Changes in intra-abdominal pressure in patients undergoing coronary artery bypass grafting and valve replacement

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Abstract

The aim of the present study was to analyze the changes in intra-abdominal pressure in patients undergoing different cardiac procedures with extracorporeal circulation (ECC).
Patients and methods: IAP was measured in 100 patients undergoing CABG or valve replacement (VR) with ECC. IAP was measured in the urinary bladder at six measurement points: 1/ just before anaesthesia, 2/ 10 minutes after ECC; 3/ just after surgery, 4/ one hour after the completed procedure, 5/ 6 hours after the completed procedure, 6/ 18 hours after the procedure. Additionally, IAP was correlated with heart rate (HR), mean artery pressure (MAP and central venous pressure (CVP). According to cardiac procedure, patients were divided into two groups: A/ CABG, B/ VR.
Results: In all patients, ECC resulted in an increase in IAP from 2nd to 6th measurement points. There were significant correlations between: IAP and BMI ($p < 0.001$; $R = 0.3487$), IAP and the duration of: anaesthesia and surgery from 2nd to 6th, ECC from 4th to 6th and aorta clamping from 3rd to 6th measurement points. In groups A and B, IAP increased from 2nd to 6th measurement points. IAP correlated with a fluid balance, BMI, duration of anaesthesia, duration of ECC and aorta clamping time. Additionally, there were strong overall correlation between IAP and CVP.
Conclusions: 1/ ECC resulted in increase in IAP; 2/ IAP correlated with BMI, 3/ IAP elevation depended on duration of: anaesthesia, surgery, ECC and aorta clamping, 4/ fluid balance had a strong impact on IAP, 5/ IAP correlated with CVP.

Changes in intra-abdominal pressure (IAP) during cardiac procedure with extracorporeal circulation (ECC) are still unknown. Several studies documented that abdominal trauma, surgical „packing", acute pancreatitis, abdominal infections, ileus, massive fluid resuscitation may lead to an increase in IAP [1-6]. Moreover, increased IAP values were observed after liver transplantation or major abdominal surgery [7,8]. The massive inflammatory responses resulted in IAP elevation, particularly after burn and during pancreatitis [2,3,9-11]. On the other hand, it is well known, that the contact between heparinised patients blood and foreign surfaces of the extracorporeal circuit during ECC activates an immune system. Therefore, it may be assumed that ECC caused IAP elevation.

The normal value of IAP ranges from 5 to 7 mmHg and generally depends on body mass index (BMI). The values higher than 12 mmHg are considered as intra-abdominal hypertension (IAH). In 1996, Burch et al. [12] graded the elevation of IAP into: I° – from 7 to 11 mmHg (10 – 15 cmH_2O); II° - from 11 to 18 mmHg (15 – 25 cmH_2O); III° - from 18 to 25 mmHg (25 – 35 cmH_2O) and IV° - higher than 25 mmHg (>35 cmH_2O). They suggested that III° and IV° patients required treatment and immediate surgical abdominal decompression.

Several studies described many side effects of IAH [1,5,8,13]. IAH may lead to a decrease in splanchnic perfusion as well as renal and liver insufficiency. Moreover, an increase in IAP higher than 15 mmHg may result in respiratory and circulatory dysfunction. It is worth stressing that sometimes multiorgan insufficiency is observed in patients after cardiac procedures with ECC and normovolemic haemodilution (NH). However, the changes in IAP haven't been documented in patients after different cardiac procedures, such as coronary artery bypass grafting (CABG) or valve replacement (VR). Therefore, the aim of our study was to analyze the changes of intra-abdominal pressure in patients undergoing different cardiac procedures with extracorporeal circulation and normovolemic haemodilution under general anaesthesia.

