3 mm Hg (90.6 mL *per* 1 mm Hg of IAP). Tumor volume strongly correlated with CVP (P=0.0000; r=0.7533, power of analysis 0.9504, effect size 0.7532) and weakly with IVP (P=0.0311; r=0.4709, power of analysis 0.9525, effect size 0.4708).

Discussion

In the present study, we demonstrated and documented changes in IAP, CVP and IVP in patients undergoing surgical laparotomy due to large colon tumors. In all patients, intra-abdominal tumor elevated IAP before surgery. Prior to surgery, IAP strongly correlated with CVP and BMI. Additionally, CVP correlated with IVP, and tumor volume had a strong impact on CVP. The induction of anesthesia and muscle relaxation significantly decreased IAP. Tumor excision resulted in a second decrease in IAP, which increased slightly ten minutes after anesthesia. We observed a strong overall correlation between IAP and CVP as well as IVP. Moreover, IAP correlated with IVP during the early postoperative period. Importantly, we calculated that an intraperitoneal volume of 90.66 mL increased IAP by 1 mm Hg in patients with IAP higher than 10 mm Hg.

The first decrease in IAP was noted just after the induction of general anesthesia. Neuromuscular blockers dramatically decreased IAP[10,11]. The injection of a single dose of *cis*-atracurium rapidly reduced IAP from 17.4±4.2 to 9.2±2.8 mm Hg[11]. This *cis*-atracurium-mediated reduction resulted from decreased abdominal muscle tone. In the present study, a single dose of 0.1 mg/kg b.w. vecuronium reduced IAP by approximately 17.5%. Interestingly, the reversal of neuromuscular blockade resulted in a 30% increase in IAP. The present study is the first one to present the effect of anesthesia completion on IAP. The elevation of IAP may have resulted from the reversal of abdominal muscle tone as well as from postoperative pain and postoperative confusion in patients; this effect requires additional studies.

This was the first study to demonstrate the correlation between IAP and intra-peritoneal volume. Several authors documented increased IAP associated with different intra-abdominal pathologies. Intraperitoneal bleeding, surgical packing, ascites or interstitial edema increased IAP[9,12,13]. The increase in IAP led to renal, circulatory or respiratory disorders, which sometimes required extraordinary interventions. Most of these pathologies were observed with IAP >15 mm Hg. Importantly, IAP increased relatively rapidly in most of these cases; therefore, the side effects of IAH were quite dramatic. In the present study, 60% of study patients had IAP >12 mm Hg; however, none of these patients exhibited IAH side effects. All patients were likely to adapt to IAH during the long-term period of tumor growth.

An increase in IAH results in dysfunction of multiple organs. Circulatory disorders are the most dramatic of these complications. Intra-abdominal hypertension significantly reduces cardiac output and stroke volume[4,6,7,14]. This cardiac depression results from decreased cardiac venous return due to direct compression of both cava veins as well as of the portal vein. The elevated diaphragm secondary to IAH causes an increase in pleural and intrathoracic pressure, which significantly reduces venous return. This pattern has been demonstrated with IAP >20 mm Hg[7]. Moreover, elevated intrathoracic pressure directly compresses pulmonary veins and cardiac atria, which reduces diastolic volume[6,7]. Furthermore, animal models have documented that IAP elevated intrathoracic pressure by approximately 20%[7]. Therefore, central circulation is dependent on IAP. Many authors documented a strict correlation between IAP and CVP[6-8,15,16]. Direct compression of the inferior vena cava decreased preload and stroke volume but increased CVP as well as IVP. Due to stroke volume reduction, compensatory tachycardia is usually observed. In the present study, IAP strongly correlated with CVP and IVP, although tachycardia was not observed, which might confirm adaptation of the circulatory system to prolonged IAP elevation. Additionally, compensatory tachycardia after tumor excision was not observed. It is likely that crystalloid and colloid infusions markedly reduced hemodynamic disturbances, although CVP and IVP decreased rapidly. The correlation between IAP and CVP was recently documented[15-18]. Intra-abdominal pressure strongly correlated with CVP in cardiac surgery patients, in major burn patients, and as well as during pneumoperitoneum. We demonstrated that IAP strongly correlated with CVP irrespective of the intra-abdominal pathology. Moreover, we documented a strong correlation between IAP and IVP. Yet, this relationship has not been fully documented. It can be assumed that IVP should correlate with IAP, since it is comparable with CVP; however, this correlation should be confirmed in additional studies.