Patients and methods

From June, 2006 to May, 2007, the prospective, non-randomized study was conducted following approval of the Bioethics Committee of the Medical University of Lublin, Poland and patients` consent. The adult patients scheduled for elective ECC with NH under general anaesthesia were investigated. The exclusion criteria were: neurological diseases, any chronic respiratory disease, serious endocrine diseases, unstable angina pectoris, abdominal surgery history, chronic renal insufficiency, serious circulatory insufficiency (NYHA IV) and EuroScore higher than 8. The patients received the same premedication consisting of lorazepam, morphine and midazolam. All of them were undergoing the same general anaesthesia with fentanyl, midazolam, and etomidate. Muscle relaxation was obtained by injecting a single dose of pancuronium, and was not controlled by peripheral nerve stimulator. After orthotracheal intubation, the intermittent positive pressure ventilation (IPPV) with the mixture of oxygen and air (40%:60%, respectively) was provided. According to blood-gas analysis, the following ventilation parameters were monitored: tidal volume – 6-7 mlkg^{-1} body weight, respiration rate – 9-12/min. Anaesthesia was maintained throughout the procedure using midazolam-fentanyl infusions and inhalation fractionated doses of isoflurane. Before ECC, all patients received 500 ml of colloids and an infusion of 1.5 mln aprotinin in 0.9% NaCl (250 ml). During ECC, circulation and ventilation were maintained with the heart-lung machine. The priming consisted of crystalloids (Ringer's lactate - 1000 ml), colloids (6% HES - 500 ml), 20% mannitol (250 ml), $NaHCO_3^-$ (20 ml), MgSO4 (20 ml) and heparin - 75mg. After the termination of ECC, the patients received dopamine or dobutamine infusions in the dose dependent on their clinical state (on average – 7.3 µg/kg body wt./min ± 3 and 5.7 µg/kg body wt./min ± 2.5, respectively). Immediately after the heart-lung machine weaning from ECC, none of the patients required intensive fluid therapy and possible postoperative deficiencies of intravascular fluids was supplemented with gelatin preparations or crystalloid fluids – with haemodynamic and haematological parameters monitored. During the early postoperative period the standard volume - controlled ventilation was used in all patients, with the following ventilation parameters monitored: tidal volume – 5-7 mlkg^{-1} body weight, respiration rate - 9/min.

The measurements of IAP were performed intermittently in the urinary bladder using the clipped Foley's catheter through which 50 ml of the sterile saline solution was earlier administered (Kron technique). The added volume of saline was then subtracted from the urine volume recorded for fluid balance. The fluid balance was measured just after surgery and in the morning of the 1st postoperative day.

The observations were conducted at 6 points: 1/ after the induction of anaesthesia before surgery, 2/ 10 minutes after the heart-lung machine weaning from ECC, 3/ after the procedure completion before sending the patient to the postoperative intensive care unit (PICU), 4/ one hour after surgery, 5/ 6 hours after surgery and 6/ 18 hours after the procedure (in the morning of the 1st postoperative day). The 1st measurement point was considered as a baseline value. Additionally, IAP was correlated with heart rate (HR), mean artery pressure (MAP) and central venous pressure (CVP).

According to the kind of cardiac procedures, patients were divided into two groups: A/ those undergoing coronary artery bypass grafting (CABG) and B/ those undergoing aortic or mitral valve replacement.

The results were statistically analysed using the Kruskal-Wallis ANOVA test for initial detection of differences as well as Dunnett's multiple comparison post-host and the Spearman's rank correlation tests for inter-point and intergroup comparisons. Additionally, the Spearman's rank correlation test was used for overall analysis. The Mann-Whitney U test was applied to detect the differences between groups A and B. Since data histograms showed skewed distributions, non-parametric methods of analysis were chosen. $P < 0.05$ was considered as significant.

Results

IAP was measured in 100 adult patients aged 42 – 80 years (65.4 ± 7.76); 70 were assigned to group A and 30 to group B. In both groups, the weaning from ECC of the heart-lung machine was uneventful and intra-aortal counterpulsation was not necessary. The postoperative course was without serious complications, diuresis was within normal values and patients were discharged in good general condition. In all patients, the mean time of anaesthesia was 257.9 min ± 38.16 (256.63 min. ± 40.68 and 261.71 min ± 35, respectively), time of surgery – 203.13 min. ± 31.24 (198.52 min. ± 30.5 and 214.92 min. ± 32.64, respectively), time of ECC – 121.11 min. ± 34.03 (110.68 min. ± 32.55 and 145.8 min. ± 25.11, respectively) and time of aorta clamping – 64.87 min. ± 24.28 (57.92 min. ± 23.34 and 81.61 min. ± 19.46, respectively). BMI was 26.24 ± 3.76 (27.09 ± 3.87 and 24.27 ± 2.7 in groups A and B, respectively). During the ECC procedure, the mean temperature was 34.31°C ± 1.04 (34.62° C ± 0.8 and 33.55° C ± 1.15, respectively). There were significant intergroup differences in the duration of surgery, ECC, aorta clamping and between temperature and BMI (table 1).

In all patients, ECC caused an increase in IAP (fig. 1). What is important, the baseline values of IAP correlated with BMI (fig. 2, table 2). In addition, there were relations between IAP and duration of anaesthesia, surgery, ECC and aorta clamping (table 2). IAP at

Table 1. The median values of duration of: anaesthesia, surgery, ECC, aorta clamping, temperature, age and BMI and their differences between groups A and B (NS - non statistically).

duration of:		**anaesthesia**	**surgery**	**ECC**	**aorta clamping**	**temp.**	**age**	**BMI**
all patients	minimum	200	160	50	24	31	42	19.91
	median	250	200	120	63	34.6	66	25.91
	maximum	400	330	203	151	35.9	80	34.79
group A	minimum	200	160	50	24	31	42	19.91
	median	250	190	105	52.5	34.6	65.5	26.85
	maximum	400	330	203	151	35.9	80	34.71
group B	minimum	220	170	100	41	32	42	20.61
	median	250	200	140	80	33.8	66	23.51
	maximum	370	300	200	129	35.2	78	31.24

the differences between group A and B – Mann-Whitney U test					
parameters	*group:*		A	B	p =
	anaesthesia		70	30	NS
	surgery		70	30	0.00171
	ECC		70	30	0.000001
	aorta clamping		70	30	0.000001
	temperature		70	30	0.000003
	age		70	30	NS
	BMI		70	30	0.000317
	IAP	*stages:*	N	N	p =
		1	70	30	0.000001
		2	70	30	NS
		3	70	30	NS
		4	70	30	NS
		5	70	30	NS
		6	70	30	NS