Interestingly, the mean increase in tumor volume of about 90.6 mL caused an increase in IAP of 1 mm Hg. Our findings are the first to demonstrate the relation between intraperitoneal volume and IAP. The measurement of volume, which causes the IAP elevation by 1 mm Hg, should be practically impossible. Intra-abdominal pressure is dependent on too many factors, such as diaphragm and abdominal muscle contractions, solid organ volume and intraperitoneal capacity. It is well documented that decompression laparotomy significantly decreases IAP; however, the volume of eviscerated ileum, which caused such an effect, has not yet been determined. Therefore, we can assume that 90.6 mL of solid, neoplasmic tumor increased IAP by 1 mm Hg; however, this relationship requires further elucidation.

A very important limitation of the present study was the small number of patients with intraperitoneal tumors. It was a pilot study and our results should be confirmed in the future. We examined IAP in patients undergoing explorative laparotomy due to intraperitoneal tumor. None of those tumors had infiltrated the great intra-abdominal vessels or abdominal wall. The patients did not require an artificial anus after tumor excision, as patients that needed an artificial anus intraoperatively were excluded. Moreover, IAP changes were not categorized according to the type of skin incision. It is well known that medial access causes fewer postoperative disorders and is less painful than the transverse mode. All patients received postoperative analgesia, but the degree of postoperative pain was not measured and we did not analyze the correlation between IAP and degree of postoperative pain. Notwithstanding such limitations, we believe that the present study may be extremely relevant for anesthesiologists, abdominal surgeons and other clinicians.

Conclusion

Finally, we demonstrated that the excision of a large, greater than 1000 mL intraperitoneal neoplasmic tumor reduced IAP by approximately 50%. Moreover, 90.6 mL of solid tumor increased IAP by 1 mm Hg. Intra-abdominal pressure correlated with BMI. The induction of anesthesia resulted in a 17.5%

decrease in IAP; anesthesia completion and reversal of neuromuscular blockade resulted in a 30% increase in IAP. Additionally, our findings showed that IAP correlated strongly with central venous and iliac venous pressures.

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Sažetak

PROMJENE INTRA-ABDOMINALNOG, ILIJAČNO VENSKOG I CENTRALNOG VENSKOG TLAKA U BOLESNIKA PODVRGNUTIH ABDOMINALNOM KIRURŠKOM ZAHVATU ZBOG VELIKIH TUMORA DEBELOG CRIJEVA – PROBNO ISPITIVANJE

J. Pilat, W. Dabrowski, J. Biernacka, J. Bicki i *S. Rudzki*

Promjene intra-abdominalnog tlaka tijekom operacijskog zahvata zbog crijevnog tumora nisu dokumentirane. Svrha ovoga ispitivanja bila je ispitati promjene intra-abdominalnog tlaka (IAT), centralnog venskog tlaka (CVT) i ilijačno venskog tlaka (IVT) u bolesnika podvrgnutih laparotomiji zbog velikog crijevnog tumora. Ispitan je 21 odrasli bolesnik podvrgnut elektivnoj abdominalnoj kirurgiji. IAT, CVT i IVT mjereni su tijekom anestezije, operacije i ranog poslijeoperacijskog razdoblja. Srednji IAT prije anestezije bio je 12,76±1,09 mm Hg, a srednji volumen crijevnog tumora 1550±227,48 mL. Indukcija anestezije snizila je IAT na 10,52±1,32 mm Hg, a ekscizija intraperitonejskog tumora na 5,24±1,51 mm Hg (49,7%). Deset minuta nakon anestezije IAT se povisio na 7,47±1,2 mm Hg, a jedan sat nakon operacije snizio na 6,19±1,43 mm Hg. Zabilježena je visoka sveukupna korelacija između IAT i CVT (*P*=0,0000; r=0,7779) te između IAT i IVT (*P*=0,0000; r=0,8635). Štoviše, IAT je korelirao s IVT odmah nakon anestezije i jedan sat nakon anestezije. U zaključku, indukcijom anestezije snizio se IAT, uklanjanje velikog crijevnog tumora dovelo je do sniženja IAT, te je utvrđena visoka korelacija IAT s CVT i IVT.

Ključne riječi: *Trbuh; Trbušna šupljina – opskrba krvlju; Trbušna šupljina – fiziopatologija; Tlak; Laparotomija – komplikacije; Hipertenzija – fiziopatologija; Novotvorine debelog crijeva - kirurgija*