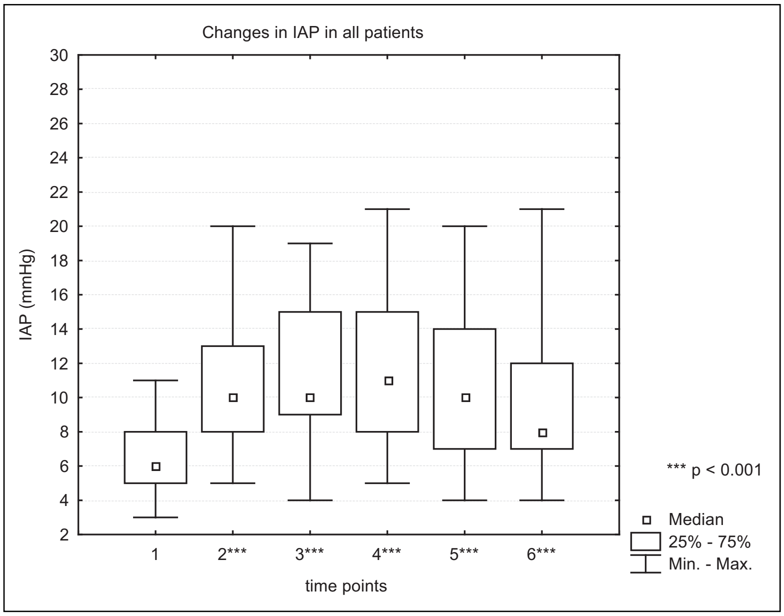

Figure 1. Changes in IAP in all patients - comparison with baseline value

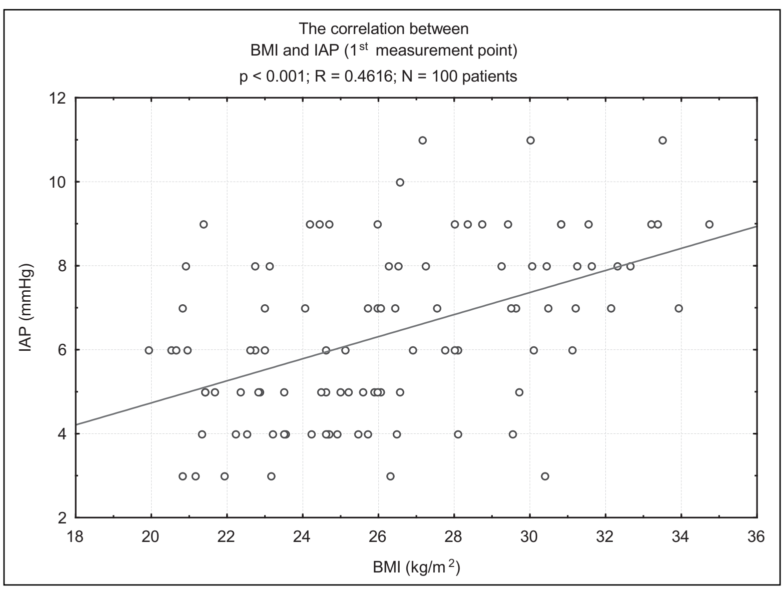

Figure 2. The relationships between BMI and IAP (measurement point 1) in all patients.

measurement point 2 was also correlated with temperature.

Similarly to overall observations, IAP increased form the 2nd to 6th measurement points in group A and B; higher values were noted after valve replacement, yet the differences were not statistically significant (fig. 3, 4, table 2). Furthermore, there were significant correlations between BMI and baseline values of IAP in group A and between the duration of anaesthesia and surgery in group A as well as between IAP and duration of anaesthesia, ECC and aorta clamping in group B (table 2).

The mean fluid balance were 2181.5 ml ± 551.66 and 423 ml ± 896.58 just after surgery and in the morning of 1st postoperative day, respectively. In group A, the mean fluid balance was 2180.71 ml ± 505.99 just after surgery and 547.42 ml ± 823.74 in the morning of 1st postoperative day. In group B, the mean fluid balance just after surgery was similar to group A (2183.33 ml ± 655.52), while it was significantly low-

*Table 2. Changes in IAP and their correlations. (** p < 0.01; *** p < 0.001, NS - non statistically)*

				1	2	3	4	5	6
	time points:			**1**	**2**	**3**	**4**	**5**	**6**
IAP in all patients	The Wilcoxon test	values	minimum	3	5	4	5	4	4
			quartile 1	5	8	9	8	6.75	6.75
			median	6	10***	10.5***	12***	10***	8***
			quartile 3	8	13	15	15	14	12
			maximum	11	20	19	21	20	21
	The Spearman correlation test	anaesthesia : IAP	p =	-	**0.000374**	**0.000245**	**0.000511**	**0.000075**	**0.000848**
			rho =	-	0.348924	0.358953	0.341291	0.385532	0.328474
		surgery : IAP	p =	-	**0.023574**	**0.000386**	**0.000347**	**0.000190**	**0.001416**
			rho =	-	0.226300	0.348171	0.350716	0.364814	0.314926
		ECC : IAP	p =	-	NS	NS	**0.026837**	**0.019562**	NS
			rho =	-	0.056318	0.176513	0.221416	0.233168	0.188979
		AC : IAP	p =	-	NS	**0.007900**	**0.001679**	**0.000423**	**0.000461**
			rho =	-	0.101821	0.264217	0.310282	0.345936	0.343840
		BMI : IAP	p =	**0.000001**	-	-	-	-	-
			rho =	0.461619	-	-	-	-	-
IAP in group A	The Wilcoxon test	values	minimum	3	5	4	5	4	4
			quartile 1	5	8	9	8	6.25	6.25
			median	7	10***	10***	10***	9,5***	8**
			quartile 3	9	12.75	14.75	15	12	10
			maximum	11	20	19	21	20	21
	The Spearman correlation test	anaesthesia : IAP	p =	-	**0.001964**	**0.001300**	**0.006792**	**0.000619**	**0.004066**
			rho =	-	0.363776	0.376897	0.320713	0.399183	0.339253
		surgery : IAP	p =	-	NS	**0.001034**	**0.003358**	**0.000733**	**0.006362**
			rho =	-	0.213471	0.383922	0.345886	0.394223	0.323142
		AC:IAP	p =	-	NS	NS	NS	**0.038369**	NS
			rho =	-	0.02918	0.20802	0.21244	0.2481	0.18622
		BMI : IAP	p =	**0.00096**	-	-	-	-	-
			rho =	0.386173	-	-	-	-	-
IAP in group B	The Wilcoxon test	values	minimum	3	5	5	6	4	4
			quartile 1	4	8.75	9	8	6.75	7
			median	4.5	10***	12***	12.5***	11.5***	10.5***
			quartile 3	6	13	15	15.25	16	15
			maximum	8	16	18	19	20	20
	The Spearman correlation test	anaesthesia : IAP	p =	-	NS	NS	**0.02058**	NS	NS
			rho =	-	0.33142	0.28589	0.42079	0.35052	0.3306
		ECC : IAP	p =	-	**0.02204**	**0.01507**	**0.03875**	NS	NS
			rho =	-	0.41653	0.43958	0.37923	0.29472	0.29659
		AC : IAP	p =	-	**0.04867**.	**0.01302**	**0.0035**	**0.0026**	**0.00152**
			rho =	-	0.36297	0.44805	0.51608	0.52978	0.55304
		BMI : IAP	p =	0.47391	-	-	-	-	-
			rho =	0.13591	-	-	-	-	-

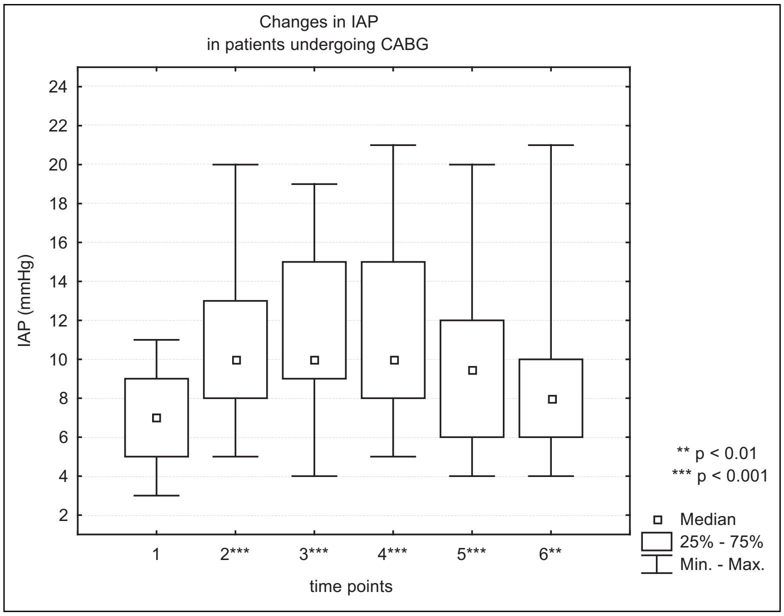

Figure 3. Changes in IAP in patients undergoing CABG - comparison with baseline value.

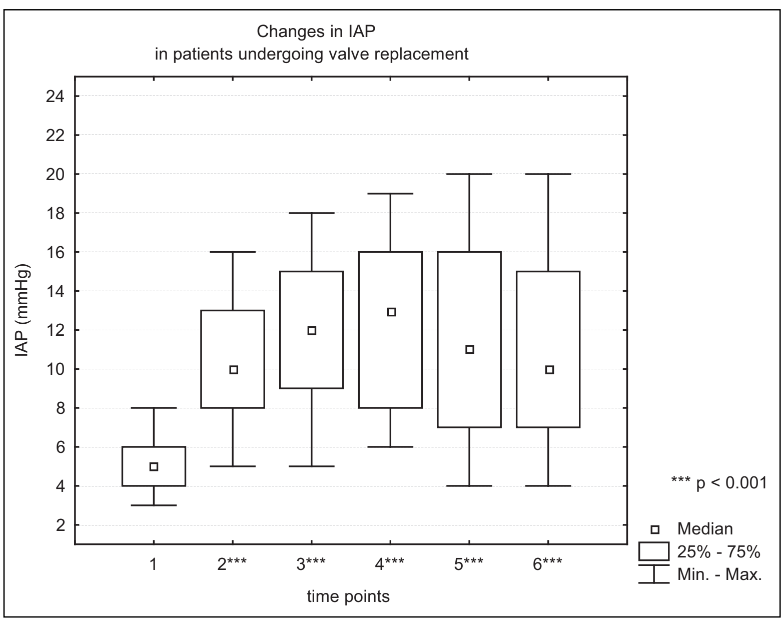

Figure 4. Changes in IAP in patients undergoing valve replacement - comparison with baseline value.

er in the 1st postoperative day (135 ml ± 1003.28). There were significant correlations between fluid balance and IAP just after surgery in both groups, but 18 hours after surgery IAP correlated with fluid balance only in group A (table 3).

The changes in: HR, CVP and MAP were presented in table 4. The correlation analysis showed significant relationships between IAP and CVP in most time points (table 4). Additionally, there was a strong overall correlation between IAP and CVP in all patients (fig. 5). The similar relationships were observed in group A and B ($p < 0.001$, $R = 0.484$; $p < 0.001$, $R = 0.686$; respectively).

	time points	rho	p =	fluid balance
all patients	2	0.241	0.015603	just after surgery
	3	0.285	0.004044	
	4	0.301	0.002291	
	6	0.244	0.014323	18 hours after surgery
group A	2	0.200	NS	just after surgery
	3	0.242	0.042996	
	4	0.265	0.026338	
	6	0.319	0.007042	18 hours after surgery
group B	2	0.316	NS	just after surgery
	3	0.372	0.042649	
	4	0.373	0.041980	
	6	0.230	NS	18 hours after surgery

Table 3. The correlations between fluid balance and IAP (Spearman's correlation test; NS - non statistically).

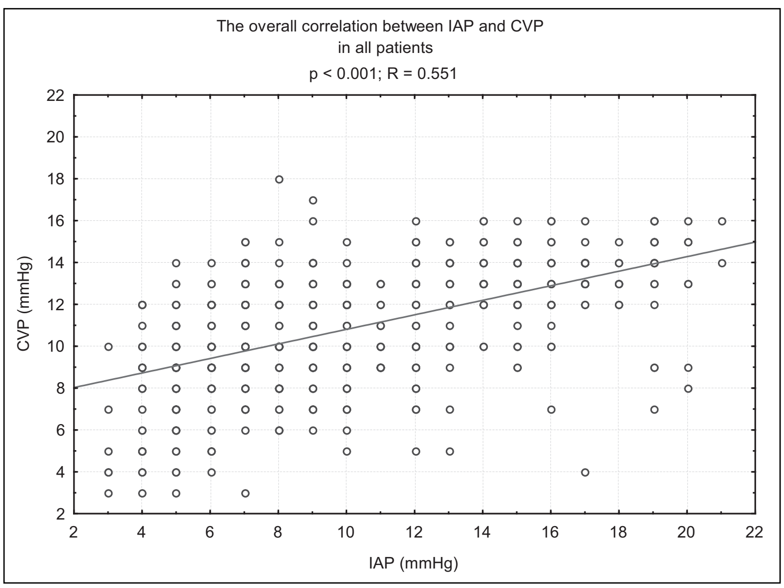

Figure 5. The overall correlation between IAP and CVP in all patients.

Discussion

It is well known that IAP may be a very helpful diagnostic measurement in critically ill patients. The measurement is very easy and safe but many physicians forget about IAP and consider its determinations useless. Several studies underline many side effects of intra-abdominal hypertension [1,2,5,6,8,13]. The most important of them are renal and splanchnic dysfunction or respiratory and circulatory insufficiency. Therefore, the observations of IAP seem to be important, particularly in patients undergoing complicated surgical procedure.

The mean baseline IAP (measurement point 1) was 6.38 ± 2.07 mmHg, which is comparable with other recent observations [1,13]. Importantly, IAP significantly correlated with BMI. This is consistent with the findings presented by Sanchez et al. [14], who determined a normal value of IAP in surgical and nonsurgical patients. According to them, IAP increased conse-

*Table 4. The changes in central venous pressure (CVP), heart rate (HR) and mean artery pressure (MAP) in several time points - comparison with baseline value. (IAP:CVP, IAP:HR, IAP:MAP - the correlations between IAP and haemodynamic parameters at the adequate time points; NS - non statistically, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$)*

		values	time points					
			1	**2**	**3**	**4**	**5**	**6**
all patients	CVP	minimum	3	6	7	5	5	4
		median	8	12***	12***	12***	10***	10**
		maximum	18	17	16	16	16	16
	HR	minimum	40	70	65	75	61	57
		median	63	94,5***	93***	90***	90***	89***
		maximum	110	120	127	115	110	113
	MAP	minimum	56	56	57	62	56	60
		median	85	84,5	85	90	88,5	88,5
		maximum	138	100	110	123	111	115
CVP	group A	minimum	3	6	7	5	5	4
		median	9	13***	12***	12***	10	9
		maximum	18	17	16	16	15	15
	IAP:CVP	p =	0.0001	0.0001	0.0001	0.0001	0.0174	NS
		rho =	0.549	0.510	0.466	0.478	0.285	0.095
	group B	minimum	4	8	7	8	8	7
		median	6	12***	12***	13***	12***	11***
		maximum	12	14	15	14	16	16
	IAP:CVP	p =	NS	0.001	0.01	0.001	0.001	0.01
		rho =	0.150	0.594	0.479	0.577	0.607	0.568
HR	group A	minimum	40	70	65	75	68	69
		median	60	91***	91***	90,5***	90***	89***
		maximum	91	110	127	115	110	105
	IAP:HR	p =	NS	NS	0.029	0.020	0.0001	NS
		rho =	-0.194	0.032	0.262	0.279	0.448	0.073
	group B	minimum	47	85	80	78	61	57
		median	68	100***	95***	90***	90***	85***
		maximum	110	120	110	101	105	113
	IAP:HR	p =	NS	NS	NS	NS	NS	0.01
		rho =	-0.291	0.210	0.279	0.355	0.282	0.458
MAP	group A	minimum	64	61	63	62	56	60
		median	89	84,5*	85,5*	92	89	89
		maximum	138	100	110	115	111	115
	IAP:MAP	p =	NS	NS	NS	NS	NS	NS
		rho =	0.139	-0.122	-0.147	-0.059	-0.106	-0.106
	group B	minimum	56	56	57	62	66	65
		median	72	82	83*	82**	85*	81*
		maximum	92	97	110	123	99	101
	IAP:MAP	p =	NS	NS	0.0124	NS	NS	NS
		rho =	-0.023	0.038	-0.450	-0.291	-0.111	0.094

quently with the elevation of BMI. Moreover, IAP was higher in men than in women; however, these differences were not significant.

There are many factors, which may influence IAP during anaesthesia and cardiac surgery. One of them is muscle relaxation. There are a few reports, which directly describe the muscle relaxation effects on IAP. The use of neuromuscular blockers may lead to a decrease in IAP, which is called a non-surgical abdominal decompression [15,16]. De Laet et al. [16], who examined the changes in IAP after massive fluid resuscitation, demonstrated its significant decrease after *cis*-atracurium administration. According to them, this treatment reduced IAP in critically ill patients with moderately elevated IAP. Interestingly, in the present study, a moderately increased IAP was observed just after ECC and surgery. It is worth stressing that the mean action time of pancuronium is about 60 min., and then patients had no muscle relaxation at measurement point 2 and 3. Thus, it seems that the lack of relaxation was one of the reasons of IAP elevation, and an extra dose of pancuronium may lead to a decrease in IAP. Nevertheless, this hypothesis needs further studies to determine the above relations in detail.

It is difficult to determine precisely the direct cause of IAP elevation. The complicated character of ECC as well as intra- and postoperative therapy may result in such pathology. Nevertheless, NH and inflammatory response, which induce tissue oedema, seem to be the most important factors. Recently, the effect of normovolemic blood dilution during ECC was documented [17]. Markedly higher increases in IAP were noted in patients with lower body mass, thus higher degree of blood dilution. Similar changes were observed during massive fluid resuscitation [18,19]. Hobson and colleagues [19] noted that infusion of 237 ml/kg bw/12h led to IAP elevation, leading to respiratory insufficiency. Moreover, aggressive fluid resuscitation was associated with an increase in gut permeability, which leads to intestinal edema [6]. Theoretically, tissue oedema may result from four physiological changes: 1st – increased microvascular permeability (permeability oedema), 2nd-decreased lymph outflow (lymph oedema), 3rd - decreased colloid osmotic pressure (hypoproteinemic oedema), 4th – increased capillary pressure (stasis oedema) [20,21]. Interestingly, the beginning of ECC results in decreased colloid osmotic pressure, increased microvascular permeability and increased capillary pressure [21-24]. Several authors demonstrated that ECC induced the inflammatory reaction, which led to tissue oedema [25-28]. Moreover, this pathology was also observed during the early postoperative period. According to Tassani et al. [29], who analyzed the microvascular protein escape before and after newborn cardiac procedures, ECC resulted in increased levels of inflammatory cytokines, such as IL-6 and IL-10, and decreased plasma colloid pressure. Furthermore, the radiologic oedema was observed in the children examined. Likewise, Seghaye and colleagues [30] reported the inflammatory response at the beginning of ECC. According to them, this reaction indicated microvascular permeability, which led to total body water accumulation. Importantly, this pathology is observed in each cardiac surgery patient, yet predominantly in paediatric patients [29,30]. The age is not the only reason of extravascular water accumulation induced by ECC. Many authors underlined a significant role of ECC's duration on the extravascular water content [22,23]. The most severe disorders were noted during first 5 – 10 min of normothermic and 30 min of hypothermic ECC [22]. After that time, fluid extravasation was constant; however, it was significantly higher in hypothermia. Similarly, in the present study, there were significant correlations between the duration of ECC and IAP, whereas there were no differences between IAP in groups A and B, despite different duration and temperature of ECC. It is difficult to explain this fact, as there are no data about changes in IAP during valve replacement and their possible differences compared with CABG. Therefore, it can be assumed that both CABG and valve replacement procedures result in similar increases in IAP. What is more, based on the results of the present study, the IAP elevation depends on the duration of anaesthesia, surgery, extracorporeal circulation and aorta clamping. Moreover, the intra-operative fluid balance has a strong impact on IAP. From the clinical point, the strong correlation between IAP and CVP is interesting, too. Thus, it seems, that IAP measurement is important during and after ECC, nevertheless, further clinical studies are necessary to directly determine the influence of cardiac procedures on changes in intra-abdominal pressure.

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